US Army Corps
of Engineers
Construction Engineering
Research Laboratories

DTIC
ELECTE
NOV 1 5 1995
S D
F

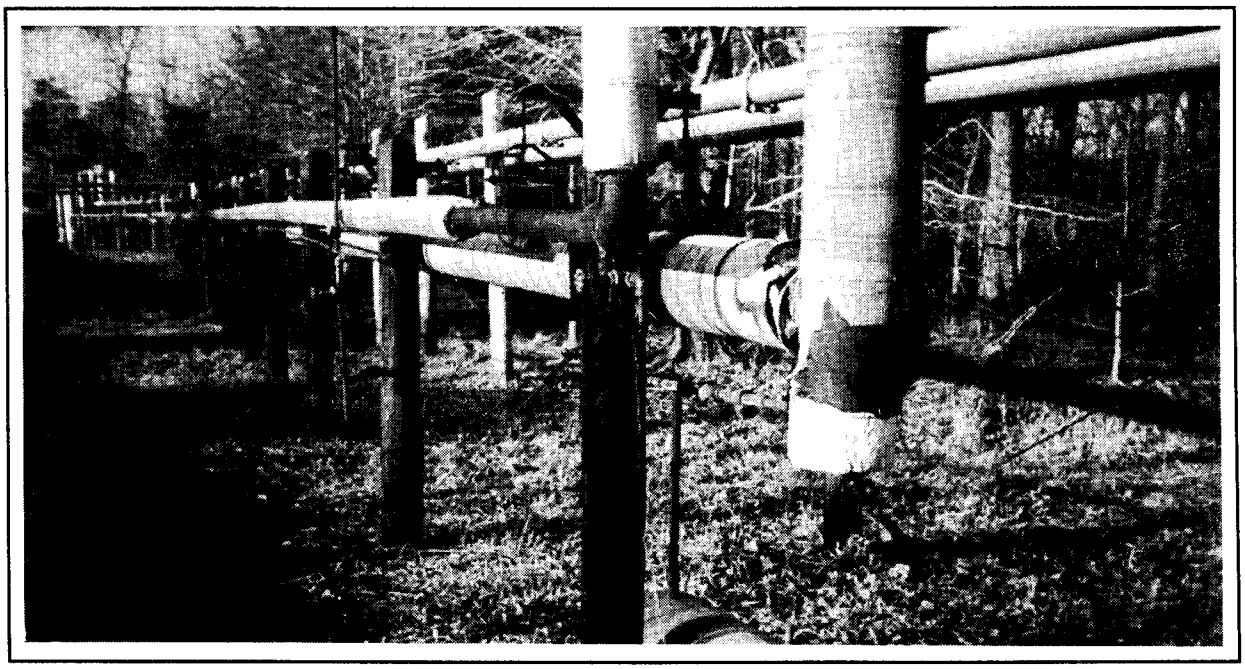
USACERL Technical Report 95/02
May 1995

"Original contains color plates: All DTIC reproductions will be in black and white"

Thermal Energy Supply Optimization for Aberdeen Proving Ground–Edgewood Area

Distribution System Condition Assessment and Recommendations

by
Vicki L. Van Blaricum, Charles P. Marsh, and Vincent F. Hock



19951114 072

This report documents the results of a study by the U.S. Army Construction Engineering Research Laboratories to assess the condition of the steam heat distribution system at Aberdeen Proving Ground (APG)–Edgewood Area (EA), MD. This report documents the portion of the study that addressed widespread corrosion and deterioration existing throughout the aging system.

A physical inventory of the steam distribution system piping and manholes was conducted. A visual condition assessment of a significant portion of the system was performed. Factors that impact the deterioration of the system were assessed, including soil chemistry, cathodic protection, and chemistry of the products conveyed by the system.

The authors developed a detailed set of recommendations that includes (1) replacement or rehabilitation of severely deteriorated, unsafe, or improperly functioning components, (2) implementation of an effective ongoing maintenance program tailored to the specific corrosion and deterioration problems at APG-EA, and (3) recommendations to ensure that new construction is performed in accordance with current Army standards and guidance.

DTIC QUALITY INSPECTED 5

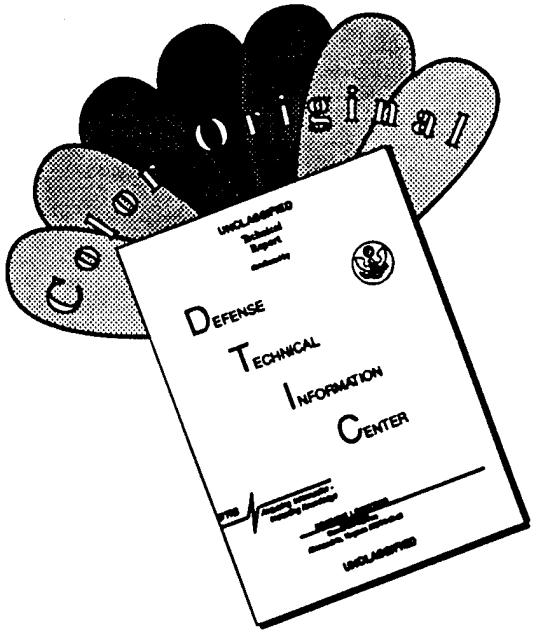
Approved for public release; distribution is unlimited.

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products. The findings of this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

DESTROY THIS REPORT WHEN IT IS NO LONGER NEEDED

DO NOT RETURN IT TO THE ORIGINATOR

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF COLOR PAGES WHICH DO NOT REPRODUCE LEGIBLY ON BLACK AND WHITE MICROFICHE.

USER EVALUATION OF REPORT

REFERENCE: USACERL Technical Report 95/02, *Thermal Energy Supply Optimization for Aberdeen Proving Ground - Edgewood Area: Distribution System Condition Assessment and Recommendations*

Please take a few minutes to answer the questions below, tear out this sheet, and return it to USACERL. As user of this report, your customer comments will provide USACERL with information essential for improving future reports.

1. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which report will be used.)

_____

_____

_____

2. How, specifically, is the report being used? (Information source, design data or procedure, management procedure, source of ideas, etc.)

_____

_____

3. Has the information in this report led to any quantitative savings as far as manhours/contract dollars saved, operating costs avoided, efficiencies achieved, etc.? If so, please elaborate.

_____

_____

4. What is your evaluation of this report in the following areas?

a. Presentation: _____

b. Completeness: _____

c. Easy to Understand: _____

d. Easy to Implement: _____

e. Adequate Reference Material: _____

f. Relates to Area of Interest: _____

g. Did the report meet your expectations? _____

h. Does the report raise unanswered questions? _____

i. General Comments. (Indicate what you think should be changed to make this report and future reports of this type more responsive to your needs, more usable, improve readability, etc.)

_____

_____

_____

_____

_____

_____

5. If you would like to be contacted by the personnel who prepared this report to raise specific questions or discuss the topic, please fill in the following information.

Name: _____

Telephone Number: _____

Organization Address: _____

_____

_____

6. Please mail the completed form to:

Department of the Army
CONSTRUCTION ENGINEERING RESEARCH LABORATORIES
ATTN: CECER-TR-I
P.O. Box 9005
Champaign, IL 61826-9005

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	May 1995	Final

4. TITLE AND SUBTITLE

Thermal Energy Supply Optimization for Aberdeen Proving Ground - Edgewood Area: Distribution System Condition Assessment and Recommendations for Maintenance and Repair

5. FUNDING NUMBERS

MIPR
93-10

6. AUTHOR(S)

Vicki L. Van Blaricum, Charles P. Marsh, and Vincent F. Hock

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Construction Engineering Research Laboratories (USACERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER

TR 95/02

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Aberdeen Proving Ground
ATTN: USAAPG/STEAP-FE-PE
Bldg 5252
APG MD 21005-5001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This report documents the results of a study by the U.S. Army Construction Engineering Research Laboratories to assess the condition of the steam heat distribution system at Aberdeen Proving Ground (APG)–Edgewood Area (EA), MD. This report documents the portion of the study that addressed widespread corrosion and deterioration existing throughout the aging system.

A physical inventory of the steam distribution system piping and manholes was conducted. A visual condition assessment of a significant portion of the system was performed. Factors that impact the deterioration of the system were assessed, including soil chemistry, cathodic protection, and chemistry of the products conveyed by the system.

The authors developed a detailed set of recommendations that includes (1) replacement or rehabilitation of severely deteriorated, unsafe, or improperly functioning components, (2) implementation of an effective ongoing maintenance program tailored to the specific corrosion and deterioration problems at APG-EA, and (3) recommendations to ensure that new construction is performed in accordance with current Army standards and guidance.

14. SUBJECT TERMS

Aberdeen Proving Ground
steam heat distribution system
maintenance and repair

15. NUMBER OF PAGES

240

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

Foreword

This study was conducted for Aberdeen Proving Ground under Military Interdepartmental Purchase Request (MIPR) No. 93-10; Work Unit 93-10, "Corrosion Survey at APG." The technical monitor was Shehreyar Husain, USAAPG/STEAP-FE-PE.

The work was performed by the Engineering Division (FL-E) and Materials Science and Technology Division (FL-M) of the Facilities Technology Laboratory (FL), U.S. Army Construction Engineering Research Laboratories (USACERL). Larry M. Windingland is Acting Chief, CECER-FL-E, Ellen G. Segan is Acting Chief, CECER-FL-M, Donald F. Fornier, Jr. is Acting Operations Chief, CECER-FL, and Alvin Smith is Acting Chief, CECER-FL. The USACERL technical editor was Gordon L. Cohen, Information Management Office.

COL James T. Scott is Commander and Acting Director of USACERL, and Dr. Michael J. O'Connor is Technical Director.

Accesion For
NTIS CRA&I ☑
DTIC TAB ☐
Unannounced ☐
Justification
By
Distribution /
Availability Codes
Dist | Avail and / or Special
A-1

Contents

SF 298 1

Foreword 2

List of Tables and Figures 5

1 **Introduction** 9
Background 9
Objectives 10
Approach 10
Mode of Technology Transfer 10
Metric Conversion Factors 10

2 **Deterioration and Failure Mechanisms in Heat Distribution Systems** 11
Overview 11
Corrosion of Carrier Pipes by the Products Conveyed 12
Corrosion of Carrier Pipes and Conduits by Insulation-Related Leachates 12
Corrosion of Metallic Conduits by Soil 14
Degradation of Terra Cotta Conduit Systems 14
Degradation of Aboveground Distribution Systems 14
Development of a Plan to Maximize Heat Distribution System Performance 15

3 **Field Survey** 16
Edgewood System Description 16
Leak/Problem History 19
Aboveground System Condition Survey 20
Underground System Condition Survey 31
Bellhole Inspections 45
Overall System Condition 51
Soil Testing 55
Soil Testing Results and Discussion 56
Pipe-to-Soil Potential Survey 60
Tests of Products Conveyed by the System 62

4 **Conclusions and Recommendations** 67
Conclusions 67
Recommendations 67

References 75

Appendix A: Maps Showing Locations of Nodes, Manholes, and Pipe Sections 77

Appendix B: Pipe Section and Manhole Inventory Spreadsheets for Edgewood Area Heat Distribution Piping 166

Appendix C: 1993 Condition Survey Results for Edgewood Area 180

Appendix D: Worksheet for Determining Potential Savings Associated With Returning Condensate 192

Appendix E: Excerpt From CEGS 02695: Site Classification Procedure 195

Appendix F: Material Safety Data Sheets (MSDS) for Boiler Water Treatment Chemicals Used at Edgewood Area 201

Appendix G: Information on Lead-Based Paint Testing 210

Appendix H: The Army Boiler Water Quality Assurance Program 211

Appendix I: Cathodic Protection Testing and Criteria and CP Diagnostic Program 214

Appendix J: The Omaha Design for Manholes 230

Distribution

List of Tables and Figures

Tables

1 Anticipated corrosion activity for steel exposed to soils of varying resistivity 14

2 Standards used for laboratory soil testing 55

3 Wenner 4-pin soil resistivity data from 1993 USACERL survey 56

4 Wenner 4-pin soil resistivity data from 1977 survey 57

5 Results from laboratory testing of soil 59

6 Results from pipe-to-soil potential survey 61

7 Boiler water chemical analysis results 64

8 Condensate chemical analysis results 64

9 Boiler feedwater chemical analysis results 65

B1 Pipe section identification spreadsheet for APG/EA 168

B2 Manhole identification spreadsheet for APG/EA 177

C1 Aboveground pipe section condition ratings for the 3000 Area 189

C2 Aboveground pipe section condition ratings for the 5000 area 191

I3 Summary of cathodic protection criteria 219

Figures

1 Deteriorated insulation on section 3312-37A near Bldg E3370 21

2 Typical example of missing insulation on pipe elbows near Bldg E3312 21

3 Typical example of deteriorated coating on support pole near Bldg E3312 23

4 Improper pipe support at Bldg TE3613 25

5 Typical example of pipe not resting properly on support rollers on line to Bldg E3570 25

6 Condensate line leak near Bldg E3607 27

7 Excessive vegetation around and between lines on Section 3312-37A 29

8 Trees growing between lines and missing insulation on pipe elbows on Section 3312-37A 29

9 Failed steam trap at Bldg E3516, reportedly replaced 3 years ago 31

10 Leaking flange gasket at junction between old and new system near 3300 area 33

11 Leaking valve packing on 2 in. return line from Bldg E3580 35

12 Condensate tank resting on the ground near Quonset huts in 3000 area, with insulation missing from pipe 37

13 Typical example of excessive debris in manhole (no. 5320) 37

14 Typical manhole (near Bldg E1570) with standing water and uninsulated pipes 39

15 Typical steaming manhole (no. 5220) with standing water 39

16 Uninsulated and severely corroded pipes in manhole no. 5100 41

17 Typical deteriorated manhole wall penetration (no. 5100), with corrosion on pipe entering the ground 43

18 Typical example of old unsealed manhole penetration 43

19 Typical example of corroded manhole support beams (no. 5100) 47

20 Corroded manhole support beams and cracking of manhole walls in manhole 4040 47

21 Plugged vents in manhole no. 4040 49

22 Excessively heavy concrete manhole cover in the 4000 area 49

23 Six in. steam line to Bldg E3081 (Section 30A-3081), with coating and pipe both in good condition 51

24 Steam line in front of Bldg E1570, with corrosion pit depths averaging 0.01 to 0.02 in 53

25 Condensate line in front of Bldg E1570, with corrosion pit depths averaging less than 0.01 in 53

26 Schematic of condensate cooling system 69

D1 Worksheet for calculating cost savings related to recycling condensate instead of dumping it 193

I1 Electric potential shifts that occur when protective current is applied to a steel structure 215

I2 IR drops in structure-to-soil potential 218

I3 Structure-to-electrolyte potential measurement setup 220

I4 Measurement of anode-to-structure current using ammeter in series 225

I5 Measurement of anode-to-structure current using shunt and voltmeter 226

I6 CP Diagnostic fact sheet 228

J1 Raised cover plate design 231

J2 Section A-A of raised cover plate 232

J3 Section B-B of raised cover plate 233

J4 Section C-C of raised cover plate 234

J5 Detail of raised cover plate 235

J6 Lifting lug detail 236

J7 Handle detail 237

J8 Notes for raised cover plates 238

1 Introduction

Background

The Directorate of Public Works at Aberdeen Proving Ground (APG), MD, required technical assistance to address two major problems with part of its steam heat distribution system: (1) inadequate system capacity and (2) system deterioration. The affected portion of the system was located in APG's Edgewood Area (EA). The U.S. Army Construction Engineering Research Laboratories (USACERL), which conducts ongoing research in maintenance management, corrosion, and energy distribution, was contracted by APG to analyze the capacity and deterioration status of the EA steam distribution system.

The first problem—system capacity—was addressed through research conducted by the Utilities Division of USACERL's Utilities and Industrial Operations Laboratory. That research is documented in USACERL Technical Report 95/01, *Thermal Energy Supply Optimization for Edgewood Area, U.S. Army Aberdeen Proving Ground: Energy Supply Alternatives* (McCammon and Savoie, May 1995).

The second problem—system deterioration—arises from the fact that much of the EA heat distribution system is 40 to 50 years old. Many corrosion-related problems and other system deficiencies have developed in recent years. Such problems are evident even along newer (less than 15 years old) sections of the system. The result has been large energy losses and significant repair costs. Reductions in the maintenance staff and budget at APG have contributed further to the problem. Some areas of the system are beyond repair and must be replaced. The life expectancy and thermal efficiency of other areas of the system could be extended with minor repairs and the application of corrosion-mitigation techniques. Therefore, strategies are needed for the maintenance and repair (M&R) of existing system deficiencies and the mitigation of ongoing corrosion and deterioration problems.

Objectives

The objectives of this research were to

1. assess the condition of the heat distribution system at Edgewood Area
2. assess factors that have impacted the deterioration of the system
3. provide APG/EA recommendations for repairing existing deficiencies and mitigating ongoing corrosion and deterioration problems.

Approach

A physical inventory of the steam distribution system piping and manholes was conducted. An overall inspection and condition assessment procedure for steam distribution systems was compiled, and a significant portion of the distribution piping and manholes was assessed according to the procedure. Factors that impact the deterioration of distribution systems—including soil chemistry, cathodic protection, and chemistry of the products conveyed—were investigated and documented for Edgewood Area. Finally, recommendations for system repair and upgrade were documented.

Mode of Technology Transfer

The inspection and assessment methodologies compiled for this research will be refined and incorporated into a Fiscal Year 1995 AT41 work unit, "Integrated Strategic Utility Distribution System." An objective of this work unit will be to develop an Engineered Management System for utility distribution systems.

Metric Conversion Factors

U.S. standard units of measure are used in this report. A list of metric (SI) conversion factors is included below for convenience.

1 in.	=	25.4 mm
1 ft	=	0.305 m
1 lb	=	0.453 kg
1 mil	=	0.025 mm
1 psi	=	6.89 kPa
1 sq in.	=	6.451 cm^2
°F	=	(°C x 1.8) +32

2 Deterioration and Failure Mechanisms in Heat Distribution Systems

Overview

To maximize the efficiency and longevity of a heat distribution system, it is essential for both the designer and the operator to understand the deterioration and failure mechanisms involved, and their causes. With such an understanding, problems can be avoided or minimized. Scarce M&R resources can be allocated to remedy the root causes instead of making *ad hoc* stopgap fixes. This is especially important when a widespread renovation or replacement is planned, such as the proposed projects at EA. Even a newly installed system is a candidate for premature failure if attention is not given to all of the factors that can cause system deterioration.

Heat distribution systems are extremely vulnerable to deterioration and premature failure due to corrosion. The high temperatures and water present in such systems tend to accelerate most deterioration mechanisms. Systems that use buried steel conduit are especially vulnerable because they have four surfaces that can be exposed to aggressive environments. The inside surface of carrier pipes can be corroded by the products conveyed (especially condensate). With the ingress of water, the outside surface of the carrier pipes and the inside surface of steel conduits and casings can be corroded by aggressive aqueous solutions leached from the insulation. In addition, steam is often produced in the annular space, which greatly promotes degradation of the metal and the insulation. The outside surface of underground steel conduits can be corroded rapidly by aggressive soils. The outside surfaces of aboveground systems are not exposed to aggressive soils, but they are subject to precipitation, condensation, and other atmospheric factors that cause deterioration. Each of these mechanisms must be considered when performing an assessment of a heat distribution system and making recommendations for maintenance and repair.

This chapter presents basic background knowledge about the failure mechanisms involved in heat distribution systems. Factors promoting these failure mechanisms were thoroughly investigated during this research. The recommended action plan considers all of these factors in the remediation of existing problems and the avoidance of future ones.

Corrosion of Carrier Pipes by the Products Conveyed

Internal corrosion of steam and high-temperature hot water pipes is generally not a problem because the water in these lines is usually treated with anti-corrosion chemicals (Myers et al. 1991, pp 8-9). However, carbon steel condensate carrier pipes are vulnerable to serious internal corrosion and pitting if the condensate contains harmful levels of dissolved carbon dioxide or oxygen. Typically, corrosion due to dissolved carbon dioxide appears as "grooving" along the bottom interior surfaces of the carrier pipe. Corrosion due to dissolved oxygen appears as pitting. Dissolved gases typically enter the system in the boiler feedwater or through leaks in the system. Condensate return lines have been known to fail in as little as 1 year due to internal corrosion. Therefore it is very important to ensure that the boiler water is properly treated to mitigate this serious problem.

According to a recent study (Myers et al., July 1991), the corrosion rate (in mils per year [mpy]) for carbon steel condensate return lines can be estimated using the following expression:

$$CR = 3.7\,(CO_2 \times V)^{0.6} + 8.6\,(O_2 - 0.4)^{0.9} \qquad \text{[Eq 1]}$$

where CR = corrosion rate (mpy)
CO_2 = dissolved carbon dioxide content of the condensate, in ppm by weight
O_2 = dissolved oxygen content of the condensate, in ppm by weight
V = condensate flow rate (ft/min).

Fiberglass-reinforced plastic (FRP) condensate return lines do not corrode in the usual sense, but they are subject to damage (failure) from live steam, which may enter the lines when steam traps fail in the open position. Depending on the resin used, reinforced fiberglass piping can tolerate continuous-use temperatures for condensate that range from 190 °F to 250 °F. However, the impingement of live steam will very quickly cause a failure in any FRP piping.

Corrosion of Carrier Pipes and Conduits by Insulation-Related Leachates

Although moisture should not normally exist in the annulus between the carrier pipes and the conduits, wet insulation is a relatively common occurrence in Army heat distribution systems. A number of sources can contribute to wet insulation, including:

1. rain or condensation absorbed by the insulation during unprotected storage before installation

2. leaks in conduit joints that allow groundwater to collect inside the annulus
3. leaks in the carrier pipes that allow the conveyed product to collect in the annulus
4. leaks in the conduits (caused by aggressive soils) that allow groundwater to collect in the annulus.

Moisture in the annulus between the carrier pipe and the conduit can lead to deterioration or "boiling" of the insulation. Species that are aggressive to carbon steel (such as chlorides and sulfates) can be leached from certain insulation. All of these situations lead to accelerated corrosion and system leaks. In addition, if moisture is allowed to accumulate in the annular space, the system will lose thermal efficiency as the insulation becomes saturated and deteriorates. This results in wasted dollars and fuel resources.

It is therefore important during the operation and maintenance of heat distribution systems to ensure that the system remains dry. For the preapproved drainable-dryable systems (i.e., RicWil™ type) this involves a number of aspects covered in the piping manufacturer's maintenance brochure. To maintain the piping insulation integrity and effectiveness, a timely response to any tell-tale steaming from vents is essential. Otherwise, the insulation will be damaged and remain so for the rest of the system's useful life. Two useful diagnostic methods involve conduit air pressure tests and checking for water at the conduit drain.

By removing the drain plug at the low point of the section the presence of water in the conduit can be determined. For safety's sake, if there is any steam coming from either vent, that segment should first be deactivated and isolated before opening the drain. Replacing the plug is important to guard against water from the manhole getting into the conduit. In addition, the use of brass plugs allows for easy removal. Steel plugs corrode over time and tend to become very difficult to remove.

The conduit air pressure test is used to test the integrity of the casing against the ingress of ground water. The conduit is sealed and is then pressurized to 15 pounds per square inch (psi) with a pressure gauge attached. If the pressure decreases there is a breach in the conduit.

For nonmetallic conduits other types of damage can occur due to moisture in the annulus. In the case of FRP conduits the presence of steam in the annular space can cause severe damage. For older terra cotta conduit systems whatever joint sealant material was used, if any, could be damaged.

Corrosion of Metallic Conduits by Soil

Table 1 shows the likelihood of corrosion of carbon steel in soils of various resistivity. It can be seen that soils having resistivities less than about 10,000 ohm-cm are corrosive to carbon steel. To guard against corrosion, underground steel conduits should be coated and cathodically protected, or else nonmetallic conduits (such as concrete shallow trench systems) should be used. Army guidance requires that underground heat distribution piping in ferrous metallic conduit is to be cathodically protected in soils with resistivity of 30,000 ohm-cm and less (ETL 1110-3-440).

When systems are cathodically protected, it is important that the protected system be electrically isolated from other underground metallic structures. Otherwise, the intended corrosion protection could be rendered ineffective. For piping, electrical isolation is achieved by the use of isolation flange kits that consist of a gasket, with nonmetallic washers and bolt sleeves for every bolt. It is important to be sure that the materials are rated for the service temperature intended, that the flange kit is installed according to the manufacturer's instructions using a torque wrench, and that the bolts are re-torqued after the system is energized.

Degradation of Terra Cotta Conduit Systems

Although terra cotta conduit systems are not subject to soil-induced corrosion, they are subject to deterioration. For example, in a 50-year-old system such as the one at Edgewood, it is almost certain that the insulation has "slumped" off of much of the carrier pipe and lost most of its effectiveness. In addition, through ground settlement and low-intensity erosion from subsurface water movement, any conduit joint sealant materials that might have been in place are almost certain to have now been compromised. Water infiltration at the manholes is also likely.

Degradation of Aboveground Distribution Systems

Aboveground heat distribution systems are generally not exposed to as much moisture as buried systems, so they usually endure well. However, it is still possible for the aluminum sheathing and insulation to deteriorate over time and, in some cases, fall off the pipe entirely. This exposes the carrier pipe to corrosion and

Table 1. Anticipated corrosion activity for steel exposed to soils of varying resistivity.

Soil Resistivity Range (ohm-cm)	Corrosion Activity
0 - 2,000	Severe
2,000 - 10,000	Moderate
10,000 - 30,000	Mild
> 30,000	Slight

avoidable excess heat loss. The internal corrosion of aboveground condensate carrier piping is still as much of a concern as in buried systems, as noted earlier in this chapter. Other components of the system, such as pipe supports and guide cables, are subject to deterioration. In addition, the coatings on support poles tend to deteriorate over time.

Development of a Plan to Maximize Heat Distribution System Performance

Maximizing the performance of a heat distribution system involves three main objectives:

1. replacement or rehabilitation of severely deteriorated, unsafe, or improperly functioning system components
2. execution of a good maintenance program that is tailored to correct the specific corrosion and deterioration problems at the installation
3. making sure that any system replacements or new systems are specified and installed in accordance with current standards and guidance.

Determining the best course of action for accomplishing these objectives involve (1) performing a physical condition survey of the system and (2) collecting data about the factors that lead to deterioration and failure of the system. From this information, recommendations for replacement, renovation, correction of problems, and system maintenance can be formulated and prioritized.

3 Field Survey

Edgewood System Description

The study area included the steam distribution and condensate return piping that serves the 3000, 4000, and 5000 areas of the Edgewood Area at Aberdeen Proving Ground. Maps of these areas are shown in Appendix A. These maps have not been revised since the mid-1970s. Maps were reviewed with installation personnel to determine where lines have been shut off, removed, and added since then. There is currently a large project underway at APG to update all of the utility maps and store them electronically on a geographic information system (GIS).

To make identification and discussion of individual pipes in the distribution system more convenient, a naming scheme was devised based upon node numbers and the building numbers that were used for identification in the energy analysis of the system (McCammon and Savoie, May 1995). Each pipe section was identified by the nodes or buildings at its end points. For example, a section of pipe running from node 37A to Building 3835 was given the name 37A-3835. In addition, the manholes have been numbered to facilitate identification. Node, building, pipe section, and manhole identifications are shown in detail on the maps in Appendix A. All of the identification information, along with data for each pipe section and manhole, has been input into a spreadsheet program. This inventory spreadsheet document will be a "living" document for APG personnel, and will be extremely helpful in organizing information as various sections of the system are replaced and new ones are added. The current inventory spreadsheet is shown in Appendix B.

High-pressure steam (350 psi) in the Edgewood area is supplied by a waste-to-energy incinerator operated by a private company, Waste Energy Partners. The line from this incinerator plant is owned and maintained by Waste Energy Partners. The output from this plant varies with the moisture content of the waste being burned and is insufficient to supply EA's full load. The variability and the balance of the installation's requirements is supplied from four boiler plants owned and maintained by the government. One plant (E3312) supplies the 3000 area, two plants (E4225 and E4160) supply the 4000 area, and one plant (E5126) supplies the 5000 area. The current "take or pay" contract makes it advisable for the installation to use all of the outside steam

supplied. However, if the waste-to-energy plant were to go off-line, there is more than enough capacity available to provide heat during extended cold periods.

Several different designs and types of insulated piping are used to convey steam from the boiler plants to the individual building equipment rooms. The following discussion represents a combination of information from the utility maps and information provided by APG Engineering Plans and Services (EP&S) and Operations and Maintenance (O&M) personnel.

In the 3000 area, most of the piping is above ground, and consists of insulated (typically asbestos) and aluminum-cased steel piping mounted on steel poles, concrete piers, or wood trestles. This piping was installed about 1940, so it is more than 50 years old. In recent years, several new sections of piping have been installed. In 1991 a new aboveground line (section 35K-3649) was installed from the line serving Bldg E3560 to Bldg E3549.

Several sections of underground piping are installed in the 3000 area. There are several sections in the area of and interconnecting Bldgs E3220, E3224, and E3226 (sections 32E-3220, 3220-3224, and 3224-3226). These sections presumably consist of steel piping and insulation contained in a full round tile conduit, installed in approximately 1940. An underground line (section 30A-3081) was installed in about 1984 to service Bldg E3081, and an underground line (section 37A-3835) was installed in 1990 to service a new building—Bldg E3835. Both lines are a prefabricated underground conduit system consisting of distribution piping surrounded by mineral wool (or possibly calcium silicate) insulation and contained in a steel casing. The steel casing is coated with a thick coal tar-type material. These are the only lines of this type at EA.

In the 4000 area, all of the piping is underground with the exception of a short aboveground section, installed in 1992, near the boiler plant E4225. The original system in the area serviced by boiler plant E4160 was reportedly installed in about 1940 and is, therefore, more than 50 years old. The original system in the area serviced by boiler plant E4225 was reportedly installed in the early 1960s and is, therefore, approximately 30 years old. The original piping in both areas consists of steel piping and insulation (typically asbestos) contained in a full round tile conduit. This type of system is not pressure-testable. Several sections of the system in the 4000 area have been replaced in recent years. In the area serviced by plant E4160, a new line was installed from the plant to Bldg E4810 (section 4160-4810) in 1991. New lines were installed from the main line to Bldg E4140 (section 44D-4140) and from the main line to E4620 (section 44F-4620) in 1991. These three lines consist of direct-buried

steel pipe surrounded by Protexulate™* with no casing. The piping in the area of Bldgs E4221, E4222, E4224, E4227, E4228, and E4229 (sections 42A-4221, 42A-4229, 42B-4227, 42C-4228, 42D-4224, 42E-4223, and 42F-4222) was reportedly replaced sometime between 1986 and 1988. It is presumed that the same materials were used here as in the other areas replaced in the 4000 area, namely direct-buried steel pipe surrounded by Protexulate with no casing. In the area serviced by E4225, pipes serving Bldgs E4210, E4215, and E4220 (sections 42M-4210, 42M-42N, 42N-4215, and 42N-4220) were reportedly replaced in 1992 with steel pipe wrapped with insulation and surrounded by Protexulate. It should be noted that Protexulate is not approved by the Federal Agency Committee (FAC) as insulation for Class A sites. The approved insulations are listed in Corps of Engineers Guide Specification (CEGS) 02695 (May 1991).

In the 5000 area, there is a mixture of aboveground and underground piping. Portions of the system are shut off in the summer. The aboveground piping in the 5000 area consists of insulated (typically asbestos) and aluminum-cased steel piping mounted on steel poles, concrete piers, or wood trestles. Like much of the heat distribution system, this piping is more than 50 years old. Exceptions are the new aboveground piping installed in 1992 to Bldg E5648 (section 56E-5648, and the new 4 in. line (section ID 56J-55A) installed from the 10 in. line near Bldg E5360 to the 4 in. line near Bldg E5560.

Much of the underground piping in the 5000 area was installed in the 1940s and consists of steel piping and insulation (typically asbestos) contained in a full round tile conduit. New sections have been added, and sections have been replaced with a variety of materials and configurations. A new 10 in. line (section 56F-56G) was installed from Bldg E5330 to the 8 in. line. Piping to Bldgs E5100, E5106, E5103, and E5116 was replaced with steel wrapped with plain fiberglass insulation and a vapor barrier. This area is scheduled for another replacement. The lines to Bldgs E5026, E5027, and E5180 (sections 51LA-51P, 51P-5026, and 51P-5027) were replaced around 1980 with steel pipe surrounded by WYECOR, which is a mixture of concrete and recycled tires. A section of the 8 in. underground line near Bldg E5330 (section 56F-56FB) was also replaced with steel pipe surrounded by WYECOR at about the same time. A portion of this line (section 56F-56FC) has recently been replaced with a steel line surrounded by fiberglass insulation and Protexulate.

In addition, a network of fiberglass condensate return lines was constructed in about 1987 in the 5000 area.

---

* Protexulate™ (also called DriTherm™) is a calcium carbonate insulation that has a white, powdery appearance.

Leak/Problem History

Interviews were conducted with personnel from the EP&S Division and the O&M Division to obtain background information on leak/maintenance history. The installation has no written records of leak and maintenance history.

The biggest problem identified by all APG personnel interviewed was the severe corrosion of condensate lines. They reported problems with condensate lines in the buildings as well as in the distribution system itself. Personnel reported that when a condensate line fails, there is typically "a grooved area in the bottom that is paper-thin." The condensate line from boiler plant E3312 to the 3700 area (section 3312-37A) was reported to be in particularly poor condition. Failures were also reported with the relatively new FRP return lines in the 5000 area. Personnel noted that there is no way to shut sections of the fiberglass line down for repairs without taking down the whole system.

Another problem noted was that condensate is not being returned from many buildings. This problem was noted for the following buildings: E-3300, E-3324, E-3370, E-3525, E-3542, E-3550, E-3570, E-3720, E-3724, E-3725, E-3726, E-3728, E-5140, E-5188, E-5244, E-5266, E-5307, E-5352, E-5354, E-5422, E-5425, E-5427, E-5441, E-5452 , E-5554, E-5560, and E-5641.

Personnel reported that the steam lines were basically in "good shape" with the exception of a few problem areas. The underground sections installed with WYECOR were identified as serious problems. In fact, as noted above, part of one of the sections cast in WYECOR has already been replaced. Other problem areas reported included the lines located in front of building 1570, the entire 4400 area, the line from boiler plant E5126 to E5100 (section 5126-51A), and the line near Bldg 5360. Personnel reported that the aboveground line from E5360 to the 5400 area (section ID 54D-54A) was in poor condition. Although the line in front of Bldg 1570 was not included in the study area, it was investigated because it has failed and been replaced four times within the last 10 years.

Personnel reported that the prefabricated conduit-type systems installed in Bldg 3081 and Bldg 3835 (sections 30A-3081 and 37A-3835) have been performing well. The only deficiency they noted was the difficulty in drainage of condensate on the line to Bldg 3835 (probably mistakenly caused during installation).

It was also reported that all replacements in the past 4 or 5 years have been made with steel pipe covered with fiberglass insulation and surrounded by Protexulate.

Aboveground System Condition Survey

A visual condition assessment of a significant percentage of the aboveground distribution system was conducted. This included examination and videotaping of the aboveground lines. During the visual condition assessment, the condition of aboveground lines was rated as good (G), fair (F), or poor (P). Lines were classified to be in good condition if no deficiencies were noted and no repairs were required. Lines were classified to be in fair condition if minor deficiencies (such as missing insulation) were noted. Lines were classified to be in poor condition if major deficiencies (such as leaks or severe steaming) were noted. Lines in poor condition were typically recommended for replacement. The lines were checked for the following deficiencies:

- deterioration of casing
- missing, wet, or otherwise damaged insulation
- leaks
- leaking valves or flanges
- areas of steaming
- deterioration of supports, including rusting, bending, failed coating, failure of the pipe to rest on the support, or other deterioration which affects functionality and/ or safety
- corroded or "slack" support wires
- vegetation around lines.

Significant observations are summarized here. Detailed observations are documented in Appendix C.

In the Edgewood area, much of the aboveground piping is still in good condition. In many places, though, the aluminum sheathing and insulation have fallen off, exposing the carrier pipe to external corrosion and avoidable excess heat loss. Figure 1 shows an example of this condition on the condensate line section 3312-37A near Bldg E3370. In this particular instance, it was noted that the insulation was asbestos.

An estimated 2,000 ft of aboveground piping, ranging from 2 to 6 in. in diameter, was found to be without insulation. In addition, there are numerous sections (such as that shown in Figure 1) where insulation and insulation covering are damaged. Missing insulation is particularly a problem at pipe elbows. Figure 2 shows an example of this.

Many of the metal support poles are in need of recoating. Figure 3 shows a typical example of deteriorated coating on support poles. An important issue here is the possible presence of lead-based paint. Testing on one of the poles supporting the aboveground piping indicated the presence of lead. One test does not provide enough

Figure 1. Deteriorated insulation on section 3312-37A near Bldg E3370.

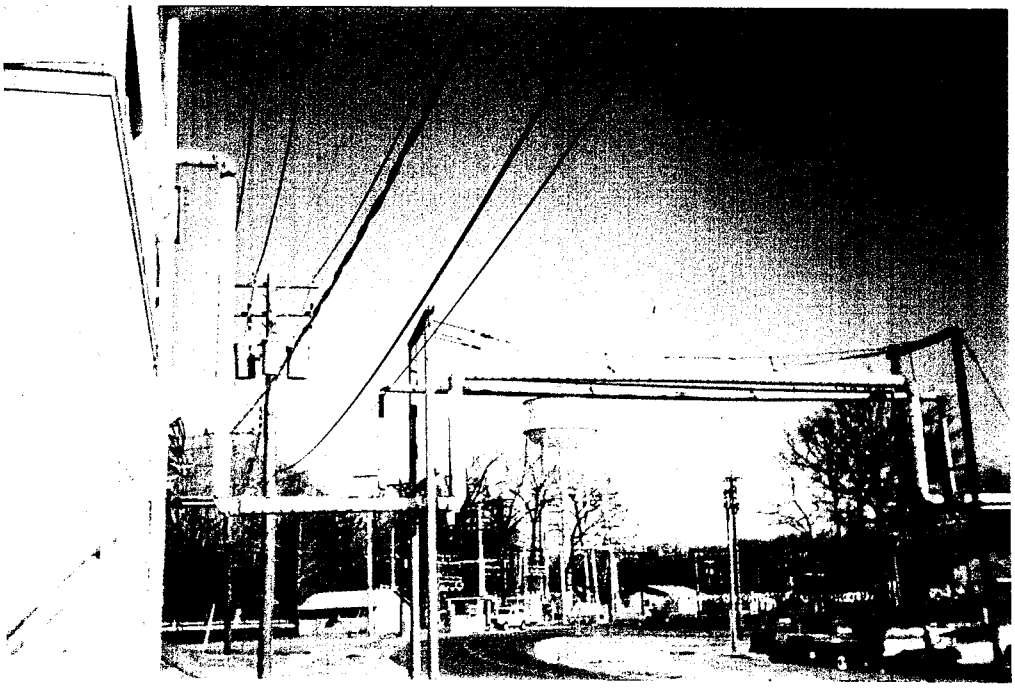


Figure 2. Typical example of missing insulation on pipe elbows near Bldg E3312.

data from which to draw conclusions, but it is important to be aware of the possibility that lead-based paint might be present when maintenance is performed or coated components are replaced or demolished. Recommendations pertaining to managing lead-based paint can be found in Chapter 4 under "Recommendations."

Figure 3. Typical example of deteriorated coating on support pole near Bldg E3312.

Aboveground piping anchors consisted of steel guy wires extending from the pipe to ground-level concrete piers. Several of these wires were broken or detached and others were severely corroded. Some of the wires and guide cables were slack and were not performing their intended function. Failure of anchors can cause unacceptable stresses in the system, possibly leading to pipe and fitting damage.

Many of the pipe guides and supports on the low profile aboveground lines were damaged and did not function as designed. Other locations were observed where "substitute" supports had been used. Figure 4 shows a location where a cloth strap was used to support a pipe. This practice should be discontinued. Figure 5 shows an example of a pipe that was not resting properly on support rollers. As noted above for piping anchors, this deficiency can result in unacceptable stresses and possible pipe or fitting damage.

The 4 in. condensate return line in the 3000 area extending from the boiler plant to near Bldg 3725 (section ID 3312-37A) was inspected in the area of Bldg 3370. The condensate line is severely corroded and is in extremely poor condition. Several leaks and areas of steaming were observed (Figure 6). Most of the leaks were along the top of the pipe. The insulation was badly deteriorated. Insulation was removed from the lines in several locations, and visual inspection revealed that the lines were corroding

Figure 4. Improper pipe support at Bldg TE3613.

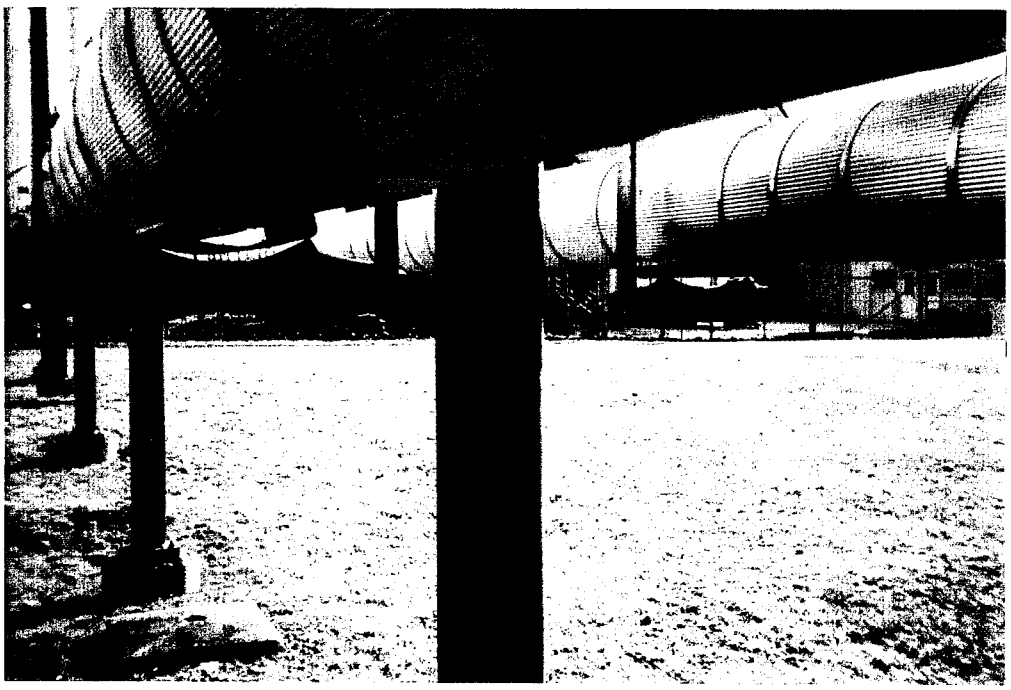


Figure 5. Typical example of pipe not resting properly on support rollers on line to Bldg E3570.

from the outside. This observation was supported by the fact that most leaks were on the top area of the pipe. If corrosion was being caused by the condensate acting from the inside, most of the leaks would appear along the bottom of the pipe. Most likely, the severe corrosion along this section is due to wet insulation at the pipe surface. The steam lines were in fair condition. In addition, there was excessive vegetation, including several trees, growing between the steam and condensate line (Figure 7). This vegetation should be removed. Areas of missing insulation were also observed (Figure 8).

Figure 6. Condensate line leak near Bldg E3607.

In some instances it was found that condensate was being dumped rather than being returned to the boiler plant. This practice, when combined with trap failure (Figure 9), dramatically reduces system efficiency. The extra costs come from having to replace the water and heat it from ambient temperature to the condensate return temperature. Further costs include the chemical treatment for the makeup water. Appendix D provides a simple method to estimate the potential savings associated with returning condensate (rather than dumping it).

Other defects observed were leaking flange gaskets (Figure 10) and leaking valve packing (Figure 11). These defects also cause significant heat loss. Figure 12 shows a condensate tank resting directly on the ground. Contact with the soil will accelerate the failure of this tank due to corrosion. In addition, Figure 12 shows a typical case of missing pipe insulation.

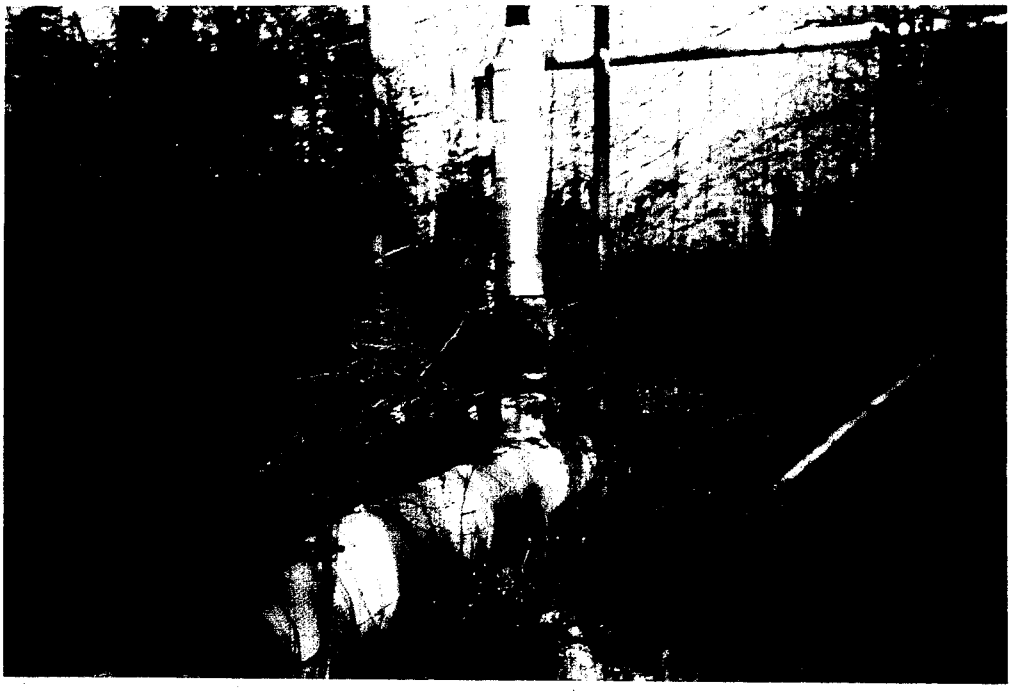


Figure 7. Excessive vegetation around and between lines on Section 3312-37A.

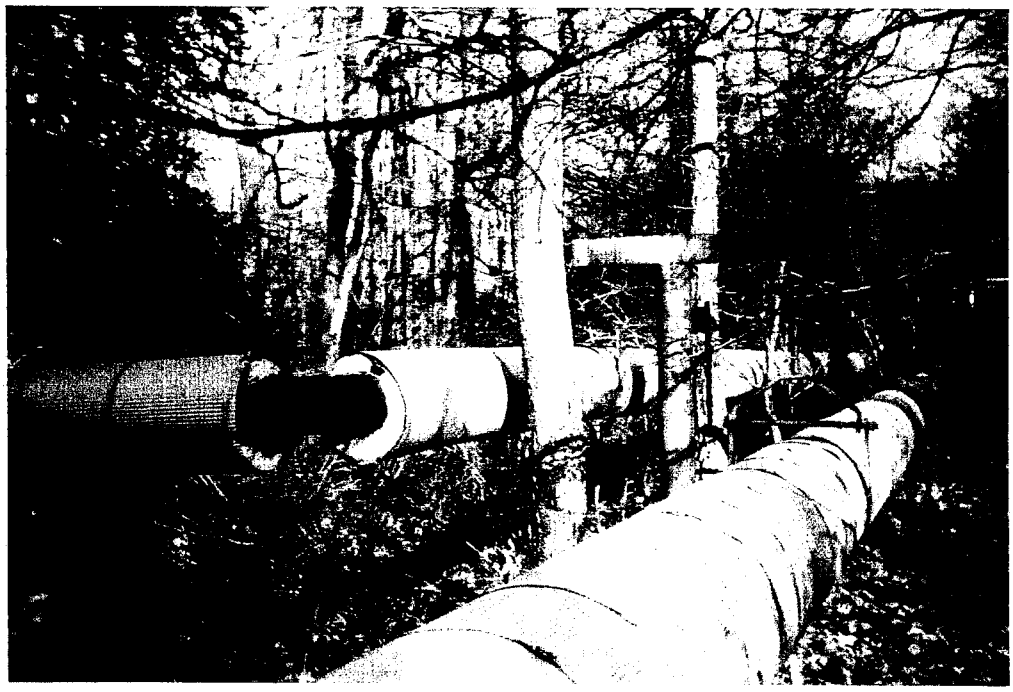


Figure 8. Trees growing between lines and missing insulation on pipe elbows on Section 3312-37A.

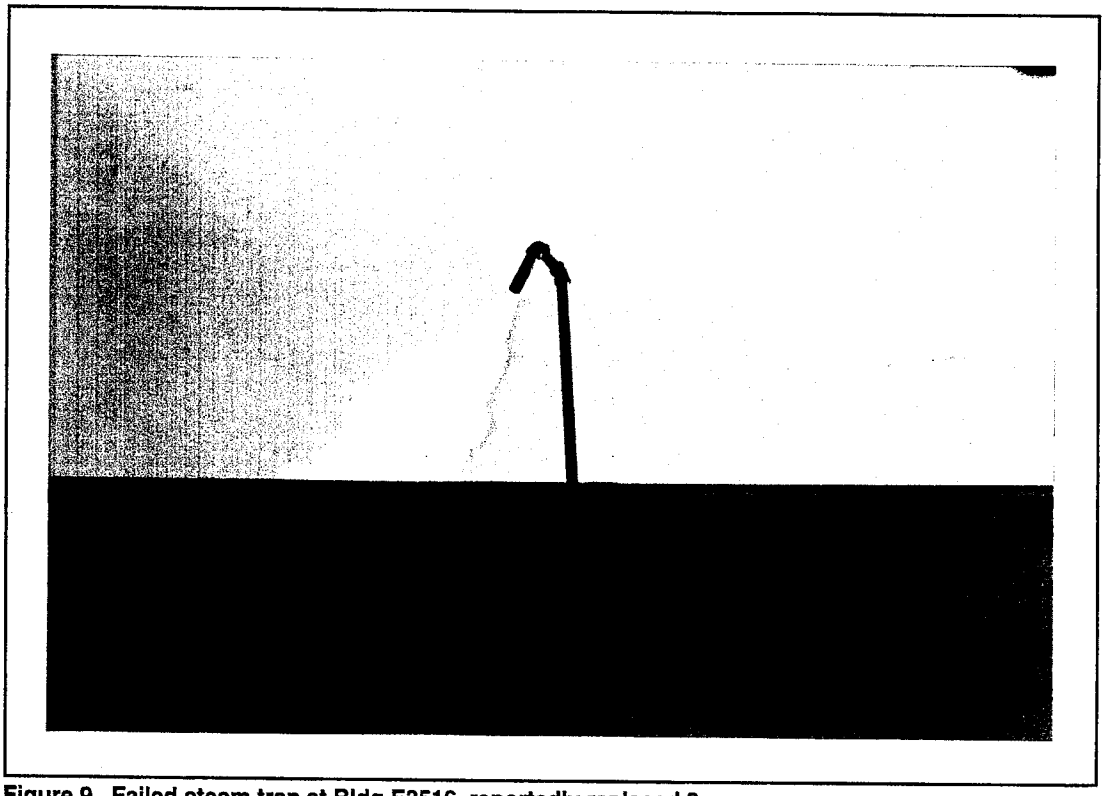


Figure 9. Failed steam trap at Bldg E3516, reportedly replaced 3 years ago.

Underground System Condition Survey

The low-lying terrain and various creek beds in the area that feed the Gunpowder River strongly suggest that Edgewood is a Class A site. This means that the water table is expected to be frequently above the bottom of the system or that surface water is expected to accumulate and remain for long periods in the soil surrounding the system. Appendix E consists of two tables, extracted from CEGS 02695, which describes in detail the process of site classification.

For the underground lines, the condition assessment involved a visual examination of the manholes and manhole internals in a significant number of the system manholes, as well as observation of the ground surface above the lines to note areas of dead grass or abnormally green grass (either of which can denote severe heat losses). Manholes were checked for the following deficiencies:

- standing water (or indication that there has been standing water)
- deterioration of manhole tops/covers (safety hazard)
- deterioration of access ladders (safety hazard)
- missing insulation on pipes
- leaking valves
- leaking or deteriorated gaskets

- deteriorated wall penetrations and evidence of water inflow
- corroded wall supports
- clogged drains
- steaming
- excessive debris
- lack of sump pumps.

Significant observations are summarized here. Detailed observations noted during manhole inspections are given in Appendix C.

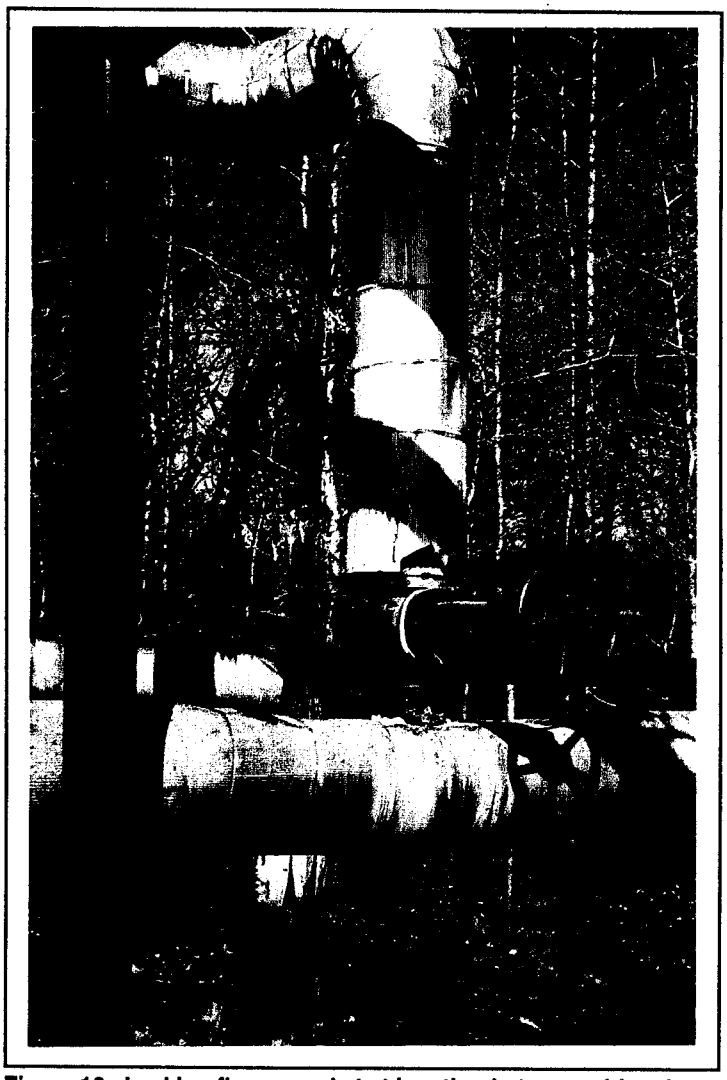


Figure 10. Leaking flange gasket at junction between old and new system near 3300 area.

Most of the manholes at Edgewood appear originally to have been constructed of brick, with a masonry facing added later. These walls are approximately 6 in. thick. The floors, typically, are concrete with a French drain built in. This type of drain consists of crossed channels free of concrete where accumulated water is intended to drain into the soil. The walls were structurally supported internally with steel beams extending from wall to opposite wall. Manhole tops are generally constructed of prefabricated steel designed to sit on the top perimeter of the manhole. The tops are about 1 ft high with screened side panels for ventilation purposes and covered with solid steel plates. A moveable or hinged panel was provided for manhole access. Conduit vents were run to near the manhole top or were extended above grade. A number of problems were observed in the manholes surveyed.

There was a lack of insulation on most interior manhole piping and internals. A typical example is shown in Figure 13. This lack of insulation on the piping often extended back into sections of the full round tile conduit. In addition, pipes were observed where the insulation had "slumped" to the bottom of the conduit. It is likely that this condition existed along the entire run connected to the manhole where the slumping insulation was found—especially since many areas of the system are approximately 50 years old. In areas where the older full round tile conduit is

installed, the conduit runs and loops were generally outlined by dead grass immediately above the piping. This indicates excessive heat loss which is probably due to deterioration of the insulation inside the conduit. In the areas where the non-tile (i.e., metallic) casing was used, con siderable corrosion was observed on some of the conduit casings that extended into the manhole. These casings are much thinner than the end plates and can be a source of early system failure.

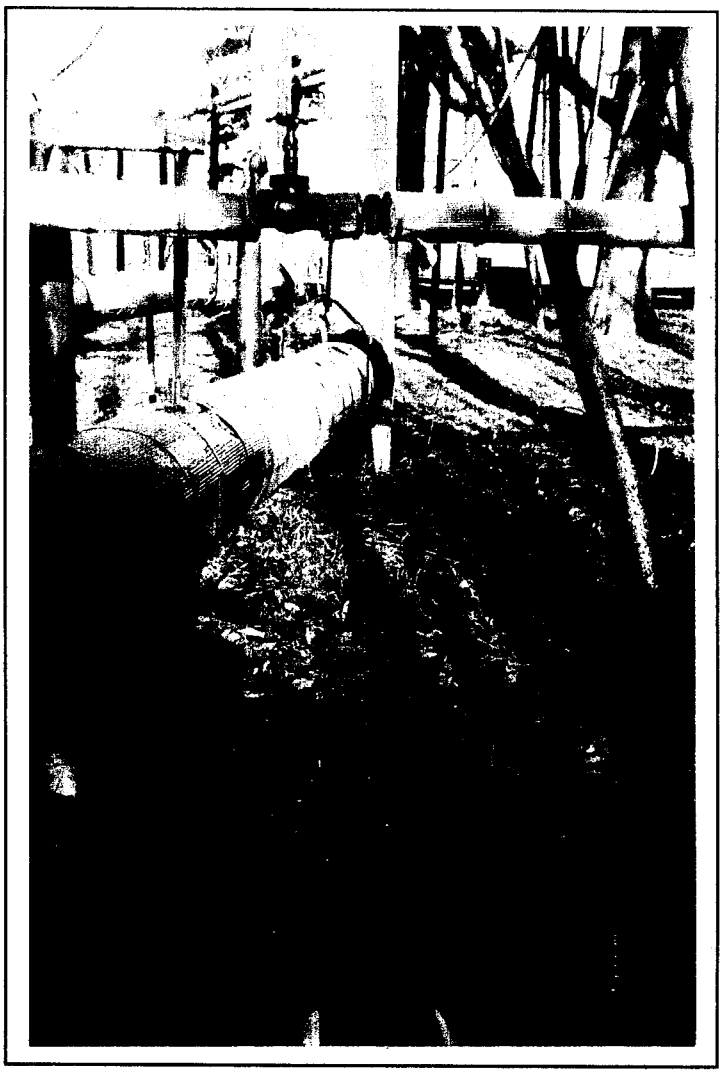


Figure 11. Leaking valve packing on 2 in. return line from Bldg E3580.

Many of the screens on the manhole tops are missing and should be replaced to prevent the manholes from collecting debris. Figure 13 shows an example of a manhole containing excessive debris. Such debris can prevent or severely impede the drainage of water from the manhole.

Strong evidence of standing water was observed in many of the manholes surveyed. Although many manholes were relatively dry at the time of this inspection, water marks on the manhole walls indicated that flooding is common. Water was observed in a few manholes, including the one shown in Figure 14. The pipes in this manhole are not insulated. The type of drain currently installed in the manholes often performs poorly. In addition, no sump pumps were found in any of the manholes surveyed. *The detrimental effect of standing water in manholes cannot be overemphasized.* The steam generated from standing water presents a significant safety hazard to maintenance personnel (Figure 15). Water, in combination with the high temperatures present, will accelerate corrosion of the manhole internals (Figure 16), and can cause accelerated failure of the casings and carrier pipes themselves.

Figure 12. Condensate tank resting on the ground near Quonset huts in 3000 area, with insulation missing from pipe.

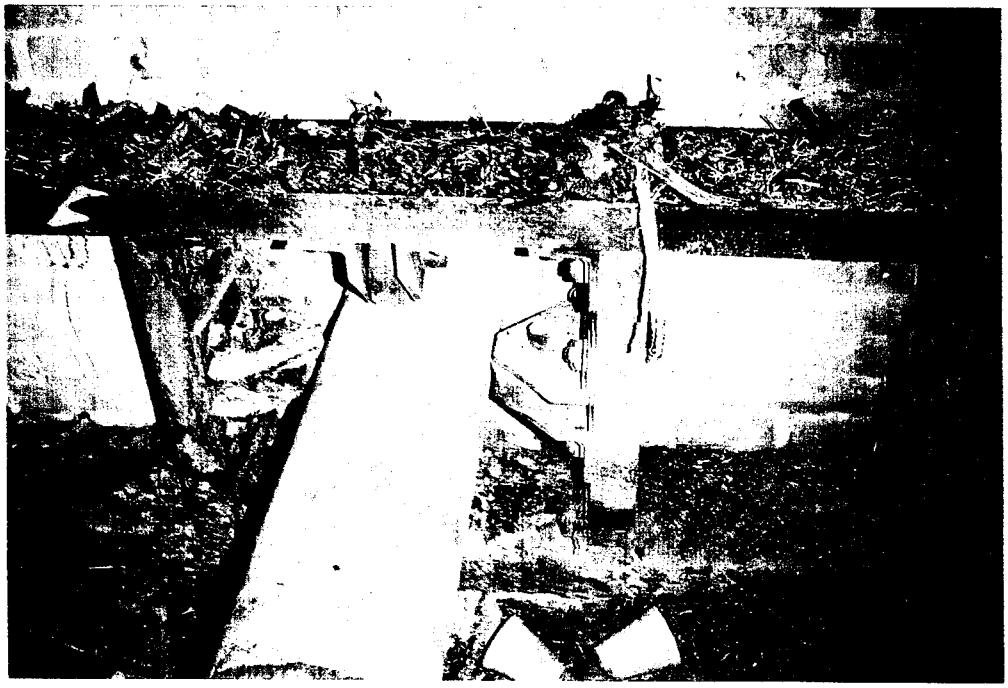


Figure 13. Typical example of excessive debris in manhole (no. 5320).

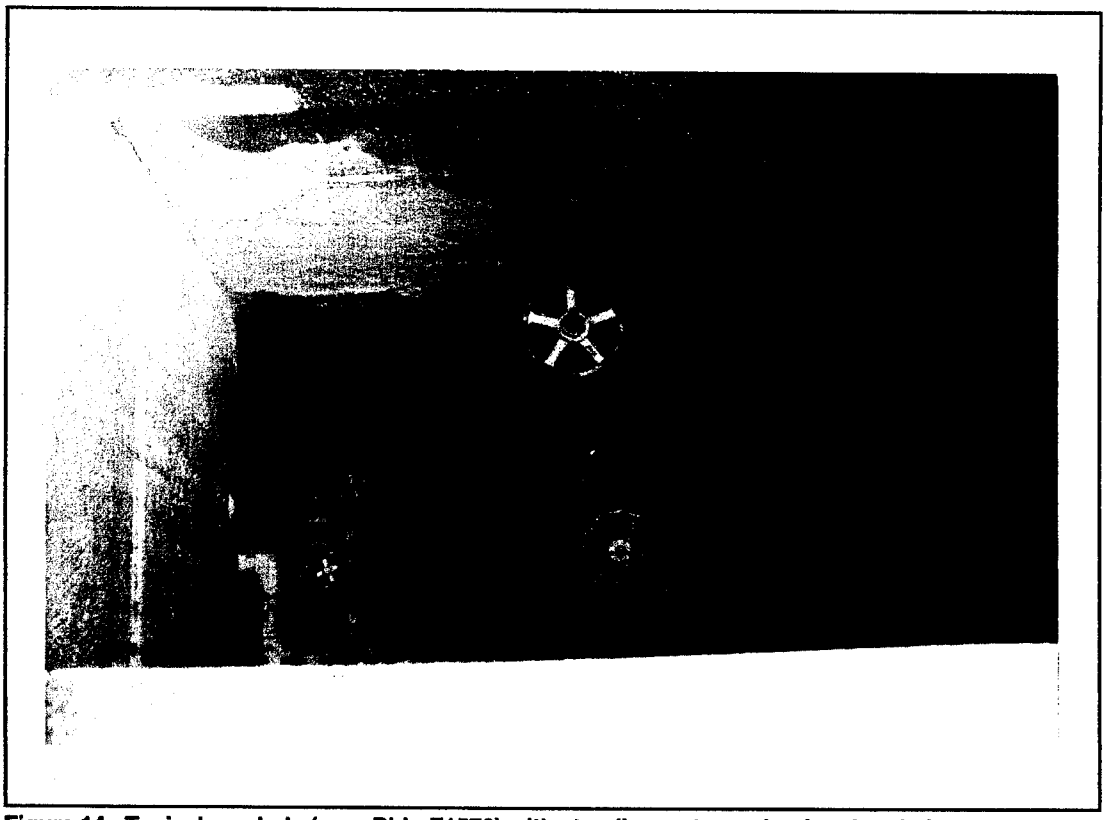


Figure 14. Typical manhole (near Bldg E1570) with standing water and uninsulated pipes.

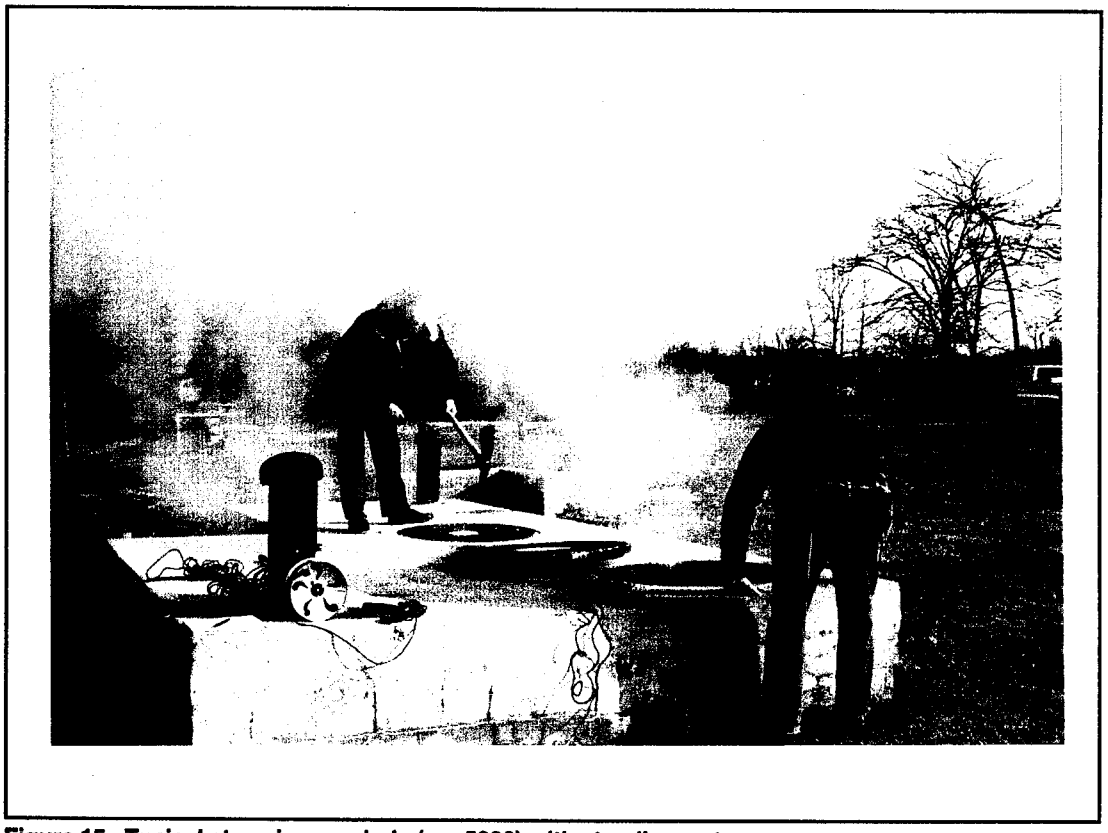


Figure 15. Typical steaming manhole (no. 5220) with standing water.

Figure 16. Uninsulated and severely corroded pipes in manhole no. 5100.

Manhole wall penetrations involved the extension of conduits through slightly oversized holes that were caulked and cemented at the interior surface of the walls. Most of the caulking at conduit wall penetrations was dried and deteriorated. Figure 17 shows a severely deteriorated manhole penetration. The caulking could not prevent groundwater infiltration into the manhole. This problem may contribute significantly to the flooding problem discussed in the previous paragraph. Also note the severe corrosion of the pipe entering the ground in Figure 17. In this example there was no evidence of the current practice, which is to use a metallic wall sleeve with a flange water stop and link seals to prevent water entry. Another problem that was frequently observed was old manhole penetrations that had not been properly sealed (Figure 18). Improper sealing provides another route for groundwater infiltration into the manhole.

Pipe moment guides for expansion joints in manholes have failed due to corrosion, and no longer serve their purpose. Improper alignment at expansion joints can cause major damage. Slip-type expansion joints require a very accurate alignment to operate as intended. Misalignment can cause the pipe to bind in the expansion joint as it tries to expand. If not taken up in the slip joint, thermal expansion forces can cause severe damage elsewhere in the system. These joints also require periodic lubrication and repacking.

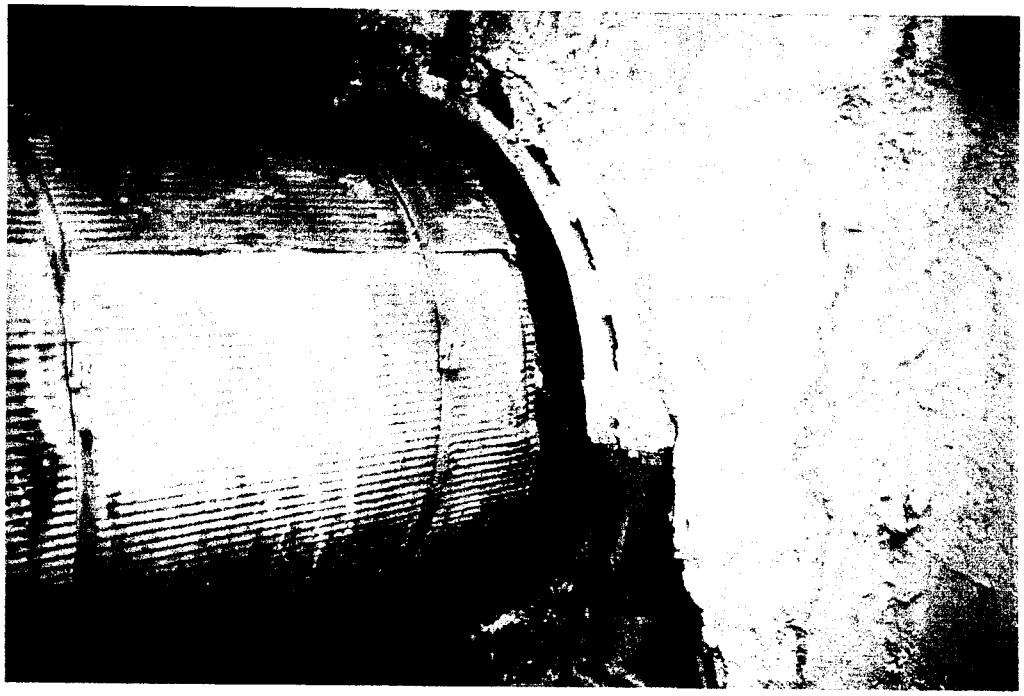


Figure 17. Typical deteriorated manhole wall penetration (no. 5100), with corrosion on pipe entering the ground.

Figure 18. Typical example of old unsealed manhole penetration.

Steel beams supporting manhole walls were heavily pitted and corroded (Figure 19), as are the inner surfaces of the steel plates on the manhole tops. Manhole walls are also deteriorating, with excessive spalling and cracking evident (Figure 20). These conditions may present a future safety problem.

In several manholes, the entry ladders were badly corroded and were not securely fastened to the manhole walls. In the interest of safety, these must be repaired.

Plugged vents were observed in some manholes (Figure 21). Steaming vents are one of the primary indicators of a leak or problem in the system. Plugging the vents eliminates this "early warning" mechanism. Furthermore, if the pipes are not properly vented, pressure can build up to unacceptable levels.

One manhole with an excessively heavy concrete manhole cover was observed (Figure 22). Such manhole covers make it very difficult to perform maintenance or inspections in the manhole.

Much of the underground heat distribution piping at Edgewood consists of a steel carrier pipe wrapped with asbestos insulation and protected by sections of 3/4 in. terra cotta conduit. In addition, a tar or tar paper, or bitumastic coating may have been used to seal the conduit joints. Because these systems are approximately 50 years old it is almost certain that the insulation has slumped off much of the carrier pipe, and consequently has lost most of its effectiveness. In addition, through ground settlement and low-intensity erosion from subsurface water movement, any conduit joint sealant materials that might have been in place are almost certain now to have been compromised. Neither of these situations can be known for certain without some exploratory excavation. However, dead grass is in evidence along many of the terra cotta conduit lines, indicating either a very shallow burial depth or excessive heat loss. To kill cool-season grasses with heat requires a steady temperature of 80-90 °F within 6 in. of the surface (Beard 1973). Although many of the variables involved are not known to great accuracy an attempt has been made to at least quantitatively bound the amount of heat loss (McCammon and Savoie, May 1995).

Bellhole Inspections

Bellhole inspections were conducted on the line to Bldg E3081 (section 30A-3081), the line in front of Bldg E1570, and the line to Bldg E3835 (section 37A-3835).

Section 30A-3081 was the prefabricated type, with a metal casing and heavy tar-type coating on the outside. The line was in good condition (Figure 23). Although the soil

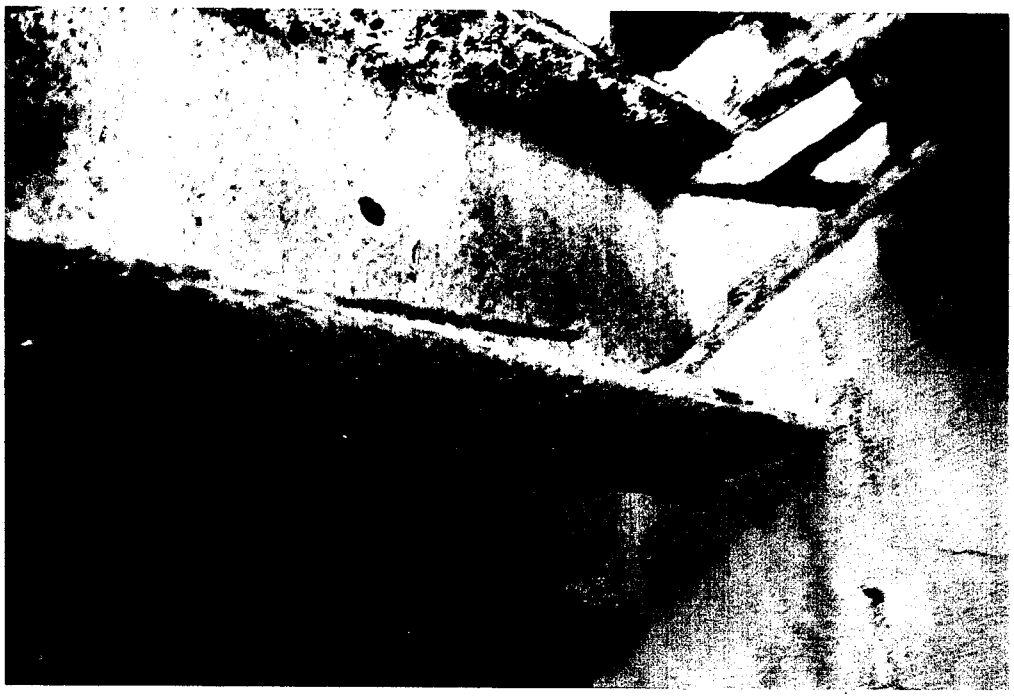


Figure 19. Typical example of corroded manhole support beams (no. 5100).

Figure 20. Corroded manhole support beams and cracking of manhole walls in manhole 4040.

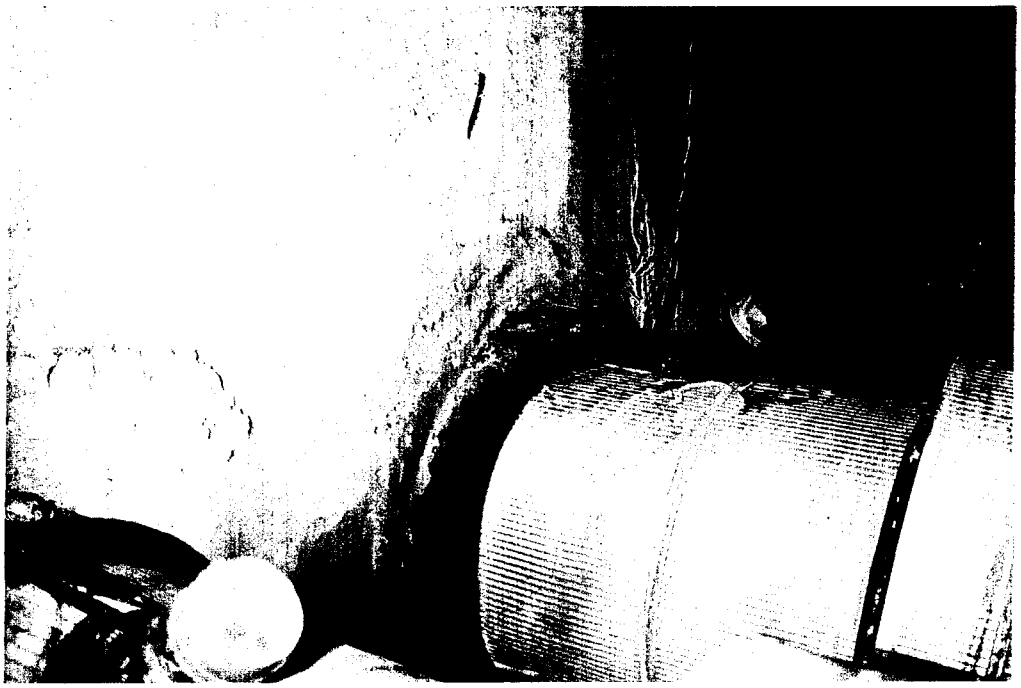


Figure 21. Plugged vents in manhole no. 4040.

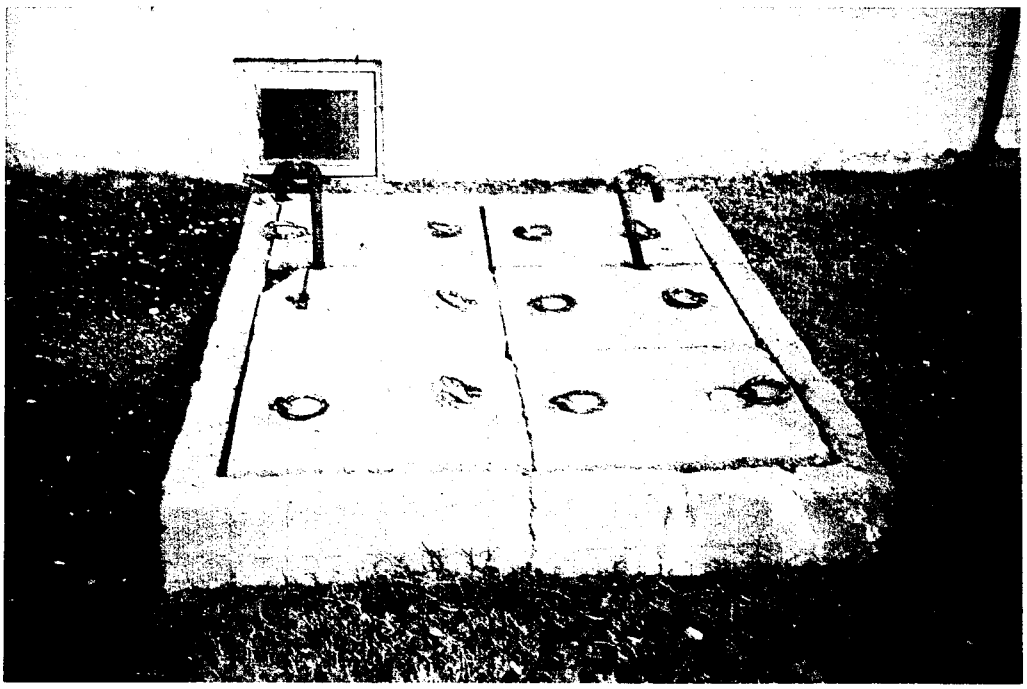


Figure 22. Excessively heavy concrete manhole cover in the 4000 area.

Figure 23. Six in. steam line to Bldg E3081 (Section 30A-3081), with coating and pipe both in good condition.

showed stratification, indicating possible differences in resistivity, the coating was intact and there were no visible corrosion pits.

The steam and condensate lines in front of Bldg E1570 were direct-buried steel surrounded by Protexulate. The corrosion pit depths on the steam line averaged approximately 0.01 to 0.02 in. (Figure 24). Corrosion pit depths on the condensate line measured less than 0.01 in. (Figure 25).

A bellhole inspection was attempted on section 37A-3835, but DPW personnel were unable to locate the line. A soil sample was taken from the excavation at a depth of approximately 5 ft. It was noted that the soil was steaming at the area where the soil sample was taken. This indicates that the piping is losing heat well in excess of design specifications.

Overall System Condition

From the standpoint of thermal efficiency and physical condition, the overall system is considered to be in fair to poor condition.

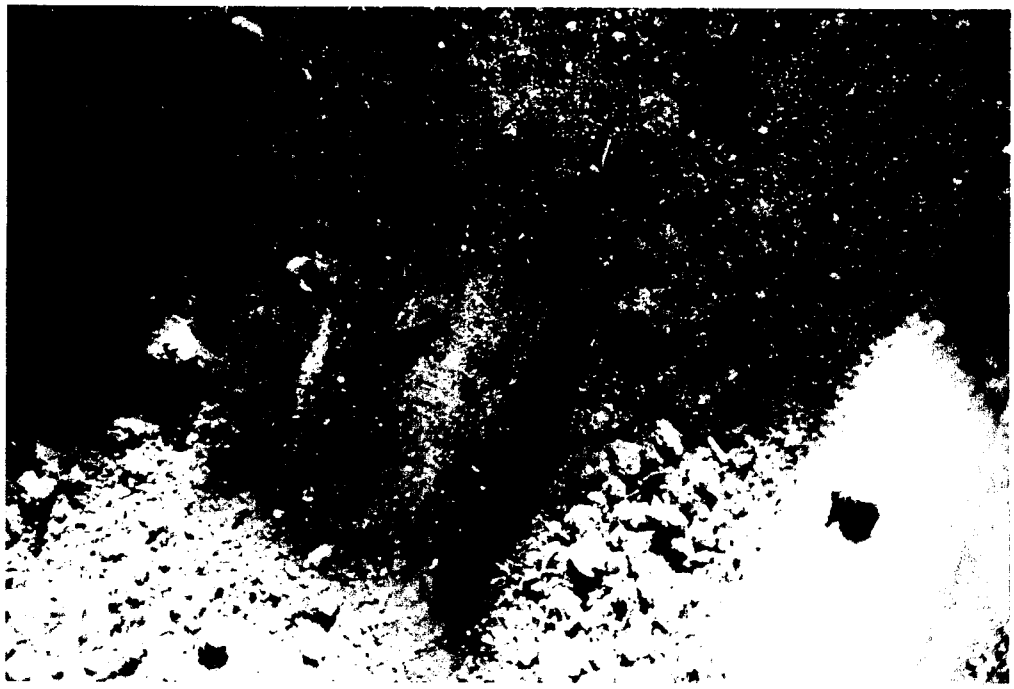


Figure 24. Steam line in front of Bldg E1570, with corrosion pit depths averaging 0.01 to 0.02 in.

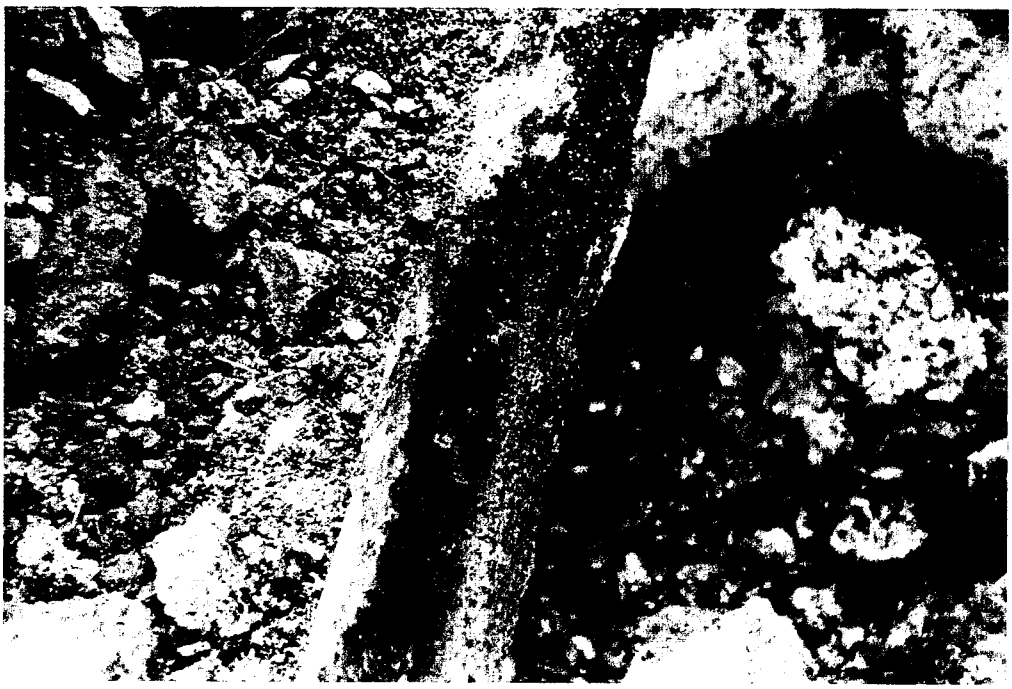


Figure 25. Condensate line in front of Bldg E1570, with corrosion pit depths averaging less than 0.01 in.

Soil Testing

To determine the potential for soil-side corrosion of underground steam or condensate piping that has metallic casing in direct contact with the soil, data on the chemical composition of the soil were obtained at several locations throughout the area covered by the study.

Procedure for Field Evaluation of Resistivity

Extensive testing of the soil resistivity at Edgewood was conducted in 1977 by the Facilities Engineering Support Agency (FESA) (McLeod and Barthelmy 1977). Since soil characteristics typically do not vary appreciably over time, these resistivity measurements can be considered valid for the current work. The variations in resistivity at any given location are caused mostly by seasonal variations in soil moisture. Soil resistivity tends to decrease during especially wet periods, and tends to increase during especially dry periods.

Despite the availability of relevant soil resistivity data, several locations for resistivity measurements and soil sampling were selected based upon the general leak history information and casing material data given. The reason for this was to verify the accuracy of the 1977 measurements and to obtain additional soil chemistry data that affects the corrosion rate. Sampling locations were selected in the E3000, E4000, and E5000 areas. A location in the E1500 area was investigated because of severe, recurrent corrosion problems, even though it is outside the area covered by this study. Soil resistivity tests were conducted in the field at each sampling location according to ASTM Standard G57 (1992). The tests were conducted on 9-10 February 1993. Pin spacings for the tests were set depending on the depth of the buried lines as observed from adjacent manholes. Measurements were conducted using an Associated Research Model 293 Vibroground®.

Procedure for Laboratory Evaluation of Soil

Soil samples were collected for laboratory evaluation at six locations on 2 June 1993. Samples were obtained by augering down to the approximate pipeline depth and collecting a 1 to 2 liter sample in a plastic "ziplock" bag. The soils were tested in the laboratory to determine pH, resistivity, moisture content, sulfate content, sulfide content, and chloride content. Standards used for testing are listed in Table 2.

Table 2. Standards used for laboratory soil testing.

Analysis Description	Analysis Method
pH	EPA 9045
Resistivity	ASTM G57
Sulfate	EPA 9038
Sulfide	EPA 376.1
Chloride	EPA 9252
Moisture	EPA 160.3
Total Acidity	EPA 305.1

Soil Testing Results and Discussion

Results from the 1993 Wenner 4-pin soil resistivity tests conducted by USACERL are shown in Table 3. Results from the 1977 FESA soil resistivity tests are shown in Table 4. Results from laboratory testing of the soils are given in Table 5. The results are discussed in the following paragraphs.

Soil Resistivity

One of the most important factors affecting corrosion activity along an underground pipeline is the resistivity of the electrolyte (soil). Corrosiveness of the environment is generally an inverse function of resistivity. Low resistivity favors the flow of current and increases the probability of corrosion; corrosion may not be a problem in very high-resistivity electrolytes. The effect of soil resistivity on the anticipated corrosion activity for steel can be predicted using information given previously in Table 1. These data, however, should not be used as an absolute criterion for corrosivity. Often, severe corrosion damage occurs in soils having relatively high resistivities. This is especially true in heterogeneous soils (e.g., an environment of clay lumps mixed with sand).

Table 3. Wenner 4-pin soil resistivity data from 1993 USACERL survey.

Location	Pin Spacing (ft)	Resistivity (ohm-cm)	Anticipated Corrosion Activity
Bldg 1570	5	8235	Moderate
	10	3850	Moderate
Bldg 3081	2.5	4787	Moderate
	5.0	5745	Moderate
Bldg 3724	2.5	8618	Moderate
	5	7852	Moderate
Bldg 4445	5	5362	Moderate
	10	3064	Moderate
Bldg 5604 Alley & 34th	5	9575	Moderate
	10	10724	Mild
Bldg 5100	5	11490	Mild
	10	9192	Moderate
Bldg 5360	5	22981	Mild
	10	24896	Mild

Table 4. Wenner 4-pin soil resistivity data from 1977 survey.

No.	Location	Soil Resistivity With 5 Ft Pin Spacing (ohm-cm)	Soil Resistivity With 10 Ft Pin Spacing (ohm-cm)
1	E Bldg 5936	17240	22980
2	Bend on Redwing Rd	5650	6894
3	S Bldg 5915	8230	8809
4	S Bldg 5888	11490	17044
5	N Bldg 5848	29680	38300
6	N Lagoon Rd	6700	12830
7	E Bldg 5690	11490	18384
8	S Bldg 5672	9580	11490
9	N Bldg 5565	9000	4404
10	E Bldg 4836	6610	1915
11	S Bldg 4677	6890	5554
12	S Bldg 4730	3450	3830
13	W Bldg 4465	6030	6320
14	S Bldg 4162	11490	10532
15	S Bldg 5405	9580	8618
16	E Bldg 5330	3540	823
17	E Bldg 5633	9580	5554
18	S Bldg 5190	3540	3638
19	S Bldg 5707	9580	6702
20	N Bldg 5703	9580	6702
21	E Siebert Rd	3350	5362
22	N Bldg 5762	8430	5745
23	W Bldg 6659	10532	9766
24	N Bldg 6619	25852	34470
25	S Bldg 5185	4980	4404
26	W Bldg 5307	14360	13405
27	N Bldg 4486	3730	4022
28	E Bldg 4530	8230	12256
29	E Bldg 4420	3730	2872
30	NE Bldg 4410	7090	9000
31	N Bldg 5238	10530	12064
32	N Bldg 5033	5080	4979
33	S Bldg 1574	5080	2681
34	S Bldg 1570	4020	3638
35	E Bldg 6165	7380	3064
36	N Bldg 5108	10530	9766

Table 4. (Cont'd).

No.	Location	Soil Resistivity With 5 Ft Pin Spacing (ohm-cm)	Soil Resistivity With 10 Ft Pin Spacing (ohm-cm)
37	N Bldg 4225	4020	2681
38	E Bldg 4370	4500	4596
39	S Bldg 4210	2780	4022
40	N Bldg 4057	8910	11682
41	N Bldg 4015	9580	14171
42	E Bldg 1934	2390	1724
43	N Bldg 1240	191510	130220
44	NW Bldg 1226	9290	28725
45	N Bldg 1366	4980	2681
46	N Bldg 3064	3450	2681
47	W Bldg 3088	3160	1915
48	NE Bldg 3100	3060	4022
49	N Bldg 3222	4790	1915
50	E Bldg 3300	5650	3638
51	S Ricketts Pt Rd	9580	14171
52	E Bldg 3312	5750	3638
53	W Bldg 2160	9190	13214
54	N Bldg 3563	28730	26810
55	NE Bldg 3580	22020	19150
56	SE Bush River & 22nd St	2300	1475
57	S Bldg 2182	7240	9192
58	NW Bldg 2204	13410	13788
59	NW Bldg 2314	3730	4213
60	NW Cadwalder & 25th St	6610	7660
61	S Bldg 2620	3830	5554
62	SE Bldg 3863	6030	3830
63	SE Bldg 2380	1440	2106
64	S Bldg 6202	37342	36385
65	NW Bldg 6210	8139	7277
66	NW Cedar Dr S & Cedar Dr E	9575	5745
67	S Cedar Dr E	18192	17618
68	NE Bldg 6542	40215	40215
69	NW Bldg 6528	47875	78515
70	SE Bldg 6560	114900	151285
71	E Bldg 6558	22980	21065

Table 5. Results from laboratory testing of soil.

Parameter	Bldg E1570: 2 ft above pipe	Bldg E3081 At pipeline depth	Line to Bldg E3835 Near Bldg E3724	Bldg E4445 Near manhole	Bldg E5126 Near first manhole SE of plant	Bldg E5360 Near manhole
pH	7.0	6.7	7.8	7.5	7.3	6.6
Paste pH	8.1	6.7	7.8	8.0	8.1	7.4
Resistivity (Ω-cm)	9932	12650	35600	43100	>44000	>44000
Sulfate (mg/kg)	118	586	67	88	<10	50
Sulfide (mg/kg)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Chloride (mg/kg)	89	112	35	31	34	35
Moisture (%)	17.1	16.7	16.1	14.5	10.7	11.8
Total Acidity (mg/kg)	55	84	58	42	42	62

Soil resistivities in the areas surveyed at EA indicate that the soil should range from mildly to moderately corrosive in most areas. The laboratory tests indicated that the soil is only slightly corrosive at some locations. It is important to note that the Wenner four-pin technique, used to measure resistivities in the field, gives an average resistivity to a depth equal to the spacing of the pins, whereas laboratory testing gives the resistivity at the exact depth and location tested.

The most significant implication of the resistivity test results is that the soil resistivity in most areas surveyed was under 30,000 ohm-cm. As stated earlier, Army guidance requires that underground heat distribution and chilledwater piping in ferrous metallic conduit in soils with resistivity of 30,000 ohm-cm or lower is to be cathodically protected. Therefore, cathodic protection should be added to existing lines contained in ferrous metallic conduit. Any new lines with metallic casings that are direct-buried underground should be coated and cathodically protected. The soil is particularly corrosive to coated metallic structures where corrosion activity is accelerated at flaws in the coating. As discussed earlier, corrosion penetration of the casing allows for water infiltration and wets the insulation, leading to excessive heat losses and accelerated failure of the piping.

Soil pH

pH is a measure of an environment's hydrogen-ion activity. By definition,

$$pH = - \log [a(H+)] \qquad \text{[Eq 2]}$$

where a (H+) is the hydrogen-ion activity (concentration, for dilute solutions, in gram-ions/liter). Neutral environments have a pH of 7, alkaline environments have a pH greater than 7, and acids have a pH lower than 7. In general, the corrosion rate increases as the pH decreases below a pH of 7. The relatively neutral soil pHs measured at EA should not have a significant impact on the corrosion rate of buried steel.

Soluble Salts

The effect of soluble salts such as sodium chloride (NaCl) generally tend to increase the corrosion rate by decreasing the resistivity of the soil (i.e., increasing the conductivity of the soil). The presence of salts such as calcium sulfate ($CaSO_4$) can lead to accelerated corrosion of steel by the production of sulfate-reducing bacteria. The soils tested at EA had relatively high concentrations of chlorides and sulfates.

Sulfides

If sulfides are found in the soil, the presence of sulfate-reducing bacteria is likely. Sulfate-reducing bacteria can result in accelerated corrosion. Sulfides were not found in any of the soil samples tested at EA, so the data do not indicate the presence of sulfate-reducing bacteria.

Soil Moisture

In addition to the mineral content, moisture greatly affects a soil's resistivity. Resistivity decreases with an increase in moisture content up to a point near saturation. Seasonal differences in soil moisture can have a significant impact on the soil resistivity. In earlier USACERL research on the predictive modeling of the corrosion process for steel buried in soil, it was found that the moisture content of the soil does not significantly increase the corrosion rate unless it is above about 28 percent. The moisture content of the soils tested at EA was well below this threshold value at all locations.

Pipe-to-Soil Potential Survey

A pipe-to-soil potential survey was conducted at various locations throughout the E3000, E4000, and E5000 areas. Potentials were measured versus a copper-copper sulfate ($Cu/CuSO_4$) reference cell using a Fluke high-resistance multimeter. Potentials were evaluated to determine (1) existence and functionality of cathodic protection, (2) existence of electrical isolation from dissimilar metals such as copper, and

(3) existence of interference. APG personnel were not aware of cathodic protection on any of the buried lines owned and maintained by APG. Personnel stated that the steam and condensate lines owned and maintained by the waste-to-energy plant is cathodically protected with sacrificial anodes. Results of the pipe-to-soil potential survey are shown in Table 6.

The presence of cathodic protection on the waste-to-energy line was verified at the one tested location. It was also found that the new line to Bldg E3835 (pipe section 37A-3835) is cathodically protected. Several cathodic protection test stations were found along the line. The potentials measured indicate that protection is being supplied by magnesium anodes. APG personnel reported that annual pipe-to-soil potential surveys are not conducted. None of the other lines tested were cathodically protected. The values of the pipe-to-soil potentials of the unprotected lines fell within normal ranges

Table 6. Results from pipe-to-soil potential survey.

Location	Pipe-to-Soil Potential,V*
Steam line to Bldg 3081, at ground entry point	-0.590
Condensate line to Bldg 3081, at ground entry point	-0.536
Steam line at manhole between E5100 and 5126, near E5100	-0.440
4 in. steam line near Bldg 5360	-0.496
10 in. steam line near Bldg 5360, east of valve	-0.525
10 in. steam line near Bldg 5360, north of valve	-0.523
Bldg 5360, line on west side of valve	-0.523
8 in. aboveground steam line at Bldg 5604 (Alley Rd. & 34th)	-0.463
Near Bldg 3724- CP test station near manhole	-0.97
Near Bldg 3724- CP test station at manhole + 100 ft south	-1.06
Near Bldg 3724- CP test station at manhole + 200 ft south	-1.11
Near Bldg 3724- CP test station at manhole + 300 ft south	-1.06
Steam line in front of Bldg 1570	-0.513
Condensate line in front of Bldg 1570	-0.514
Waste-to-energy steam line near Bldg 5141	-1.04
Waste-to-energy condensate line near Bldg 5141	-0.996
Bldg 4445 near manhole-- condensate line running south	-0.52
Bldg 4445 near manhole-- steam line running south	-0.52
Bldg 4445 near manhole-- condensate line running back to plant	-0.526
Bldg 4445 near manhole-- steam line from plant	-0.525

for steel buried in soil. Neither electrical contact with dissimilar metals nor interference were detected at any of the testing locations.

In addition, data from the 1989 cathodic protection survey conducted by the U.S. Army Engineering and Housing Support Center—now the Center for Public Works—were reviewed (Spoerner 1989). Results of the survey indicated that none of the steam distribution lines owned by APG in the Edgewood area was cathodically protected. (Note: This is before the cathodically protected line to Bldg E3835 was installed.) The survey found that 97 percent of the locations tested on the waste-to-energy plant line met the criteria for cathodic protection.

Tests of Products Conveyed by the System

On 10 February 1993, two personnel from the U.S. Army Center for Public Works (USACPW) collected boiler, condensate, and makeup water samples for chemical analysis at boiler plants E5126, E3312, and E4160. Information on the chemical treatment applied at each plant was obtained from the boiler operators. The boilers in Bldgs E5126 and E3312 only supplement the steam supply from the waste-to-energy plant.

Boiler Plant E5126

This plant has six boilers. At the time of the survey, most of the load was being carried by boilers no. 5 and no. 6. Boiler no. 5 is a 1941 Union Iron Works 478 hp boiler, with a maximum capacity of 200 psi. It was operating at 130 psi. Boiler no. 6 is a 1985 Cleaver Brooks 600 hp watertube boiler with a maximum capacity of 260 psi. It was operating at 128 psi. The other boilers are smaller and were in wet layup at the time of the survey. All of the boilers have blowdown controllers on the continuous blowdown line. All makeup water is softened. The deaerator was operating at 230 °F and 7 psi. There is no condensate return to this plant; all returned condensate goes to the waste-to-energy plant. Treatment chemicals are supplied by Calgon Chemical. CB421™ is a combination of a dispersant and antifoam. CB260™ is sodium sulfite. Defend 327™ is a neutralizing amine which is used as a condensate corrosion inhibitor. Material Safety Data Sheets (MSDS) for the boiler treatment chemicals are reproduced in Appendix F. Chemicals are added to the boiler by feedpumps. Sample coolers were present on the boilers and the condensate sampling line for the waste-to-energy plant, but there was no sample cooler for the condensate from the APG boilers.

Boiler Plant E3312

There are five boilers in this plant. All were in layup at the time of this survey. The most recently fired boiler was boiler no. 4. The boilers are Cleaver Brooks firetube package boilers; the oldest was installed in 1975. There is a duplex softening system. The deaerator was not in operation at the time of the survey. Chemicals used here are Calgon CB421™, CB260™, CB150™, CB409™, and Magnamine 327™. CB421™ and CB260™ are described above. CB150™ is a combination of sodium hexametaphosphate and polyacrylate. CB409™ is a solution of caustic soda. Magnamine 327™ is a combination of morpholine, DEAE*, and sodium erythorbate.

Boiler Plant 4160

This plant has two boilers (boiler no. 1 and boiler no. 3). A new boiler no. 2 is to be installed in the future. The existing boilers are 1975 Cleaver Brooks firetube package boilers with a maximum operating pressure of 150 psi. Boiler no. 1 was operating at 22 psi and boiler no. 3 was operating at 25 psi. Steam from this plant goes to the 4000 area and does not mix with the waste-to-energy plant steam. Water is softened. The deaerator was operating at 235 °F and 9 psi. There is one chemical feed pump for each boiler. Chemicals used in this plant are the same as for Bldg E3312.

Results and Discussion

Results of the laboratory tests are given in Tables 7-9.

There were sample coolers on all of the boilers sampled, as well as a sample cooler for the waste-to-energy condensate line. This is a good feature of the systems.

The use of blowdown controllers on the boilers in E5126 is also very good. The load is so variable based on the output of the waste-to-energy plant that it is difficult to consistently maintain good chemistry without the controllers.

However, control of the water chemistry in all boilers requires improvement. In many cases, the values of the parameters tested were not within the Army-recommended ranges (Technical Manual [TM] 5-650).

Condensate samples collected at E5126 indicated the possibility of carryover from both the APG boilers and the waste-to-energy plant. The term *carryover* means that small droplets of the boiler water become entrained in the steam and are carried into the

* DEAE: diethylaminoethanol.

Table 7. Boiler water chemical analysis results.

Bldg No.	E5126	E5126	E5126	E3312	E4160	E4160	E4225	Army Range*
Boiler No.	4	5	6	4	1	3	3	
Boiler Status	Wet Layup	On	On	On	On	On	On	
Total Dissolved Solids (mg/l)	2100	2000	2200	1950	650	850	1850	
Conductivity (µS/cm)	2610	2880	3160	2780	940	1210	2630	3000 - 3500
pH	12.8	12.3	12.5	12.5	11.4	11.7	12.5	
Sulfite (Na_2SO_3)	56	8	5	8	<2	<2	<2	20 - 40
Total Hardness ($CaCO_3$)	<2	<2	<2	<2	<2	<2	<2	
P Alkalinity ($CaCO_3$)	700	460	510	600	510	120	410	
Causticity, Hydroxide (OH^-)	130	850	940	1080	130	210	270	20 - 200
Orthophospate, Filtered (PO_4)	<1	16.8	18	36	<1	3	10	30 - 60
Tannin Color	1	<1	<1	<1	<1	<1	<1	

* *Army Range* refers to the Army-recommended range of values for this parameter as given in TM 5-650. These ranges are for boilers that are operating and do not include boilers that are in wet layup.

Table 8. Condensate chemical analysis results.

Building No.	E5126 W/E line	E5126	E4160	E4225	Army Range*
Color	Clear	Clear	Clear	Brown	
Total Dissolved Solids (mg/l)	200	110	11	64	
Conductivity (µS/cm)	287	222	15	92	< 35
pH	9.8	9	7.7	7.9	7.5 - 8.5
Total Hardness ($CaCO_3$)	<2	<2	<2	<2	<2
M Alkalinity ($CaC0_3$)	2	3	<1	2	
Total Suspended Solids	None	None	None	None	
Carbon Dioxide (mg/l)	----------	<1	14	21	
Total Iron (mg/l)	0.015	5.823	0.015	42.02	

* *Army Range* refers to the Army-recommended range of values for this parameter as given in TM 5-650. These ranges are for boilers that are operating and do not include boilers that are in wet layup.

distribution system. Condensate conductivity over 35 µmho is considered a sign of excess carryover. The condensate sampled from the waste-to-energy line at E5126 had a conductivity of 287 µmho and the condensate sample from the APG condensate line at E5126 had a conductivity of 222 µmho. Operators need to check for carryover in condensate samples by performing a quick conductivity check. The chemical levels measured in the boilers themselves were not high enough to be causing carryover, but there could be some contaminant causing foaming in the boiler, or there could be a mechanical problem causing carryover.

Table 9. Boiler feedwater chemical analysis results.

Building No.	E5126	E4160	E4225
Total Dissolved Solids (mg/l)	110		110
Conductivity (µS/cm)	153		151
pH	8		8
Total Hardness ($CaCO_3$)	<2		<2
M Alkalinity ($CaCO_3$)	31		30

There were high levels of iron in the condensate from Bldg E5126 (5.823 mg/l) and in the condensate from Bldg E4225 (42.02 mg/l), indicating that there is corrosion somewhere in the system. Corrosion testers are being installed in the condensate system to monitor corrosion rates. The testers consist of 2 in. diameter galvanized steel pipe nipples inside of which are enclosed six specially machined and preweighed "test ring" coupons (specimens). Testers will be installed for 90 days and removed. Corrosion rates will be determined by a weight-loss measurement technique. These corrosion testers are to be installed in the following locations:

1. Boiler plant E3312, near condensate pump to waste energy plant (on line where condensate is returned from system)
2. Boiler plant E4160, on main condensate return line (2 in. line) between the two boilers
3. Boiler plant E5126, near condensate pump to waste energy plant.

New testers should be used each year.

The total dissolved solids (TDS) levels in all of these boilers were lower than optimum for best energy efficiency, water consumption, and chemical consumption. The TDS levels ranged from 650 to 2,200 ppm. The optimum level is usually 3,000 to 3,500 ppm, if this can be achieved without the silica level exceeding 200 ppm in the boiler. This may be the case at EA. TDS levels are controlled by blowdown. The chemical supplier should be able to determine whether these boilers can reach optimum TDS levels. (Note that the lower the TDS levels in a boiler, the higher is the chemical usage

rate. Unnecessarily low TDS levels are often favored by sales representatives to increase chemical sales.)

Chemical levels in some of these boilers were not within control limits. Results showed that sulfite levels were very low in all of the on-line boilers tested. The Army-recommended sulfite level for on-line boilers is 20 –40 ppm; the boilers tested here had sulfite levels ranging from less than 2 ppm to 8 ppm.

Phosphate levels were very low in all of the boilers tested except for one. The Army-recommended range for phosphate is 30 – 60 ppm. Boiler no. 4 at Bldg E3312 was the only boiler within this range with a phosphate level of 36 ppm. The other boilers tested here had phosphate levels ranging from less than 1 ppm to 18 ppm.

Causticity was excessively high in three of the boilers tested and slightly high in two others. The Army-recommended range for causticity is 20 – 200 ppm. Boilers no. 5 and no. 6 at Bldg E5126 and boiler no. 4 at Bldg E3312 had causticities in excess of 800 ppm. Levels were slightly high in boiler no. 3 at Bldg E4160 and in boiler no. 3 at Bldg E4225.

One of the boilers, no. 4 in Bldg 5126, was in wet layup at the time of the survey. The sulfite and causticity levels were low for layup conditions. The recommended minimum sulfite level for wet layup is 200 ppm; the level in this boiler was 56 ppm. The recommended minimum causticity level for wet layup is 500 ppm; the level in this boiler was 130 ppm.

As a potential remedy to the problem of controlling chemical levels, a proportional chemical feed system should be strongly considered for these boilers. The chemical feed pumps can be controlled by pulsing makeup water meters. This system would greatly facilitate maintaining chemical control. A typical proportional feed system costs about $500. The Calgon sales representative should be able to sell and install them. The installation of proportional feed systems is in the best interest of the chemical company because these systems make the treatment chemical look better for controlling scale and corrosion.

4 Conclusions and Recommendations

Conclusions

1. The overall heat distribution system at APG/ EA was found to be in fair to poor condition according to the criteria set forth in Chapter 3.
2. The most common defects found on the underground system were (1) the presence (or evidence) of standing water in the manholes and (2) the lack of insulation on much of the piping in the manholes. The major factor contributing to the problem of standing water in the manholes is the complete absence of sump pumps in the system.
3. The most common defect found on the aboveground system was missing and damaged pipe insulation: an estimated 2,000 feet of aboveground piping was found to be without insulation.
4. Soil test results in the areas surveyed at EA indicate that the soil probably ranges from mildly to moderately corrosive in most areas.
5. The cathodic protection survey revealed the presence of cathodic protection on only one line.
6. Testing of the boiler water and condensate revealed problems with chemical control in the boilers at APG/EA. The values of several key chemical parameters were not within the Army-recommended ranges as set forth in TM 5-650. In addition, a high iron content was observed in the condensate from two different locations. This indicates that CO_2 or O_2 corrosion is occurring in the system.

Recommendations

The recommendations that follow are organized according to the three principles discussed in Chapter 2 for maximizing the performance of a heat distribution system:

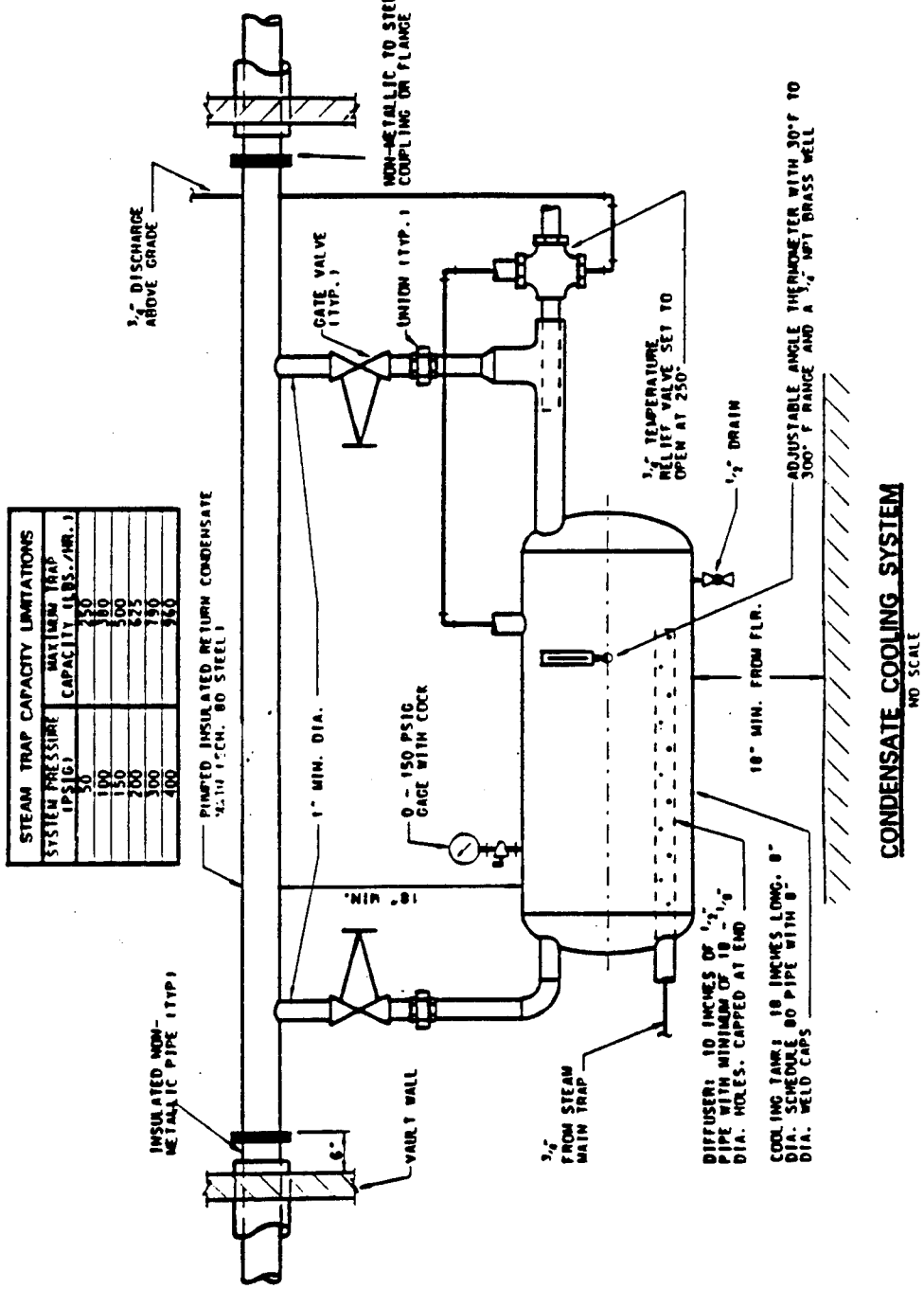
1. replacement or rehabilitation of severely deteriorated, unsafe, or improperly functioning components
2. execution of a good ongoing maintenance program that is tailored to the specific corrosion and deterioration problems at the installation
3. ensuring that any system replacements or new systems are specified and installed in accordance with current standards and guidance.

Please note that the recommendations under "Replacement or Rehabilitation" (immediately below) should be followed in conjunction with the condition ratings and inspection comments given in Appendix C. Any costs specified in the recommendations (except for the sump pump cost) are based on the findings of Uzarski (July 1991) and Demetroulis (May 1990), but adjusted to 1994 dollars assuming a 4 percent annual inflation rate.

Recommendations for Repair or Replacement of Unsafe or Malfunctioning Components

Short-Term Replacement/Rehabilitation Recommendations:

1. On the aboveground lines, bare sections of piping and sections with damaged insulation and covering should be reinsulated and covered with an aluminum casing. Because many of the older lines at EA are covered with asbestos insulation, full compliance with all worker safety and environmental regulations will add cost to this work.
2. On underground lines, bare piping in manholes should be insulated and covered. Insulation at valves should be of the removable, reusable blanket type. Insulating and covering bare piping in manholes costs about $5.85 per linear foot.
3. Before or during the reinsulation of pipes, it is recommended that good quality electric sump pumps or drainage piping to the storm sewer (with a back-check valve) be installed. Installation of power and sump pumps at APG costs approximately $7,000 to $10,000 per manhole. Specific requirements are given in CEGS 02695. (This guide specification requires the installation of a dedicated electric line to the pump and the posting of a sign to warn personnel that power service is not to be interrupted.)
4. Steam condensate leaks should be repaired as quickly as possible to prevent excessive heat losses. In lines where multiple failures have occurred, consideration should be given to replacing the line.
5. To address the failures in the FRP condensate return line system in the 5000 area, which are probably caused by the release of live steam into the condensate system through failed steam traps (Chapter 3), it is recommended that a condensate cooling system be installed at each steam trap. The approach described in Army TM 5-810-17, sec 8-2e is recommended (see Figure 26).
6. As a safety precaution, the damaged, corroded, and loose access ladders in manholes should be replaced with prefabricated, galvanized steel ladders rigidly attached to the manhole walls. A new ladder costs approximately $170 per manhole.



(Source: TM 5-810-17.)

Figure 26. Schematic of condensate cooling system.

7. All aboveground anchor assemblies should be checked to ensure anchor stability. Broken and badly corroded guy wires should be replaced and guy wire tensions should be equalized.
8. Pipe supports and guides should be repaired to ensure proper operation. Special consideration should be given to broken and corroded moment guides at expansion joints in manholes.
9. At many of the conduit wall penetrations on the underground system's manholes, the caulking is no longer effective at keeping water out of the manhole. Caulking should be replaced as required. Old manhole penetrations should be sealed with concrete and waterproofed. Replacement of caulking inside the manhole costs about $47 per penetration.
10. Excessively corroded manhole internals should be replaced. This includes valves, piping, vents, supports, traps, and conduit end plates. The average cost of replacement is $175 each.
11. Before any maintenance or demolition of the aboveground systems, additional testing should be performed to determine whether lead-based paint is present beyond the single location at which it was found. Initial tests for lead can be performed inexpensively with any commercially available test kit approved by an appropriate national standards organization. Additional information on the regulations that must be considered, as well as on testing for the presence of lead, is given in Appendix G.
12. Leaking flange gaskets and valve packing should be replaced. This costs approximately $120 per location.
13. Excess vegetation (including several trees) growing up between the aboveground lines in the 3000 area should be removed.
14. Many of the screens on the manhole tops are missing and should be replaced to prevent debris from collecting in the manholes. Screen replacement costs approximately $4.70/sq ft.

Long-Term Replacement/Rehabilitation Recommendations:

1. The 4 in. condensate return line in the 3000 area extending from the boiler plant to near Bldg 3725 (section ID 3312-37A) is in extremely poor condition and should be replaced.
2. It is recommended that an economic analysis should be conducted to determine potential savings and payback period for the installation of condensate return lines in locations where condensate is dumped. Because of its vulnerability to failure, FRP should not be used for the new lines.
3. To provide greater flexibility in the operation and maintenance of the heating system, it is recommended that the Edgewood Area DPW consider installing a modified loop or interconnecting lines between heat plants. This enhancement

would allow operation of only one plant during low-load periods, leaving the others available for inspection and maintenance without disrupting service. If properly sectionalized (with valves), this concept would also allow for system emergency repairs with minimal impact on heat service to individual buildings.

4. A review is recommended to determine the cost of locating and replacing individual failed traps. This review should compare the costs of location and replacement with those of a scheduled program of trap replacement (using high-quality components). Consideration should be given to using high-quality inverted bucket traps such as those described in Maga (November 1991), or thermostatic traps with a delta-loop feature, which have been the subject of favorable comments from maintenance personnel at Ft. Lewis, WA, and Grissom Air Force Base (AFB), IN (Charles Keller and Jim Thayer, DPW, Fort Lewis, WA, telephone conversation, 3 September 1993; James Williams, Grissom AFB, IN, 14 July 1993). Replacement of a failed steam trap costs approximately $88.00.

Recommendations for a More Effective Maintenance Program

The following recommendations address four general elements of an effective maintenance program:

- a thorough, well monitored boiler water chemical treatment program
- a regular, systematic inspection program
- periodic testing of cathodic protection systems
- complete and accurate recordkeeping.

Boiler Water Chemical Treatment Program:

1. It is strongly recommended that boiler water and condensate chemistry immediately move within and be maintained at the Army-recommended control ranges specified in TM 5-650, and as set forth in the "Army Range" column of Tables 7 and 8 (Chapter 3).
2. It is recommended that proportional chemical feed systems immediately be installed on operating boilers. As noted earlier, these systems cost about $500 per boiler.
3. Maintain TDS levels of at least 2000 ppm by decreasing blowdown when necessary. The optimum level is 3000 to 3500 ppm. Obtain Calgon's input on how to increase the TDS level.
4. Reduce carryover at boiler plant E5126 as much as feasible.
5. Install sample coolers at all condensate sampling points.

6. Collect condensate samples on a regular basis from different points in the system and have them analyzed to help determine the cause of corrosion in the condensate system.
7. Install corrosion testers at various locations in the main condensate return system to further identify and locate the cause of corrosion.
8. Participate in the Army's Boiler Water Quality Assurance Program. An information paper briefly describing this program is reproduced in Appendix H.
9. Consult with the U.S. Army Center for Public Works (USACPW) when necessary for assistance with questions on boiler water chemistry.
10. Personnel who are responsible for performing, specifying, or supervising the chemical treatment of boiler water should attend USACPW's Boiler Water Treatment Workshop. This workshop is sponsored by the Sanitary Chemical Division (CECPW-ES) and is held two or three times per year at Fort Belvoir, VA.

Systematic Inspection Program:

1. It is recommended that the procedures for inspecting underground heat distribution systems (Demetroulis, Hock, and Segan, March 1991) be implemented at EA, including annual manhole inspections. This type of inspection costs approximately $200 per manhole.
2. It is recommended that the aboveground system be inspected regularly, with deficiencies noted and repaired. USACERL has not yet published formal guidelines for conducting this kind of an inspection, but such guidelines are anticipated as a product of scheduled research and development. In lieu of formal guidelines, the following items will be covered during inspection of the aboveground system:
   - deterioration of casing
   - missing, wet, or otherwise damaged insulation
   - leaking pipes
   - leaking valves or flanges
   - steaming around system components
   - deterioration of supports, including rusting, bending, failed coating, failure of the pipe to rest on the support, or other deterioration which affects functionality and/ or safety
   - corroded or slack support wires
   - vegetation around lines.

3. It is recommended that DPW personnel investigate the possible benefits of commercially available computer programs that may enhance the installation's steam trap maintenance program. Steam traps should be inspected regularly and failed traps should be replaced as stated previously.

Periodic Testing of the Cathodic Protection System:

1. It is recommended that the sacrificial anode cathodic protection system on the line to Bldg E3835 be tested annually to ensure that the system continues to provide corrosion protection to the coated line and, thus, help to maximize the life of this relatively new line. A pipe-to-soil potential survey should be conducted along the entire length of the line, and the results should be evaluated against the National Association of Corrosion Engineers' criteria for cathodic protection (Standard Recommended Practice RP0169-92). Any problems indicated by the test results should be remedied promptly to ensure that the line does not fail prematurely due to soil-side corrosion. Information on cathodic protection testing is included in Appendix I.
2. It is recommended that APG/EA use the USACERL-developed Cathodic Protection Diagnostic program (Appendix I) to store and evaluate cathodic protection test data. This program can be used to store data on cathodic protection systems for all underground piping systems, underground storage tanks, and elevated water storage tanks.
3. Personnel who are responsible for performing, specifying, or supervising the testing of cathodic protection systems should attend the PROSPECT Corrosion Control Course or the Facilities Engineer Corrosion Course. Both courses are offered annually at USACERL.

Recordkeeping

1. It is recommended that centralized maintenance/repair/leak records be kept to document justification for major repair projects, replacements, or installation of cathodic protection, and to help to establish the locations of recurring problems.
2. It is recommended that the current efforts to computerize utility maps on the installation GIS incorporate the leak and repair records described above. It is also recommended that the GIS be used to record the inventory, condition assessment, and soil testing information in the test and appendices of these reports. Incorporating these data into the GIS will provide a reliable, uniform set of information and frame of reference for all DPW engineers and planners.

Recommended System Replacements

1. It is recommended that APT/EA discontinue the use of system piping systems and materials not approved by FAC (i.e., steel pipe covered with fiberglass insulation and Protexulate™. An FAC pre-engineered, pre-approved piping system should be used for all replacements and should be installed in accordance with the FAC approved brochure. Details are in CEGS 02695.

2. It is recommended that aboveground distribution systems be used wherever feasible, because of their ease of inspection and maintenance, as well as their low life-cycle cost. See CEGS 02697 (May 1991) for current Army guidance on aboveground heat distribution systems.
3. It is recommended that the slab-on-grade concrete trench system be used where aboveground systems are not permitted (e.g., housing, administrative areas). Current Army guidance on this system—a protective concrete trench in which insulated piping is mounted on sliding supports or rollers, with easily removable trench lids for leak location—is specified in TM 5-810-17.
4. In areas with extremely high water tables that could flood a concrete trench, a preapproved drainable-dryable conduit system is recommended. CEGS 02695 lists those companies who currently have FAC-accepted brochures.
5. It is recommended that raised-top, reinforced concrete manholes with solid aluminum plate covers be used in future construction and replacement. This type of manhole—the "Omaha design"—provides easy access and an excellent environment for inspection and repairs. The section from TM 5-810-17 that describes the Omaha design is reprinted in Appendix J.
6. It is recommended that fiberglass-reinforced plastic condensate return lines no longer be used because of the high potential for line failure when live steam enters the line due to a steam trap failure.

References

ASTM G57-78 (R84), *Standard Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method* (American Society for Testing and Materials, 1984).

Beard, James B., *Turfgrass: Science and Culture* (Prentice Hall, 1973).

Corps of Engineers Guide Specification (CEGS) 02695, *Underground Heat Distribution System and Condensate Return System* (Headquarters, U.S. Army Corps of Engineers [HQUSACE], May 1991).

CEGS 02697, *Aboveground Heat Distribution System* (HQUSACE, May 1991).

Demetroulis, N.M., V.F. Hock, and E.G. Segan, *Guidance for Manhole Rehabilitation in Army Underground Heat Distribution Systems*, Technical Report [TR] M-91/01/ADA233709 (U.S. Army Construction Engineering Research Laboraborie [USACERL], March 1991).

Demetroulis, N.M., *Procedures for Inspection of Heat Distribution Systems at Fort Dix, NJ* (Contractor report prepared for USACERL, May 1990).

Engineer Technical Letter (ETL) 1110-3-440, *Cathodic Protection*, (HQDA, 20 August 1992).

Guglomo, R.C., V.L. Van Blaricum, C.D. Page, and A. Kumar, *MicroGPIPER Implementation Guide*, TR FM-92/04/ADA256755 (USACERL, July 1992).

Husock, B., *Evaluation of Cathodic Protection Criteria*, Engineering and Services Laboratory (ESL) TR-79-14 (Headquarters, Air Force Engineering and Services Center, April 1979).

Maga, S., *Steam Loss Test of Steam Traps*, unnumbered contractor report prepared for USACERL (Naval Civil Engineering Laboratory Report, November 1991).

Marsh, C., "Lessons Learned to Date From the Fort Jackson, SC, FEAP Heat Distribution Systems Demonstration Project," *Proceedings of the 1992 Electrical-Mechanical Conference* (July 1992).

McCammon, T.L., and M.J. Savoie, *Thermal Energy Supply Optimization for Edgewood Area, U.S. Army Aberdeen Proving Ground: Energy Supply Alternatives*, USACERL TR 95/01 (USACERL, May 1995).

McLeod, M.E., and M.P. Barthelmy, *Corrosion Survey Report, Aberdeen Proving Ground, Maryland*, Report No. ED-7707 (U.S. Army Facilities Engineering Support Agency, 19 December 1977).

Myers, J.R., E.G. Segan, C.P. Marsh, and V.F. Hock, *Causes and Control of Corrosion in Buried-Conduit Heat Distribution Systems*, TR-M-91/08/ADA238958 (USACERL, July 1991).

Spoerner, T. W., *Cathodic Protection Systems Evaluation: Aberdeen Proving Grounds and The Edgewood Arsenal, MD*, Report No. E-89052 (U.S. Army Engineering and Housing Support Center, May 1989).

Technical Manual (TM) 5-650, *Central Boiler Plants* (Headquarters, Department of the Army [HQDA], 1 August 1962).

TM 5-810-17, *Heating and Cooling Distribution Systems* (HQDA, 1994).

Standard Recommended Practice RP0169-92, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems* (National Association of Corrosion Engineers, April 1992).

Uzarski, D.R., R.E. Rundus, D.M. Bailey, M.J. Binder et al., *Layaway Procedures for U. S. Army Facilities, Volume I: Decision Criteria and Economics*, TR M-91/23/ADA240054 (USACERL, July 1991).

Appendix A: Maps Showing Locations of Nodes, Manholes, and Pipe Sections

To facilitate identification of system elements, a naming scheme was developed for the key components of the heat distribution system. System nodes are designated either by building numbers, or, where a node does not correspond with a building, the nodes are given an alphanumeric designation such as "37A." Manholes also were numbered to facilitate their identification. In general, manhole identifications were assigned for each area beginning at the heating plant and proceeding around the loop. The manholes closest to the plant in each area (E3312, E4160, and E5126) were assigned the numbers 3000, 4000, and 5000, respectively. Identification numbers were assigned to subsequent manholes based on increments of 10.

APG personnel wished to be able to easily correlate this naming scheme with their existing 40-scale maps. For this reason, the maps have been reduced and included in this report. The maps show the specific locations of buildings, nodes, pipe sections, and manholes along with their assigned identifications. The 8.5 x 11 in. maps on the following pages are 65 percent reductions of the 40 scale maps of the utility distribution systems at Edgewood Area. The 40-scale maps were marked with node, manhole, and pipe section identification numbers. To facilitate inclusion of the maps in this report, each 40 scale map was divided into quadrants according to the following chart:

Sample 40-Scale Map

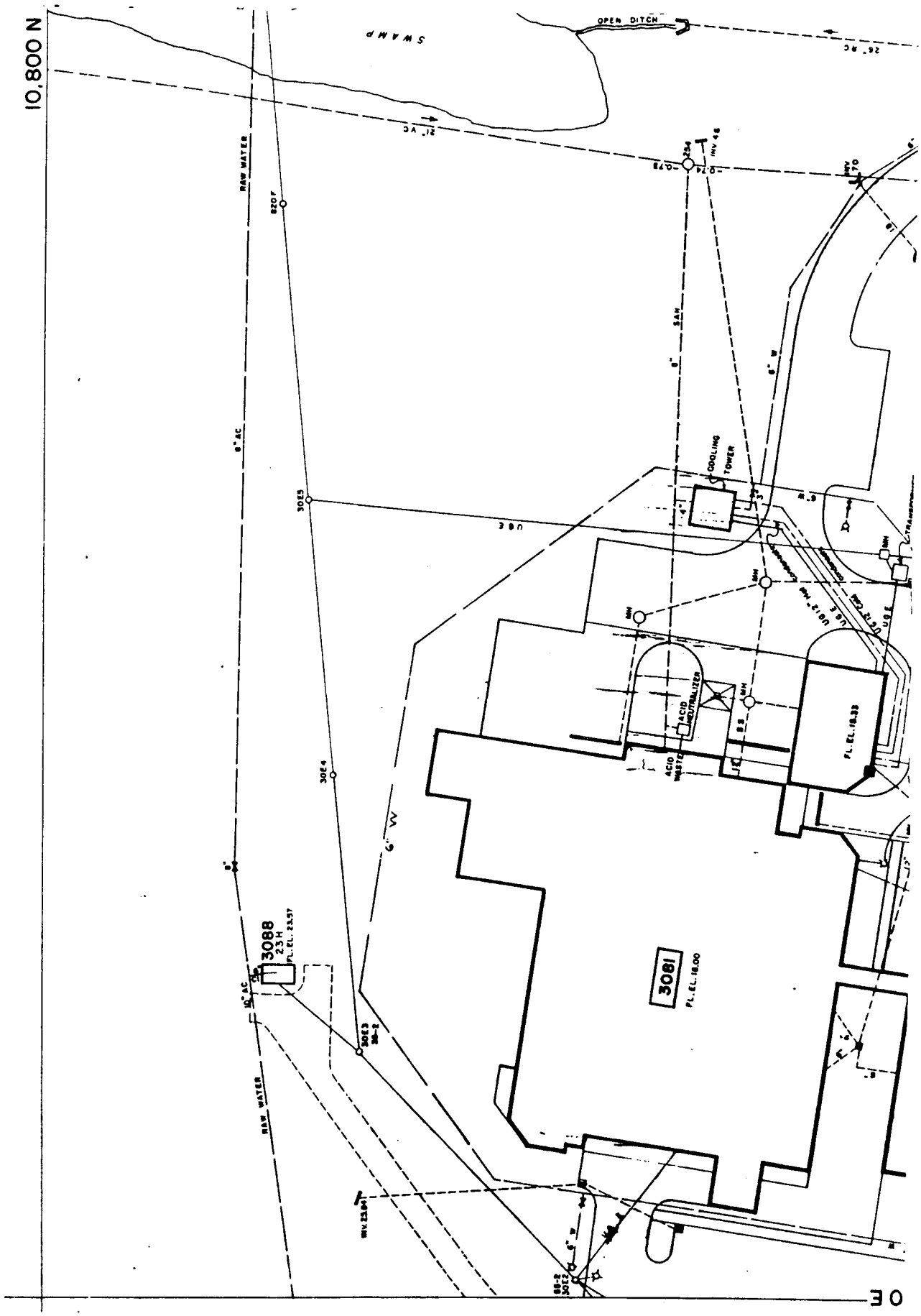
1	2
3	4

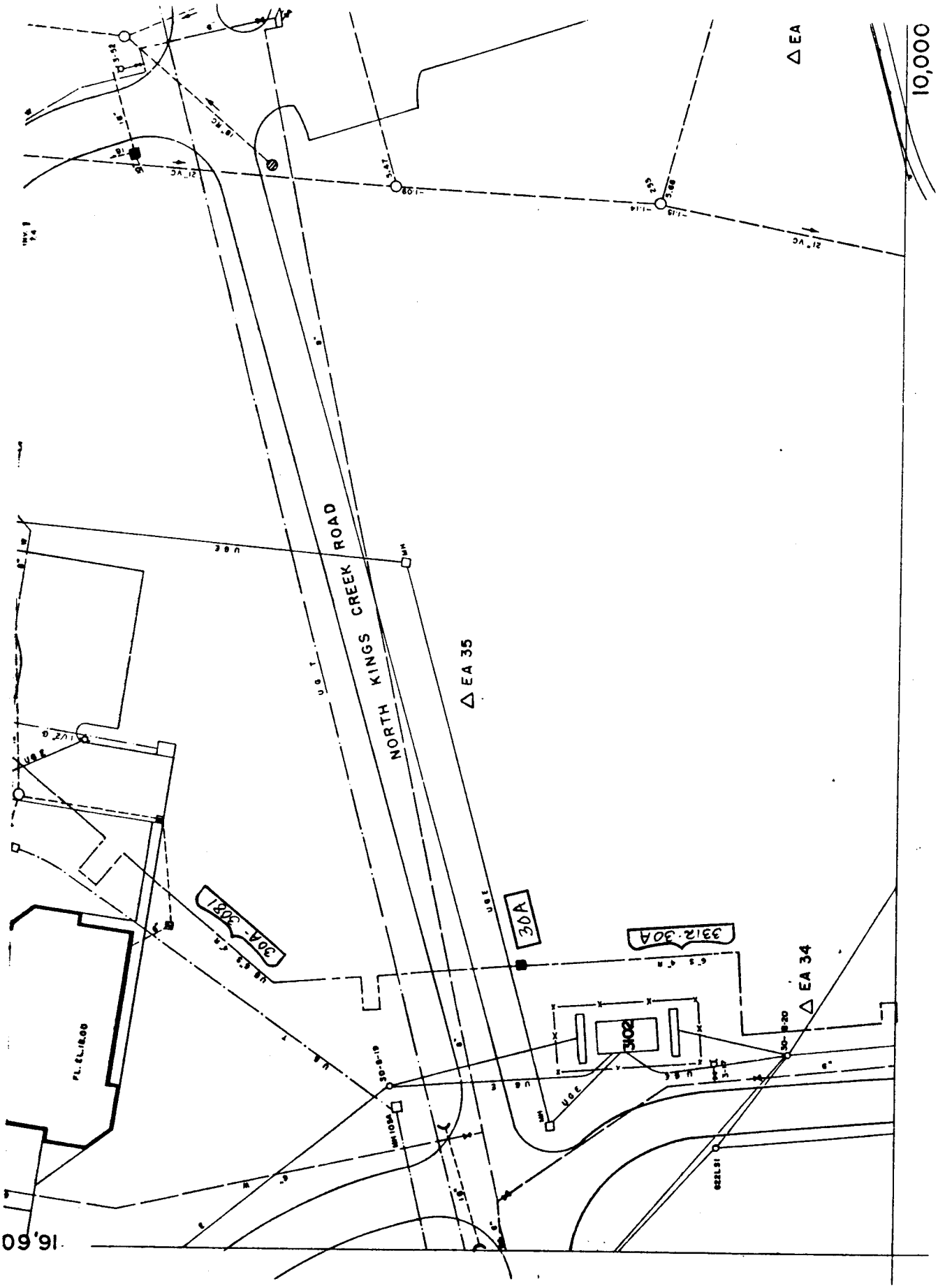
Each quadrant of the map was reduced by 65 percent to a size of 8.5 x 11 in. Each reduced quadrant map was identified by first giving the number of the 40-scale map sheet, followed by a hyphen, followed by the number of the map quadrant. For

example, the sheet representing the lower right-hand quadrant of 40 scale map sheet number 23L would be identified as 23L-4. The layout chart below gives the exact layout of the map sheets for the 3000 area. The map sheets identified in the chart are reprinted after the chart, arranged in alphanumeric order. A layout chart for the 4000 area is then shown, followed by the 4000 area quadrant map sheets. Finally, a layout chart for the 5000 area is given, followed by the 5000 area quadrant map sheets.

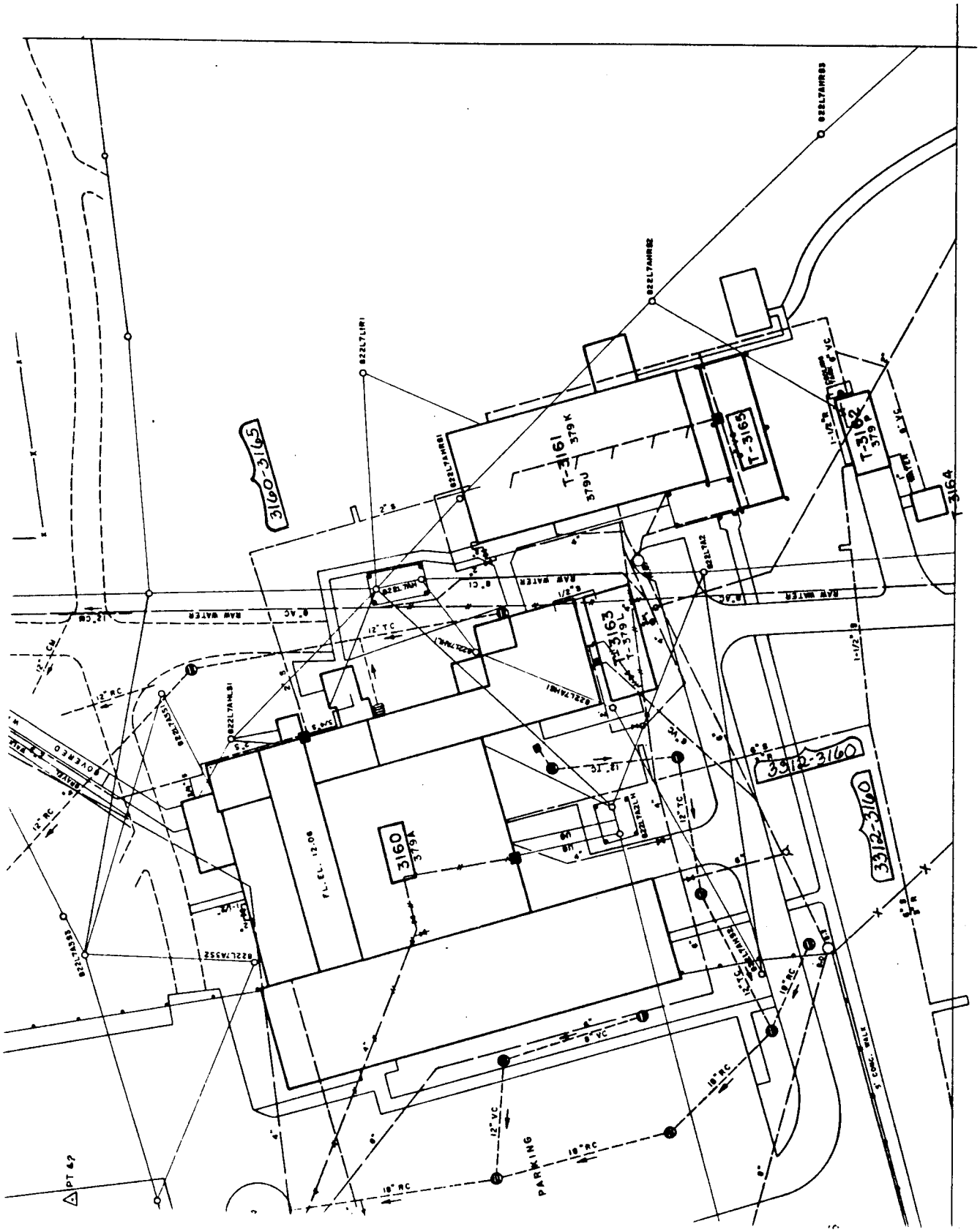
Layout Chart for 3000 Area Quadrant Map Sheets

	21Q-1				
	21Q-3	21Q-4			
22P-2	22Q-1				
22P-4					
23P-2					
23P-4					
24P-2	24Q-1				24S-1
24P-4	24Q-3	24Q-4	24R-3	24R-4	24S-3
25P-2	25Q-1	25Q-2	25R-1		25S-1
	25Q-3		25R-3		

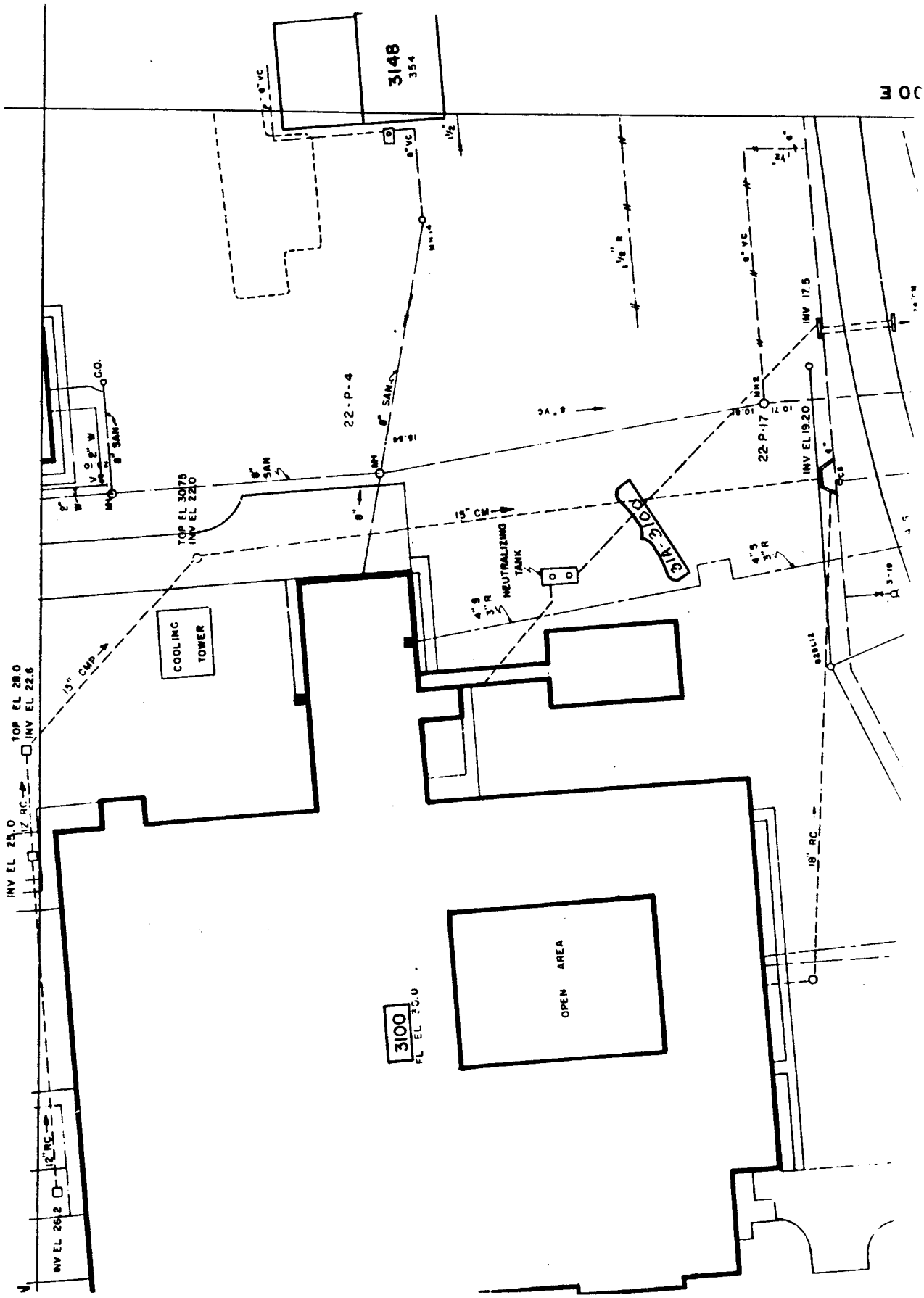

10,800 N
SWAMP
OPEN DITCH
RAW WATER
COOLING TOWER
ACID NEUTRALIZER
ACID WASTE
3088
23 H
FL. EL. 23.97
3081
FL. EL. 18.00
FL. EL. 18.33
30E
21Q-1


NORTH KINGS CREEK ROAD
EA 35
EA 34
EA
30A
3302
30A-3081
3312-30A
FL. EL. 18.00
16,60
10,000

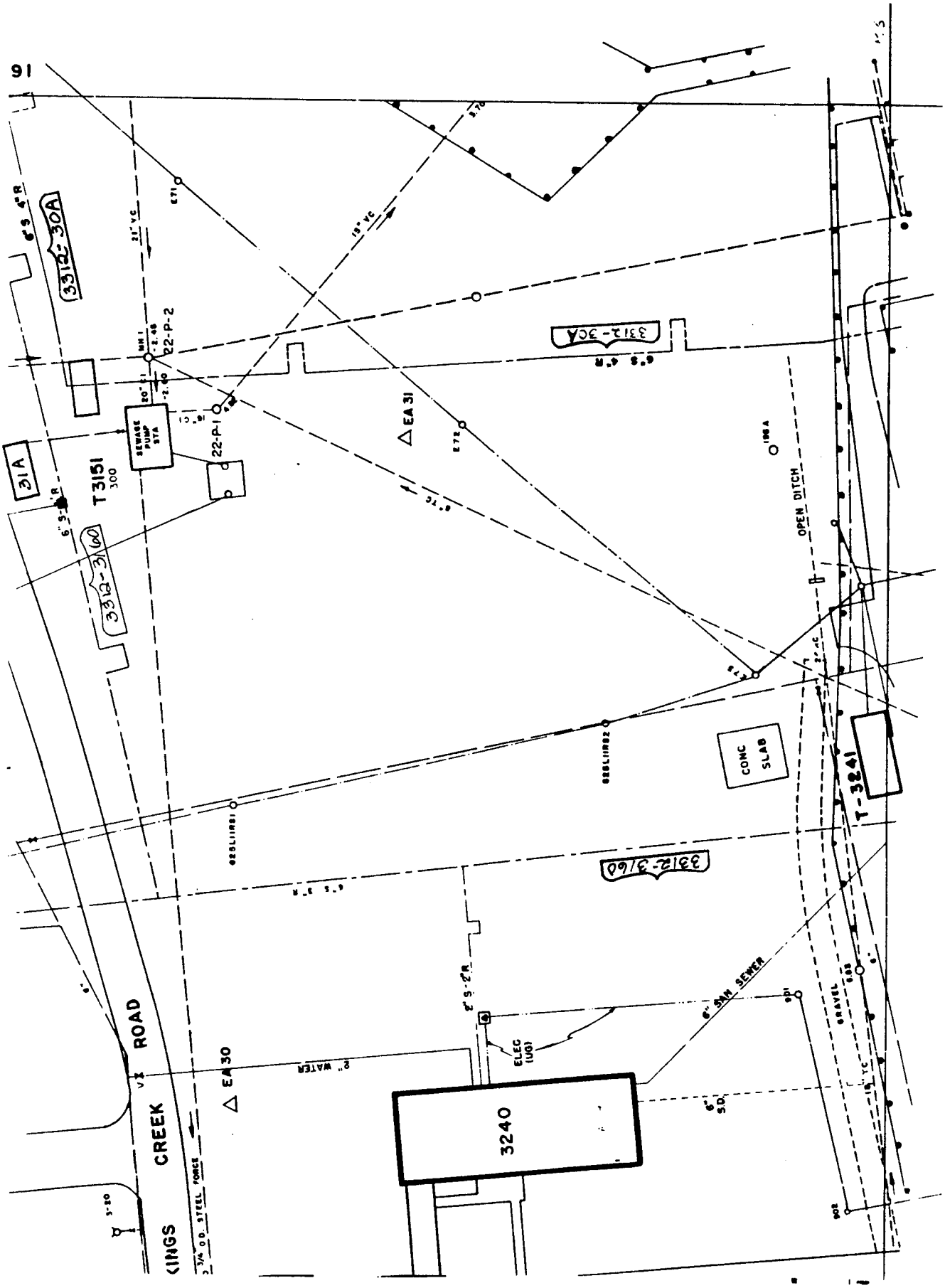
21Q-3


3160-3165
T-3161
379K
379U
T-3165
T-3162
379P
T-3164
T-3163
T-379L
3160
379V
3312-3160
3312-3160
RAW WATER
PARKING
PT 62

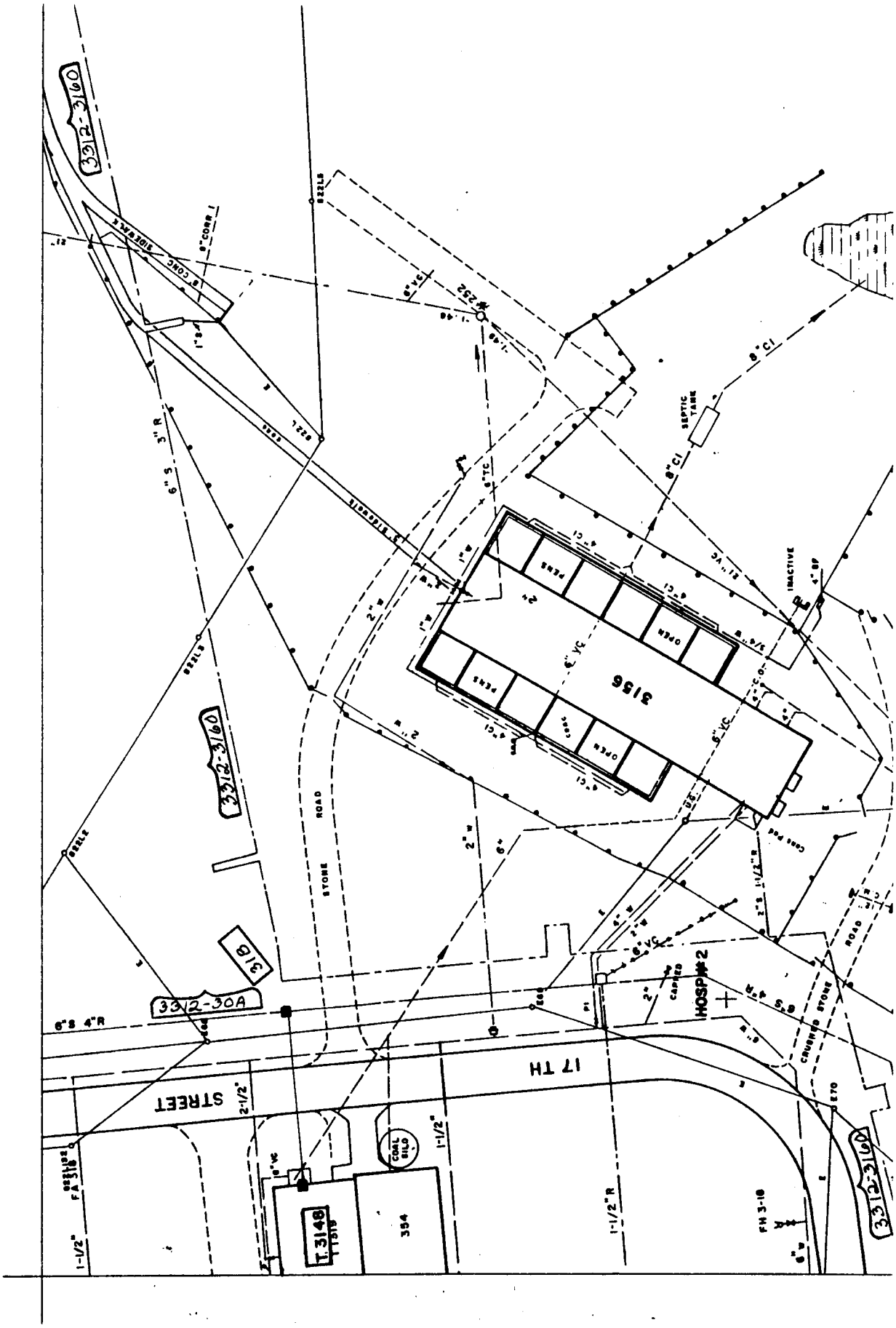
21Q-4


3148
354
22-P-4
8" SAN
8" VC
C.O.
TOP EL 30.75
INV EL 22.0
15" CM
NEUTRALIZING TANK
COOLING TOWER
15" CMP
TOP EL 28.0
INV EL 22.6
INV EL 25.0
12" RC
INV EL 26.2
3100
FL EL 25.0
OPEN AREA
22-P-17
INV EL 19.20
INV 17.5
18" RC
3300

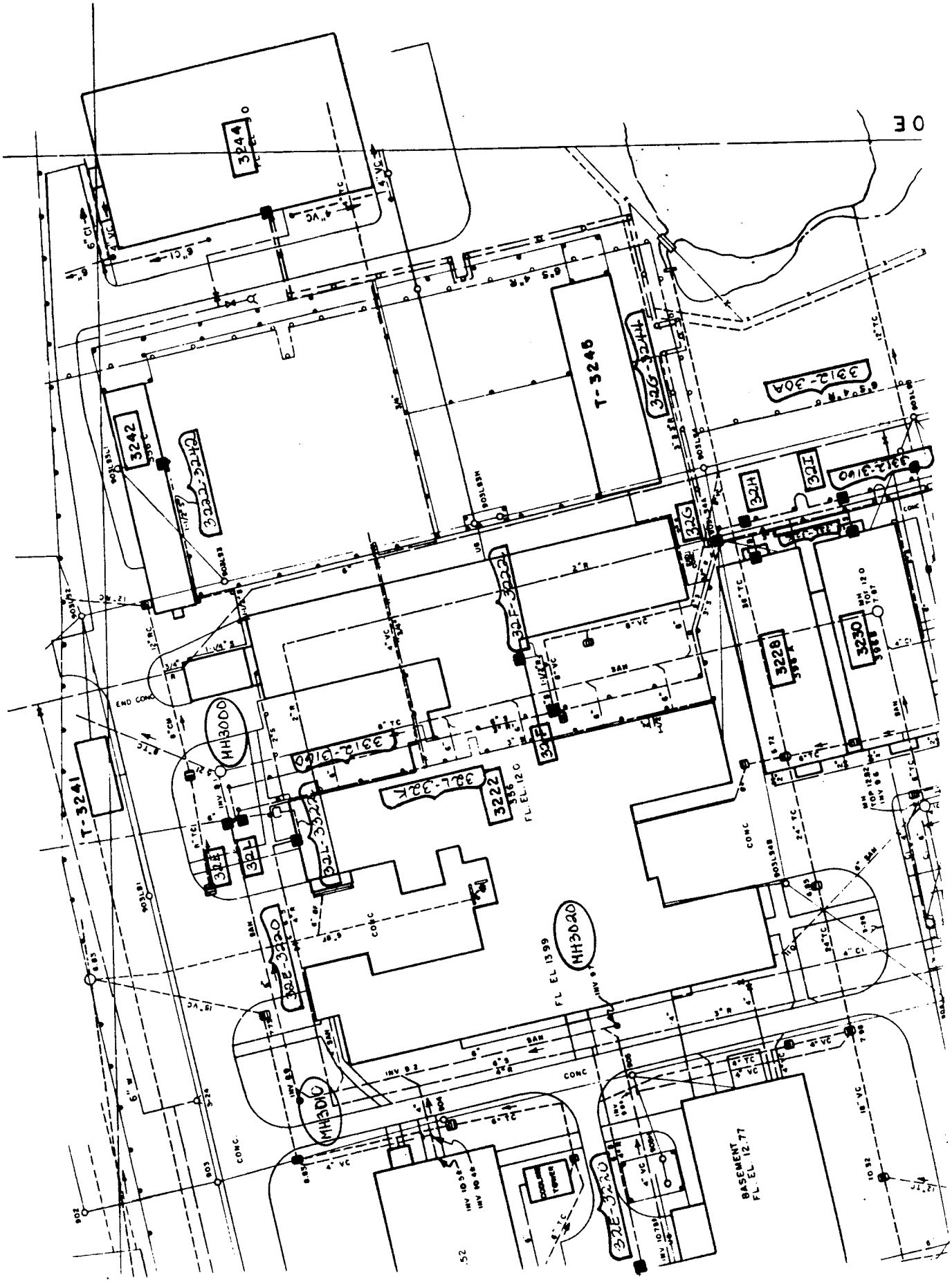
22P-2


3312-30A
3312-30A
3312-31A
3312-31A
T 3151
300
SEWAGE PUMP STA
22-P-1
22-P-2
EA 31
EA 30
OPEN DITCH
CONC SLAB
T-3241
3240
ELEC (UG)
6" SAN SEWER
GRAVEL
2" WATER
CREEK ROAD
KINGS

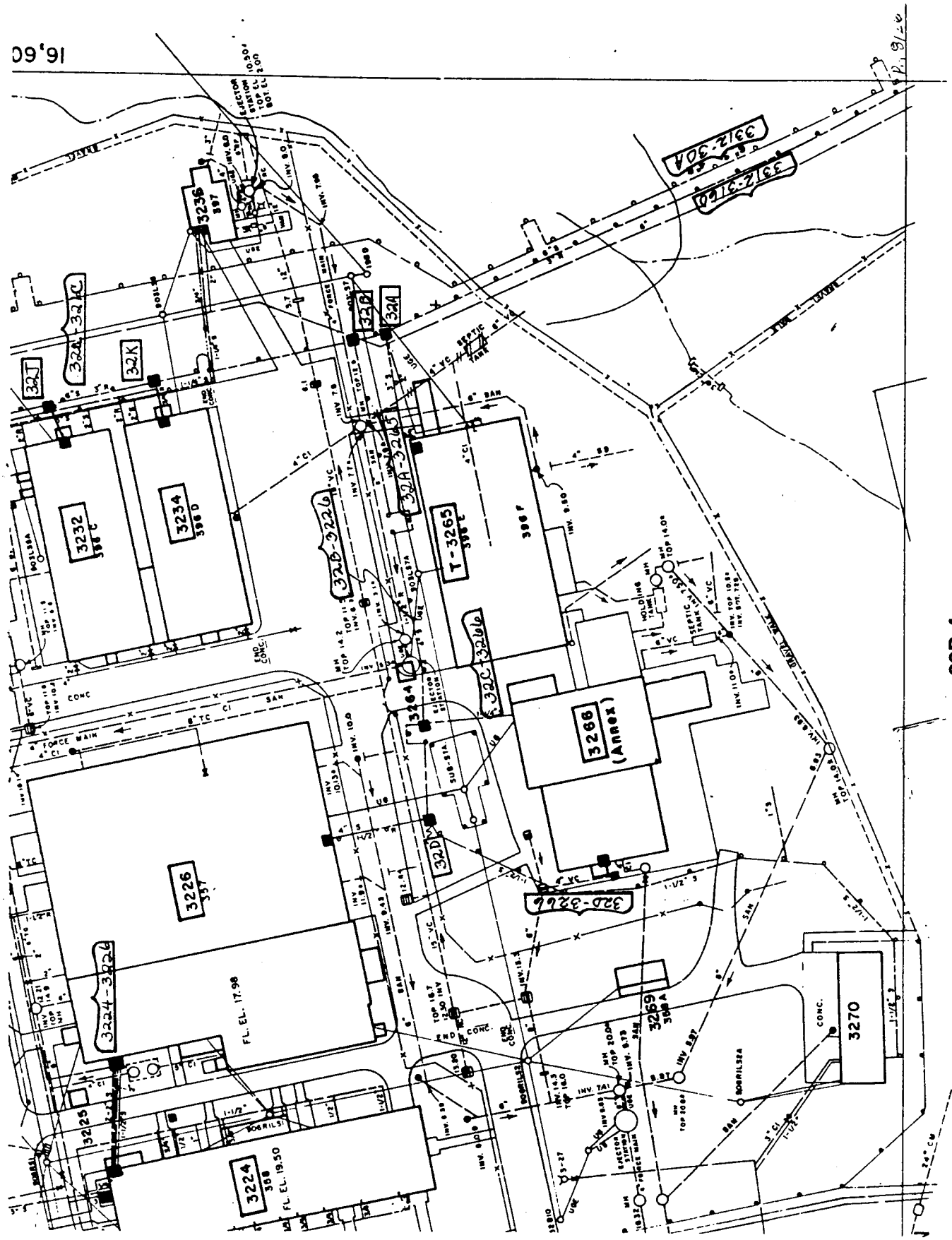
22P-4


3312-3160
3312-30A
3156
3148
354
17TH STREET
STORE ROAD
HOSP#2
SEPTIC TANK
INACTIVE
CRUSHED STONE ROAD
COAL BLD
OPEN
PENS
CAPPED

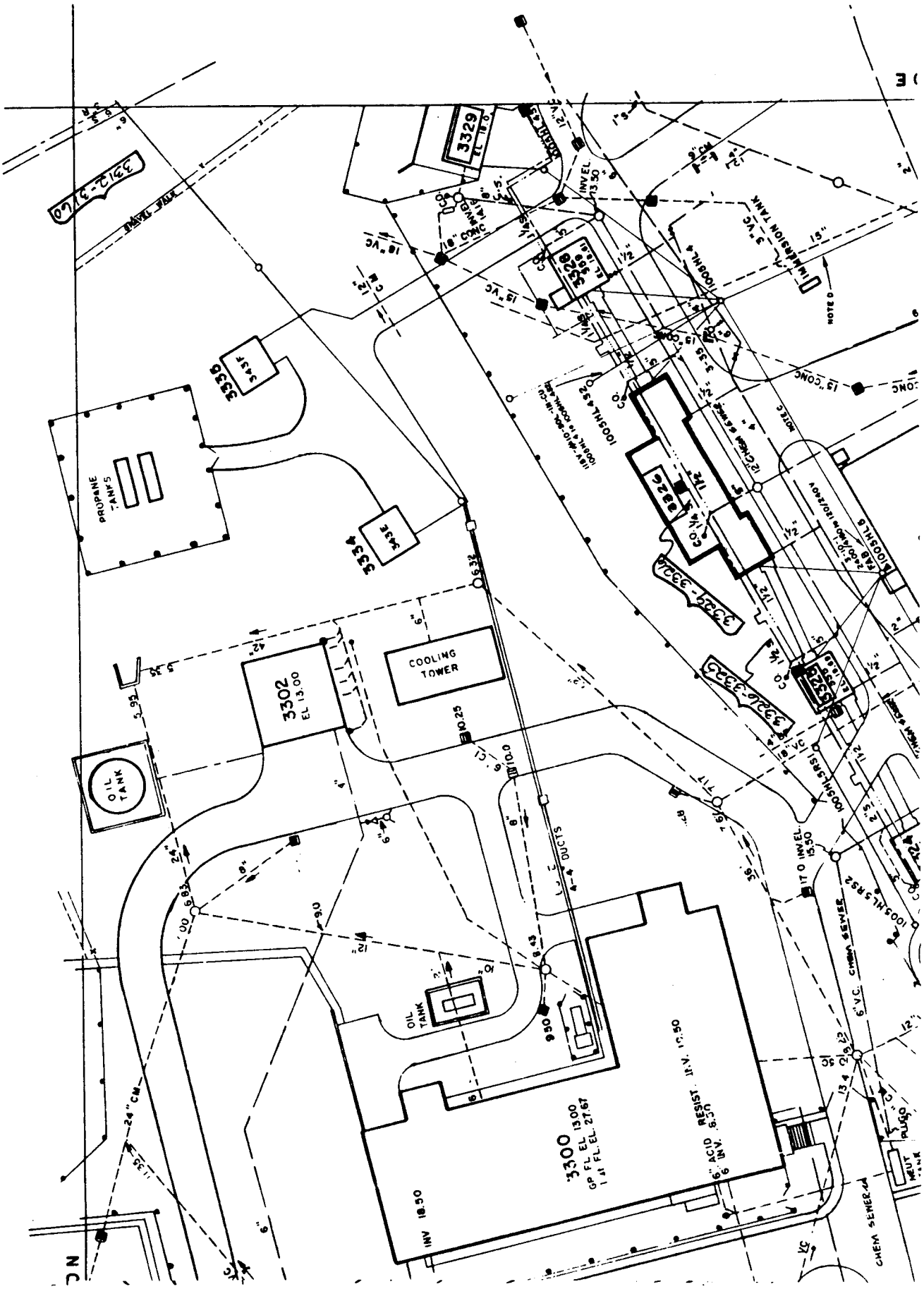
22Q-1


3244
3242
T-3245
T-3241
3228
3230
3222
BASEMENT
FL. EL. 12.77
FL EL 13.99
CONC
END CONC

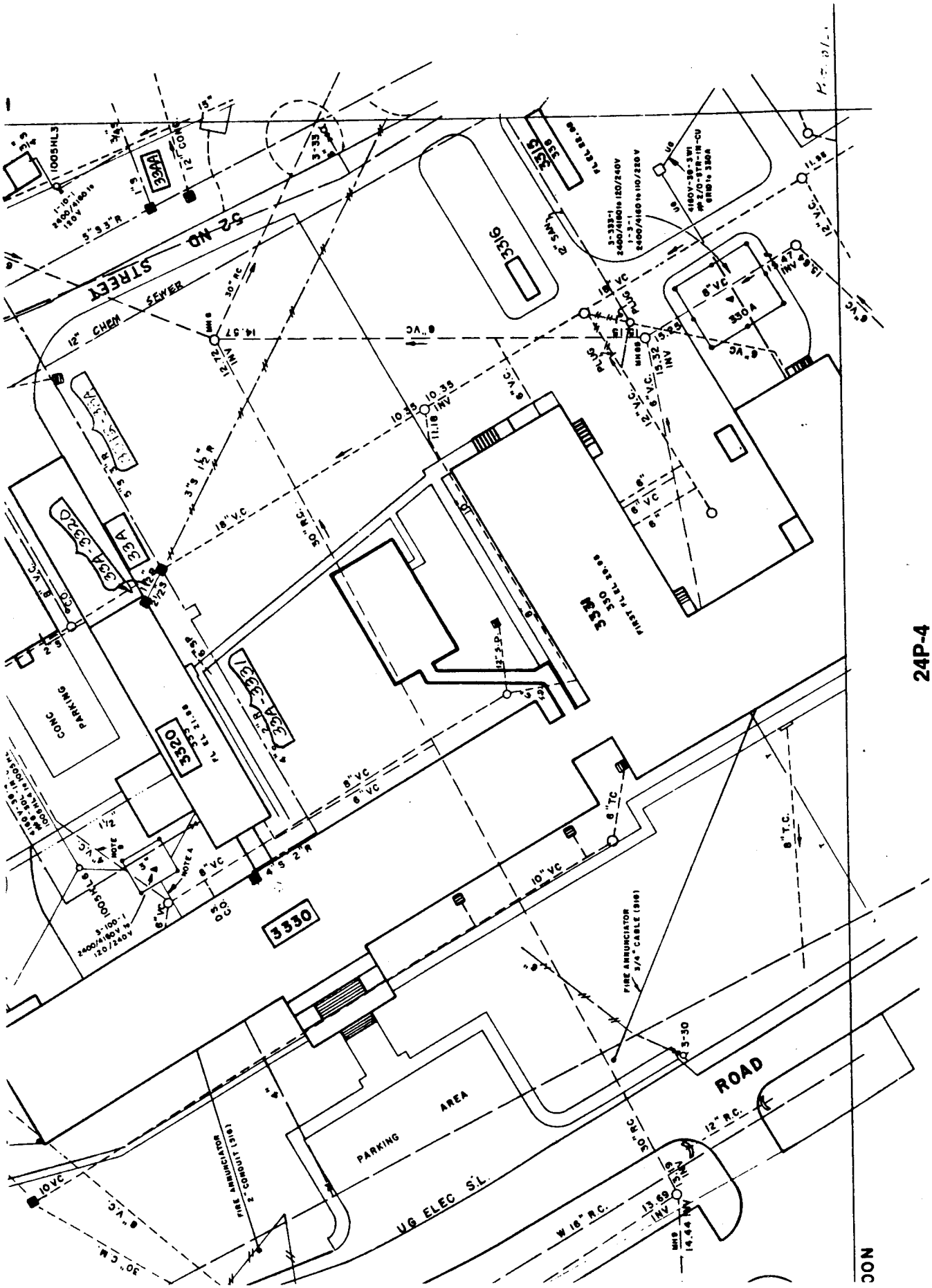
23P-2


3232
3234
3236
3226
3224
3225
3264
T-3265
3266
(Annex)
3269
3270
FL. EL. 17.98
FL. EL. 19.50
32T
32K
32J
32H
32G
32C
32D
32A
3312-30A
3312-31A
3224-3226
3226-3226
3226-3266
3224-3224
16,60

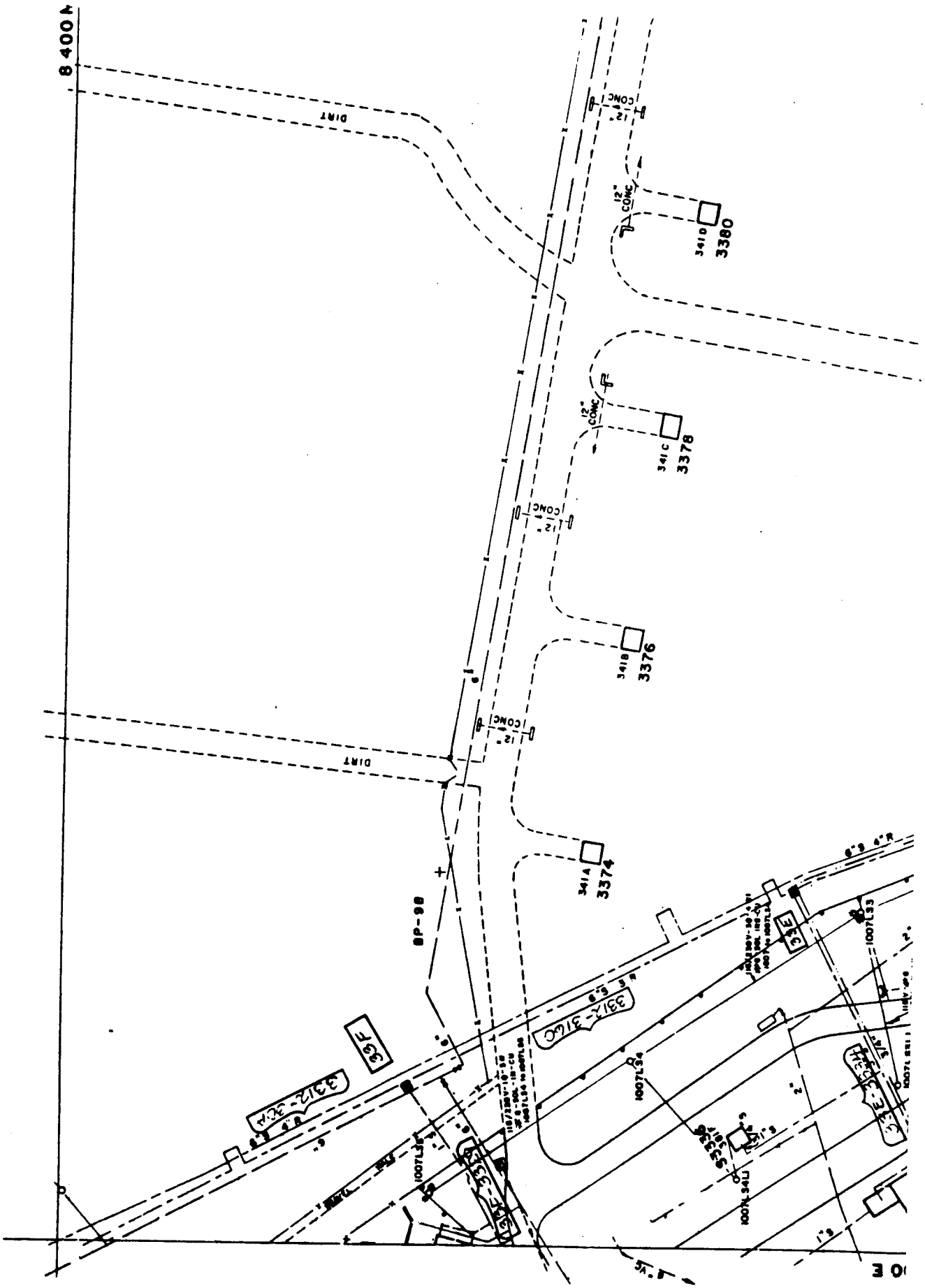
23P-4


3329
3328
3339
3338
3334
3326
3302
EL 13.00
COOLING TOWER
PROPANE TANKS
OIL TANK
3300
GP FL EL 13.00
1st FL EL 27.67
ACID RESIST
INV. 6.50
INV 18.50
DUCTS
CHEM SEWER
INV EL 13.50
IMMERSION TANK
NOTE 0
NOTE E
NOTE F
NOTE G
NOTE H
NOTE I
NOTE J
NOTE K
NOTE L
NOTE M
NOTE N
NOTE O
NOTE P
NOTE Q
NOTE R
NOTE S
NOTE T
NOTE U
NOTE V
NOTE W
NOTE X
NOTE Y
NOTE Z
NOTE AA
NOTE AB
NOTE AC
NOTE AD
NOTE AE
NOTE AF
NOTE AG
NOTE AH
NOTE AI
NOTE AJ
NOTE AK
NOTE AL
NOTE AM
NOTE AN
NOTE AO
NOTE AP
NOTE AQ
NOTE AR
NOTE AS
NOTE AT
NOTE AU
NOTE AV
NOTE AW
NOTE AX
NOTE AY
NOTE AZ
NOTE BA
NOTE BB
NOTE BC
NOTE BD
NOTE BE
NOTE BF
NOTE BG
NOTE BH
NOTE BI
NOTE BJ
NOTE BK
NOTE BL
NOTE BM
NOTE BN
NOTE BO
NOTE BP
NOTE BQ
NOTE BR
NOTE BS
NOTE BT
NOTE BU
NOTE BV
NOTE BW
NOTE BX
NOTE BY
NOTE BZ
NOTE CA
NOTE CB
NOTE CC
NOTE CD
NOTE CE
NOTE CF
NOTE CG
NOTE CH
NOTE CI
NOTE CJ
NOTE CK
NOTE CL
NOTE CM
NOTE CN
NOTE CO
NOTE CP
NOTE CQ
NOTE CR
NOTE CS
NOTE CT
NOTE CU
NOTE CV
NOTE CW
NOTE CX
NOTE CY
NOTE CZ
NOTE DA
NOTE DB
NOTE DC
NOTE DD
NOTE DE
NOTE DF
NOTE DG
NOTE DH
NOTE DI
NOTE DJ
NOTE DK
NOTE DL
NOTE DM
NOTE DN
NOTE DO
NOTE DP
NOTE DQ
NOTE DR
NOTE DS
NOTE DT
NOTE DU
NOTE DV
NOTE DW
NOTE DX
NOTE DY
NOTE DZ
NOTE EA
NOTE EB
NOTE EC
NOTE ED
NOTE EE
NOTE EF
NOTE EG
NOTE EH
NOTE EI
NOTE EJ
NOTE EK
NOTE EL
NOTE EM
NOTE EN
NOTE EO
NOTE EP
NOTE EQ
NOTE ER
NOTE ES
NOTE ET
NOTE EU
NOTE EV
NOTE EW
NOTE EX
NOTE EY
NOTE EZ
NOTE FA
NOTE FB
NOTE FC
NOTE FD
NOTE FE
NOTE FF
NOTE FG
NOTE FH
NOTE FI
NOTE FJ
NOTE FK
NOTE FL
NOTE FM
NOTE FN
NOTE FO
NOTE FP
NOTE FQ
NOTE FR
NOTE FS
NOTE FT
NOTE FU
NOTE FV
NOTE FW
NOTE FX
NOTE FY
NOTE FZ
NOTE GA
NOTE GB
NOTE GC
NOTE GD
NOTE GE
NOTE GF
NOTE GG
NOTE GH
NOTE GI
NOTE GJ
NOTE GK
NOTE GL
NOTE GM
NOTE GN
NOTE GO
NOTE GP
NOTE GQ
NOTE GR
NOTE GS
NOTE GT
NOTE GU
NOTE GV
NOTE GW
NOTE GX
NOTE GY
NOTE GZ
NOTE HA
NOTE HB
NOTE HC
NOTE HD
NOTE HE
NOTE HF
NOTE HG
NOTE HH
NOTE HI
NOTE HJ
NOTE HK
NOTE HL
NOTE HM
NOTE HN
NOTE HO
NOTE HP
NOTE HQ
NOTE HR
NOTE HS
NOTE HT
NOTE HU
NOTE HV
NOTE HW
NOTE HX
NOTE HY
NOTE HZ
NOTE IA
NOTE IB
NOTE IC
NOTE ID
NOTE IE
NOTE IF
NOTE IG
NOTE IH
NOTE II
NOTE IJ
NOTE IK
NOTE IL
NOTE IM
NOTE IN
NOTE IO
NOTE IP
NOTE IQ
NOTE IR
NOTE IS
NOTE IT
NOTE IU
NOTE IV
NOTE IW
NOTE IX
NOTE IY
NOTE IZ
NOTE JA
NOTE JB
NOTE JC
NOTE JD
NOTE JE
NOTE JF
NOTE JG
NOTE JH
NOTE JI
NOTE JJ
NOTE JK
NOTE JL
NOTE JM
NOTE JN
NOTE JO
NOTE JP
NOTE JQ
NOTE JR
NOTE JS
NOTE JT
NOTE JU
NOTE JV
NOTE JW
NOTE JX
NOTE JY
NOTE JZ
NOTE KA
NOTE KB
NOTE KC
NOTE KD
NOTE KE
NOTE KF
NOTE KG
NOTE KH
NOTE KI
NOTE KJ
NOTE KK
NOTE KL
NOTE KM
NOTE KN
NOTE KO
NOTE KP
NOTE KQ
NOTE KR
NOTE KS
NOTE KT
NOTE KU
NOTE KV
NOTE KW
NOTE KX
NOTE KY
NOTE KZ
NOTE LA
NOTE LB
NOTE LC
NOTE LD
NOTE LE
NOTE LF
NOTE LG
NOTE LH
NOTE LI
NOTE LJ
NOTE LK
NOTE LL
NOTE LM
NOTE LN
NOTE LO
NOTE LP
NOTE LQ
NOTE LR
NOTE LS
NOTE LT
NOTE LU
NOTE LV
NOTE LW
NOTE LX
NOTE LY
NOTE LZ
NOTE MA
NOTE MB
NOTE MC
NOTE MD
NOTE ME
NOTE MF
NOTE MG
NOTE MH
NOTE MI
NOTE MJ
NOTE MK
NOTE ML
NOTE MM
NOTE MN
NOTE MO
NOTE MP
NOTE MQ
NOTE MR
NOTE MS
NOTE MT
NOTE MU
NOTE MV
NOTE MW
NOTE MX
NOTE MY
NOTE MZ
NOTE NA
NOTE NB
NOTE NC
NOTE ND
NOTE NE
NOTE NF
NOTE NG
NOTE NH
NOTE NI
NOTE NJ
NOTE NK
NOTE NL
NOTE NM
NOTE NN
NOTE NO
NOTE NP
NOTE NQ
NOTE NR
NOTE NS
NOTE NT
NOTE NU
NOTE NV
NOTE NW
NOTE NX
NOTE NY
NOTE NZ
NOTE OA
NOTE OB
NOTE OC
NOTE OD
NOTE OE
NOTE OF
NOTE OG
NOTE OH
NOTE OI
NOTE OJ
NOTE OK
NOTE OL
NOTE OM
NOTE ON
NOTE OO
NOTE OP
NOTE OQ
NOTE OR
NOTE OS
NOTE OT
NOTE OU
NOTE OV
NOTE OW
NOTE OX
NOTE OY
NOTE OZ
NOTE PA
NOTE PB
NOTE PC
NOTE PD
NOTE PE
NOTE PF
NOTE PG
NOTE PH
NOTE PI
NOTE PJ
NOTE PK
NOTE PL
NOTE PM
NOTE PN
NOTE PO
NOTE PP
NOTE PQ
NOTE PR
NOTE PS
NOTE PT
NOTE PU
NOTE PV
NOTE PW
NOTE PX
NOTE PY
NOTE PZ
NOTE QA
NOTE QB
NOTE QC
NOTE QD
NOTE QE
NOTE QF
NOTE QG
NOTE QH
NOTE QI
NOTE QJ
NOTE QK
NOTE QL
NOTE QM
NOTE QN
NOTE QO
NOTE QP
NOTE QQ
NOTE QR
NOTE QS
NOTE QT
NOTE QU
NOTE QV
NOTE QW
NOTE QX
NOTE QY
NOTE QZ
NOTE RA
NOTE RB
NOTE RC
NOTE RD
NOTE RE
NOTE RF
NOTE RG
NOTE RH
NOTE RI
NOTE RJ
NOTE RK
NOTE RL
NOTE RM
NOTE RN
NOTE RO
NOTE RP
NOTE RQ
NOTE RR
NOTE RS
NOTE RT
NOTE RU
NOTE RV
NOTE RW
NOTE RX
NOTE RY
NOTE RZ
NOTE SA
NOTE SB
NOTE SC
NOTE SD
NOTE SE
NOTE SF
NOTE SG
NOTE SH
NOTE SI
NOTE SJ
NOTE SK
NOTE SL
NOTE SM
NOTE SN
NOTE SO
NOTE SP
NOTE SQ
NOTE SR
NOTE SS
NOTE ST
NOTE SU
NOTE SV
NOTE SW
NOTE SX
NOTE SY
NOTE SZ
NOTE TA
NOTE TB
NOTE TC
NOTE TD
NOTE TE
NOTE TF
NOTE TG
NOTE TH
NOTE TI
NOTE TJ
NOTE TK
NOTE TL
NOTE TM
NOTE TN
NOTE TO
NOTE TP
NOTE TQ
NOTE TR
NOTE TS
NOTE TT
NOTE TU
NOTE TV
NOTE TW
NOTE TX
NOTE TY
NOTE TZ
NOTE UA
NOTE UB
NOTE UC
NOTE UD
NOTE UE
NOTE UF
NOTE UG
NOTE UH
NOTE UI
NOTE UJ
NOTE UK
NOTE UL
NOTE UM
NOTE UN
NOTE UO
NOTE UP
NOTE UQ
NOTE UR
NOTE US
NOTE UT
NOTE UU
NOTE UV
NOTE UW
NOTE UX
NOTE UY
NOTE UZ
NOTE VA
NOTE VB
NOTE VC
NOTE VD
NOTE VE
NOTE VF
NOTE VG
NOTE VH
NOTE VI
NOTE VJ
NOTE VK
NOTE VL
NOTE VM
NOTE VN
NOTE VO
NOTE VP
NOTE VQ
NOTE VR
NOTE VS
NOTE VT
NOTE VU
NOTE VV
NOTE VW
NOTE VX
NOTE VY
NOTE VZ
NOTE WA
NOTE WB
NOTE WC
NOTE WD
NOTE WE
NOTE WF
NOTE WG
NOTE WH
NOTE WI
NOTE WJ
NOTE WK
NOTE WL
NOTE WM
NOTE WN
NOTE WO
NOTE WP
NOTE WQ
NOTE WR
NOTE WS
NOTE WT
NOTE WU
NOTE WV
NOTE WW
NOTE WX
NOTE WY
NOTE WZ
NOTE XA
NOTE XB
NOTE XC
NOTE XD
NOTE XE
NOTE XF
NOTE XG
NOTE XH
NOTE XI
NOTE XJ
NOTE XK
NOTE XL
NOTE XM
NOTE XN
NOTE XO
NOTE XP
NOTE XQ
NOTE XR
NOTE XS
NOTE XT
NOTE XU
NOTE XV
NOTE XW
NOTE XX
NOTE XY
NOTE XZ
NOTE YA
NOTE YB
NOTE YC
NOTE YD
NOTE YE
NOTE YF
NOTE YG
NOTE YH
NOTE YI
NOTE YJ
NOTE YK
NOTE YL
NOTE YM
NOTE YN
NOTE YO
NOTE YP
NOTE YQ
NOTE YR
NOTE YS
NOTE YT
NOTE YU
NOTE YV
NOTE YW
NOTE YX
NOTE YY
NOTE YZ
NOTE ZA
NOTE ZB
NOTE ZC
NOTE ZD
NOTE ZE
NOTE ZF
NOTE ZG
NOTE ZH
NOTE ZI
NOTE ZJ
NOTE ZK
NOTE ZL
NOTE ZM
NOTE ZN
NOTE ZO
NOTE ZP
NOTE ZQ
NOTE ZR
NOTE ZS
NOTE ZT
NOTE ZU
NOTE ZV
NOTE ZW
NOTE ZX
NOTE ZY
NOTE ZZ

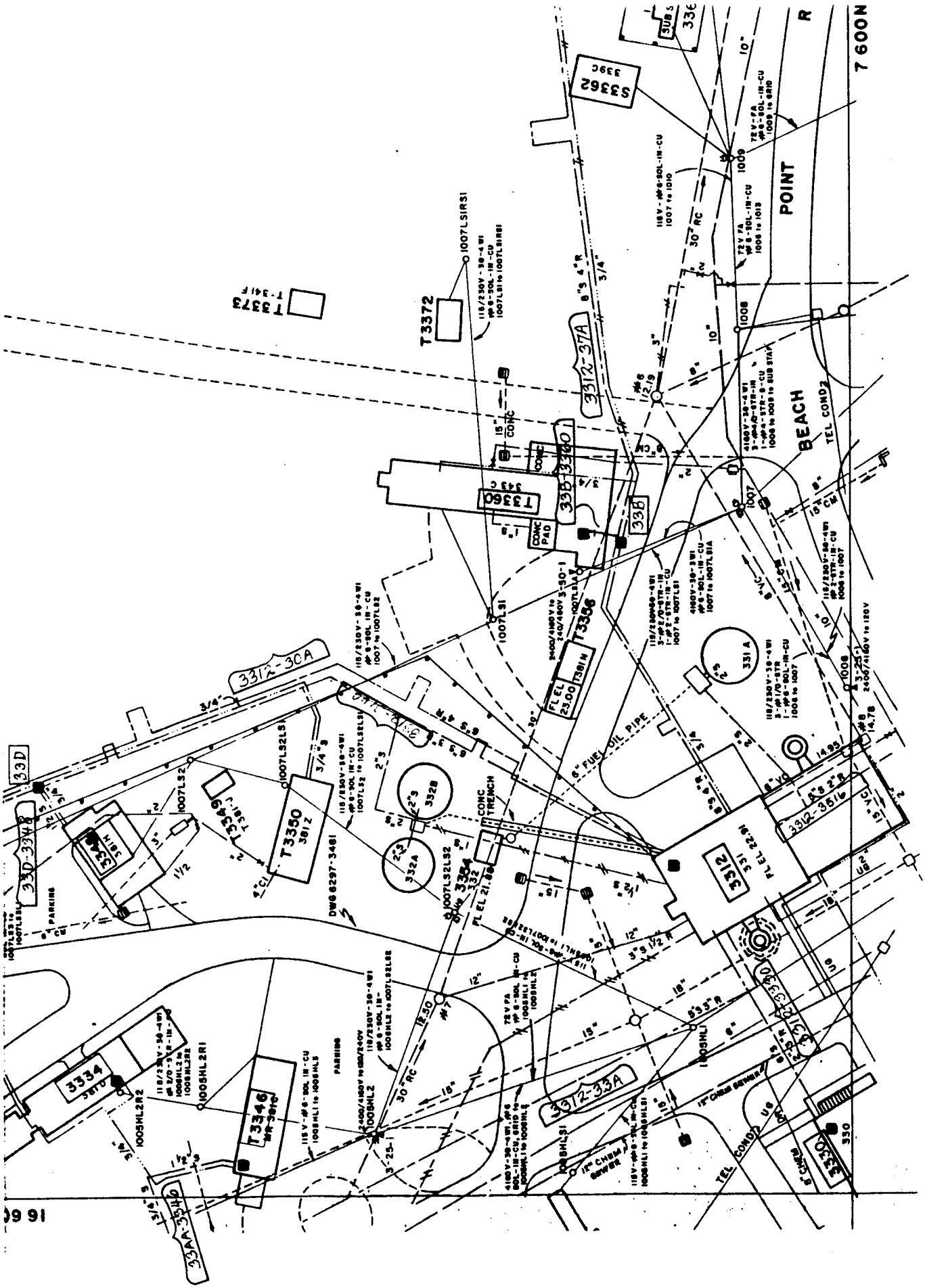
24P-2

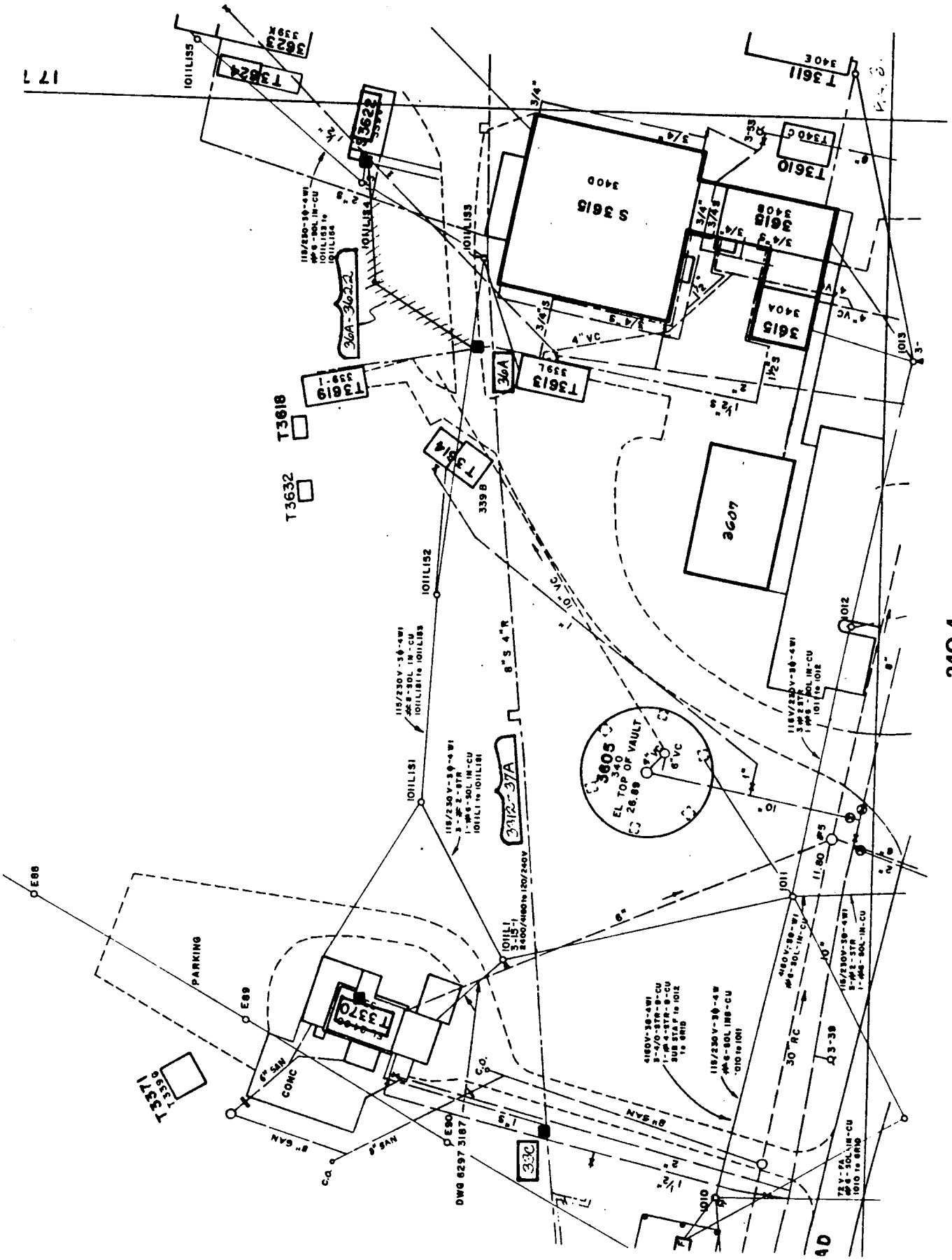

52ND STREET
12" CHEM SEWER
3330
3320
3316
3334
3334-3320
3334-3331
CONC PARKING
PARKING AREA
UG ELEC S.L.
ROAD
FIRE ANNUNCIATOR 3/4" CABLE (316)
2" CONDUIT (316)
FIRST FL EL 28.08
FIRST FL EL 21.08
330A

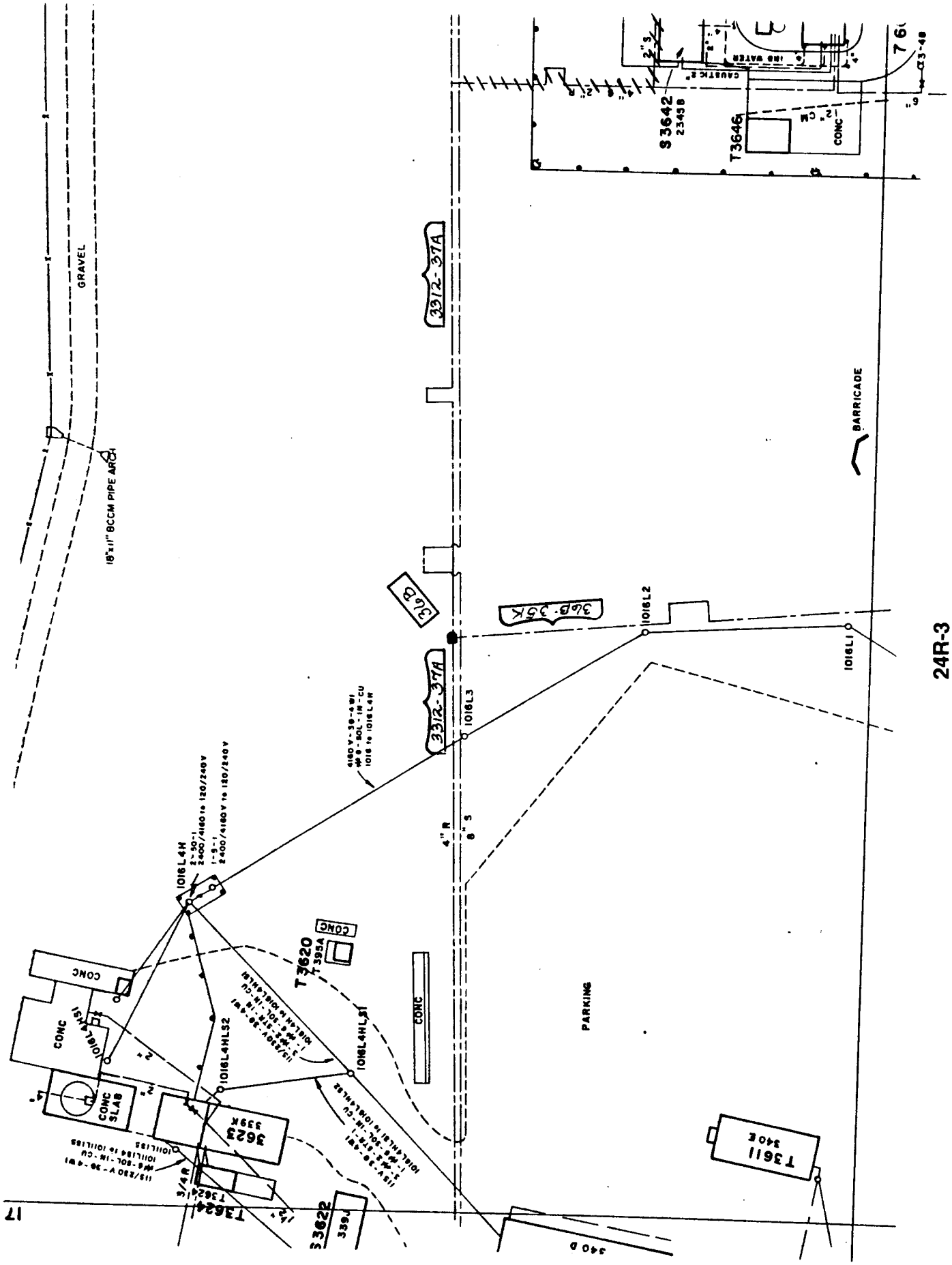
24P-4


8 400 N
DIRT
DIRT
12" CONC
12" CONC
12" CONC
12" CONC
3410
3380
341C
3378
341B
3376
341A
3374
BP-98
3312-3CA
3F
331A-31AC
3E
1007L34
1007L33
1007L34U
0 E

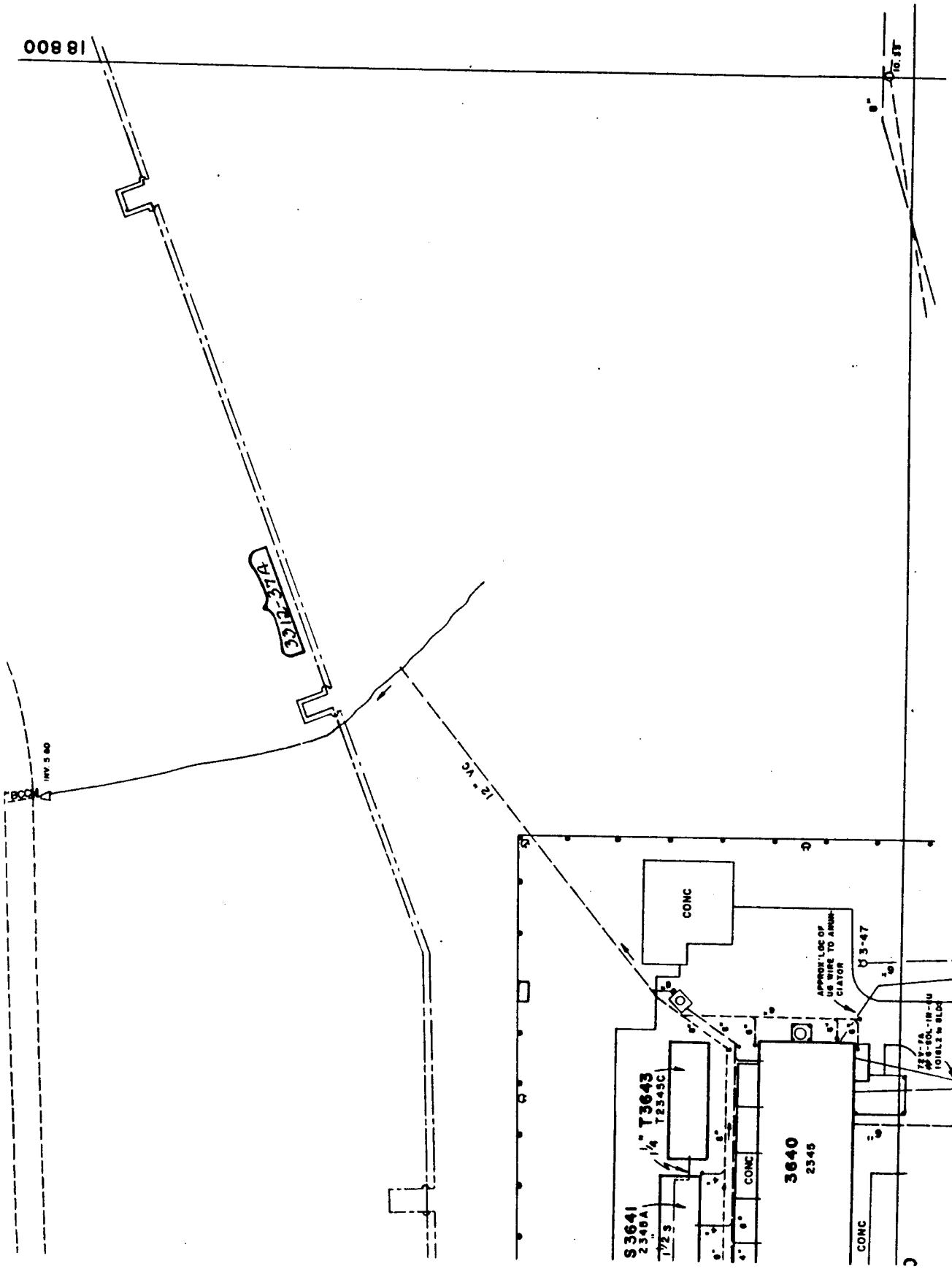
24Q-1


7 600N
POINT
BEACH
R
S3362
T3372
T3373
3312-37A
T3360
3312-30A
T3350
3312
3312-35A
3312-33A
3334
T3346
3312-36A
3312-34A
FUEL OIL PIPE
CONC TRENCH
PARKING
TEL COND2
TEL COND1
FL EL 23.00
FL EL 21.88
FL EL 22.00
DWG 6297-3461
1007LS1RS1
1007LS1
1007LS2
1007LS2LS1
1007LS2LS2
1005HL2R1
1005HL2R2
1005HL2
1005HL1
1005HL1R1
1005HL1R2
1005HL1S1
1005HL2S1
1005HL2S2
1005HL2S3
1005HL2S4
1005HL2S5
1005HL2S6
1005HL2S7
1005HL2S8
1005HL2S9
1005HL2S10
1005HL2S11
1005HL2S12
1005HL2S13
1005HL2S14
1005HL2S15
1005HL2S16
1005HL2S17
1005HL2S18
1005HL2S19
1005HL2S20
1005HL2S21
1005HL2S22
1005HL2S23
1005HL2S24
1005HL2S25
1005HL2S26
1005HL2S27
1005HL2S28
1005HL2S29
1005HL2S30
1005HL2S31
1005HL2S32
1005HL2S33
1005HL2S34
1005HL2S35
1005HL2S36
1005HL2S37
1005HL2S38
1005HL2S39
1005HL2S40

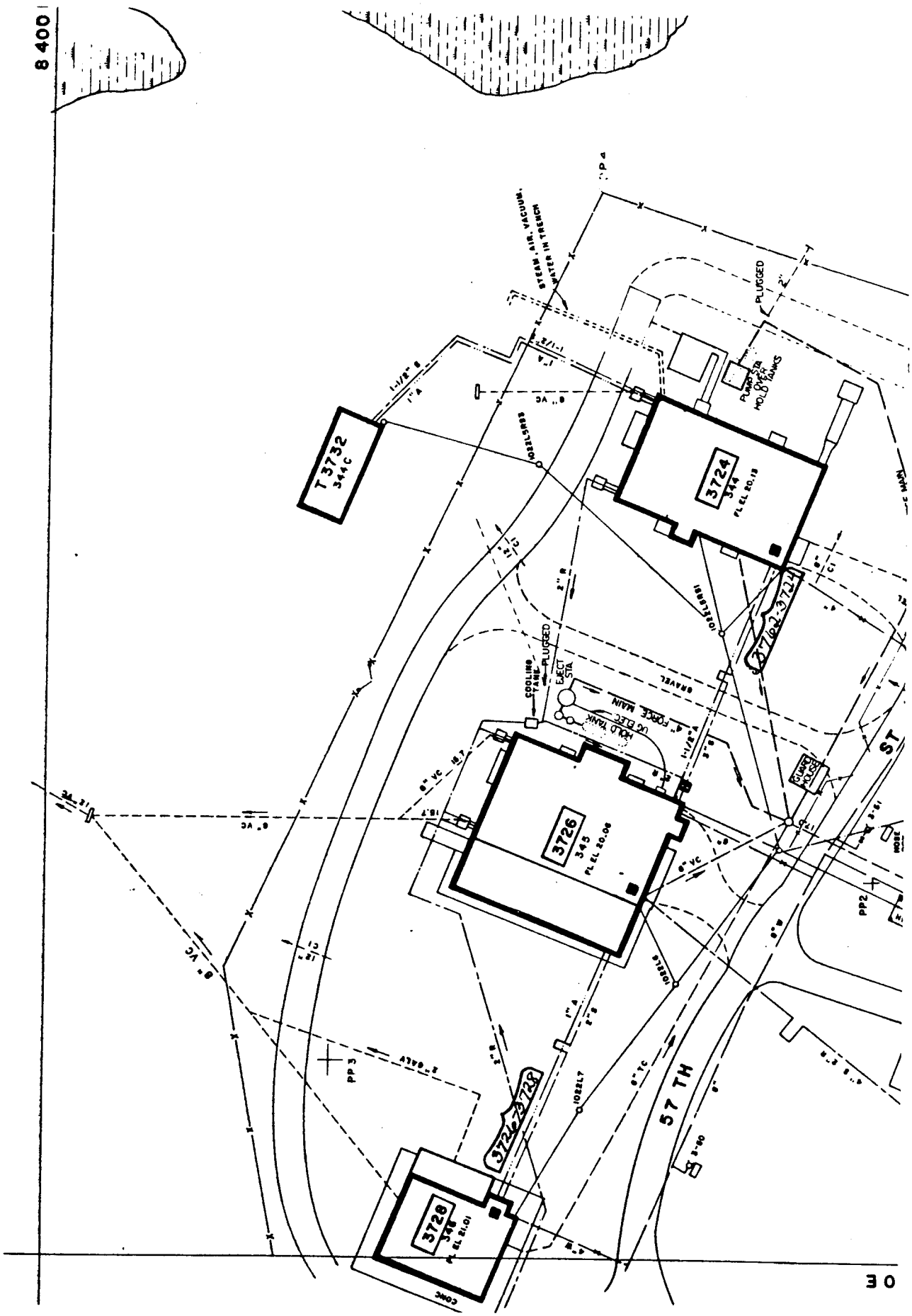

S 3615
3400
3615
3400B
3615
3400A
T3610
T3611
T3613
T3614
T3619
T3622
T3623
T3624
T3370
T3371
T3618
T3632
3605
EL TOP OF VAULT
PARKING
CONC
DWG 6297 3187
1011L151
1011L152
1011L153
1011L154
1011L155
1011
1012
1013
1010
E88
E89
E90
17 T
24Q-4


GRAVEL
18"x11" BCCM PIPE ARCH
3312-37A
3B
3B-35K
1016L2
1016L1
1016L3
BARRICADE
4160 V-3Ø-4 W
#8-SOL-1Ø-CU
1016 to 1016L4H
1016L4H
2-50-1
2400/4160 to 120/240 V
1-5-1
2400/4160 V to 120/240 V
4" R
8" S
CONC
T3620
395A
CONC
CONC
CONC SLAB
1016L4HL1
1016L4HL2
1016L4HL3
PARKING
3623
339K
T3624
3/4 R
3622
339J
T3611
340E
340D
S3642
234B
T3646
CONC
CAUSTIC
IRR WATER
17

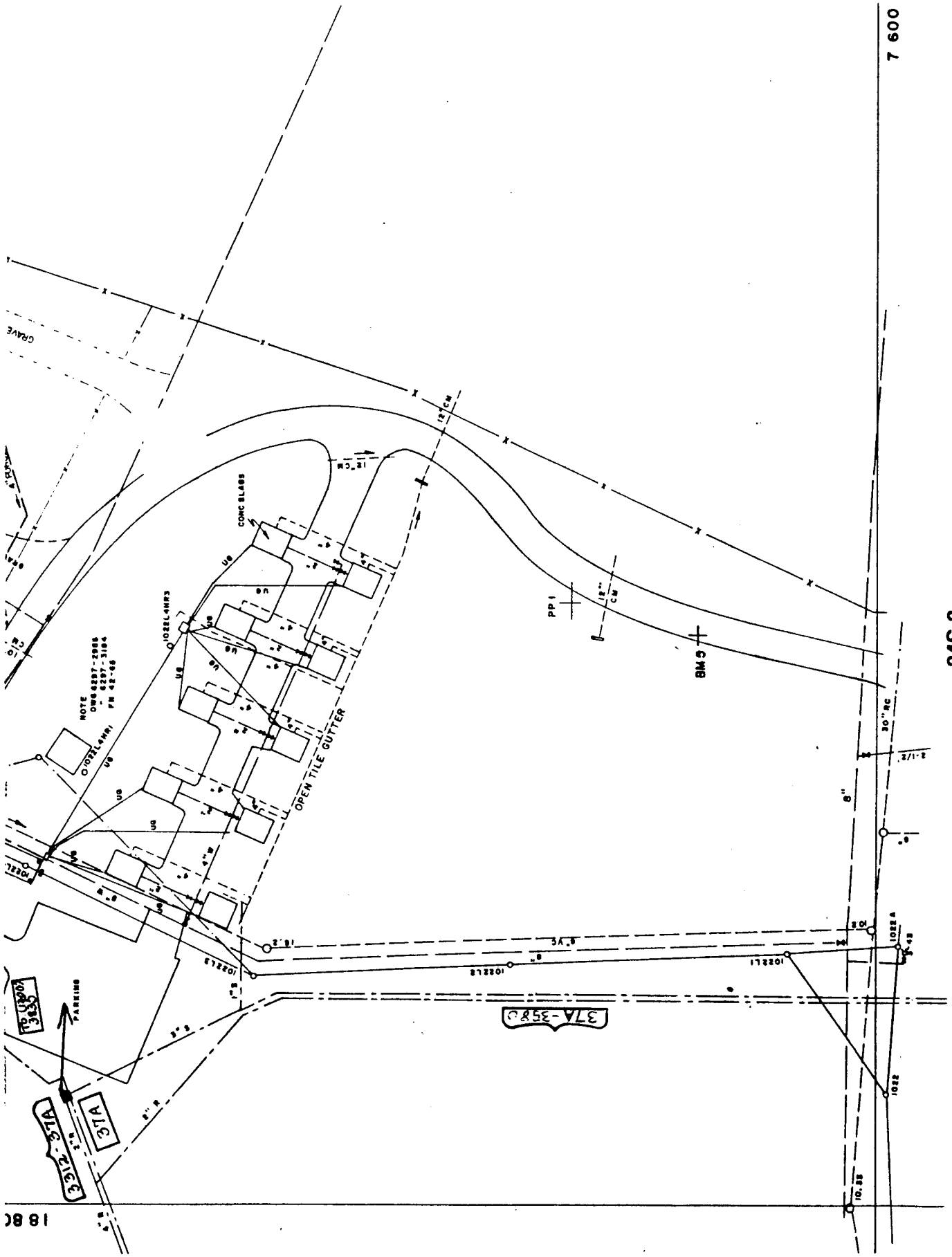
24R-3

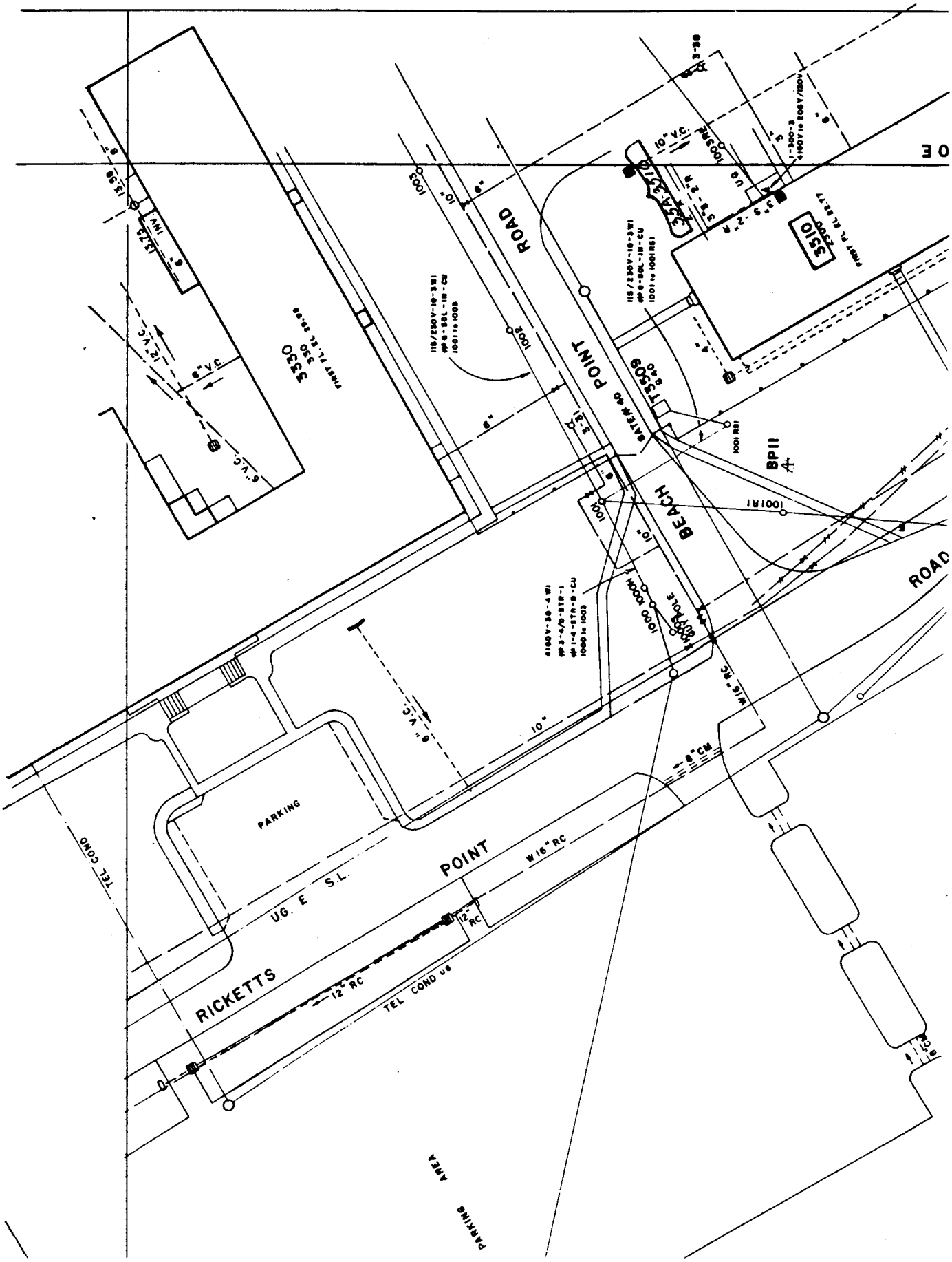

18 800
8"
12" VC
CONC
APPROX LOC OF
UG WIRE TO ANNUN-
CIATOR
3-47
T3643
T2345C
3640
2345
S3641
2345A
CONC
CONC

24R-4

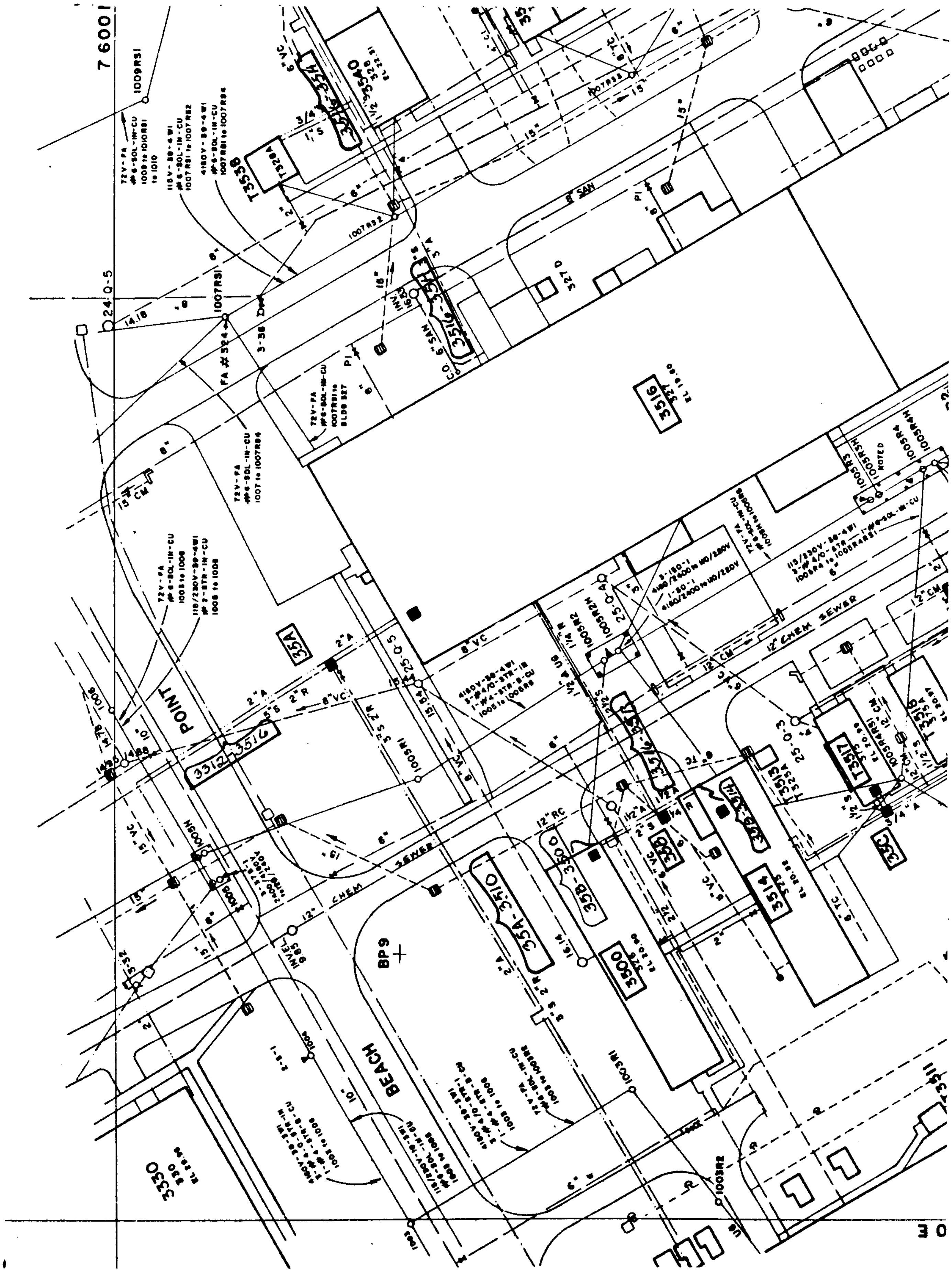

8 400
T 3732
344 C
3724
344
FL EL 20.18
3726
345
FL EL 20.08
3728
346
FL EL 21.01
3726-3728
3724-3726
PLUGGED
COOLING TOWER
EJECT STA
HOLD TANK
UG EJECT
4" FORCE MAIN
GRAVEL
GUARD HOUSE
PP 2
PP 3
57 TH
ST
30

24S-1

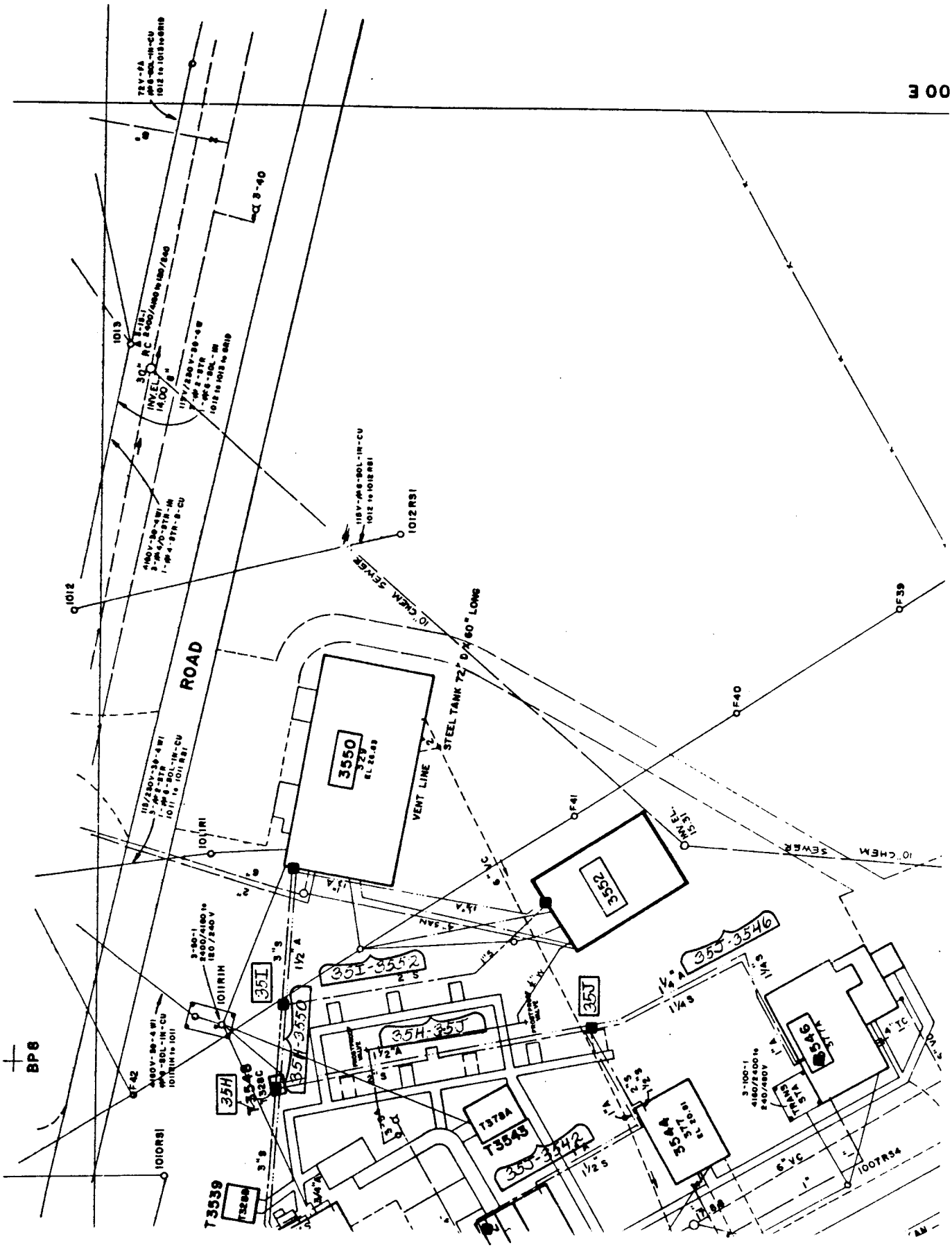

7 600
24S-3
OPEN TILE GUTTER
CONC SLABS
BM 5
PP 1
NOTE
DWG 6297-2888
6297-3184
FR 42-68
FARKING
3TA
3TA-3S&C
3TA-3TA
3S&C
18 80

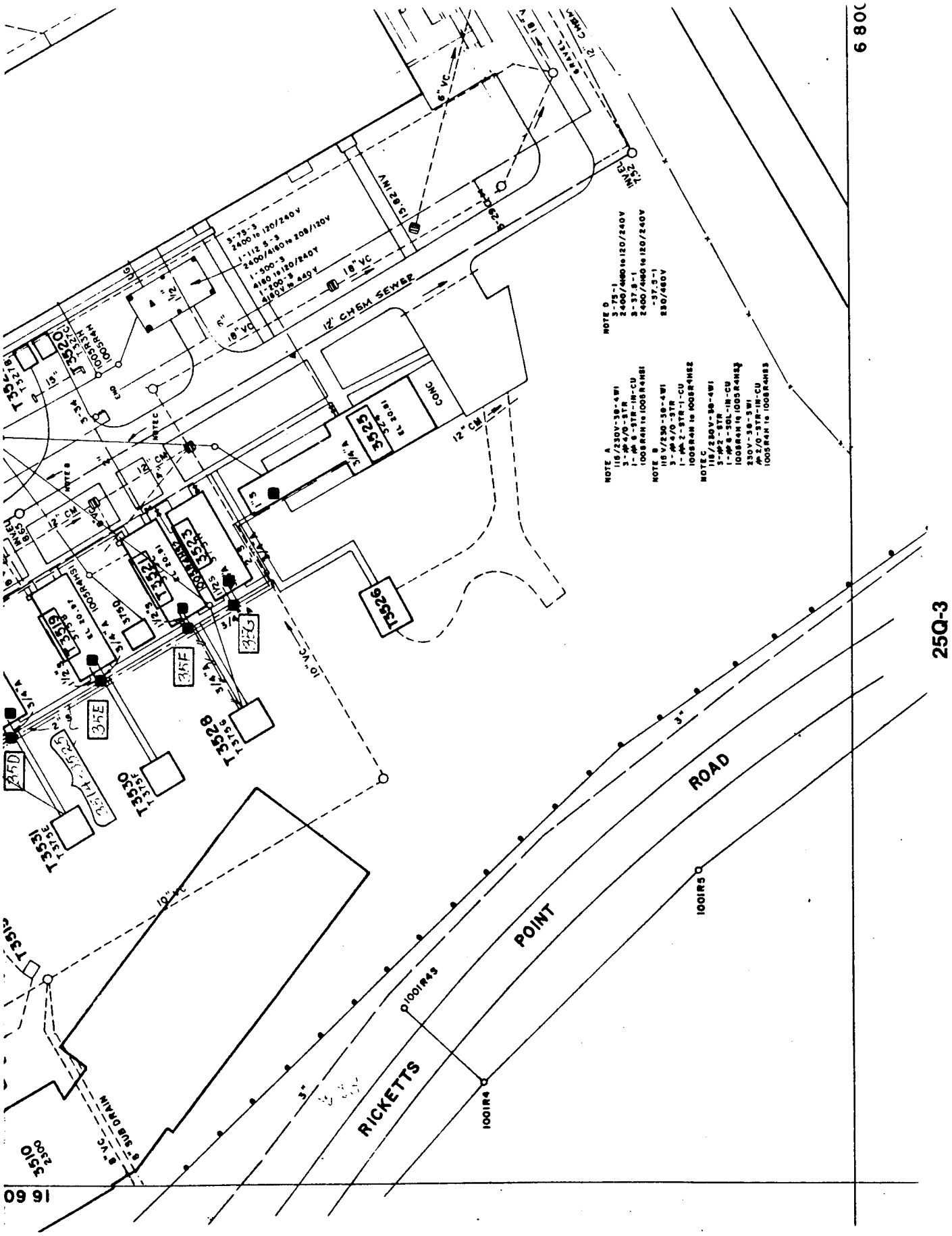

ROAD
POINT
BEACH
3310
3330
3350
BPII
PARKING
RICKETTS
POINT
UG. E S.L.
TEL COND
W16" RC
12" RC
PARKING AREA

25P-2

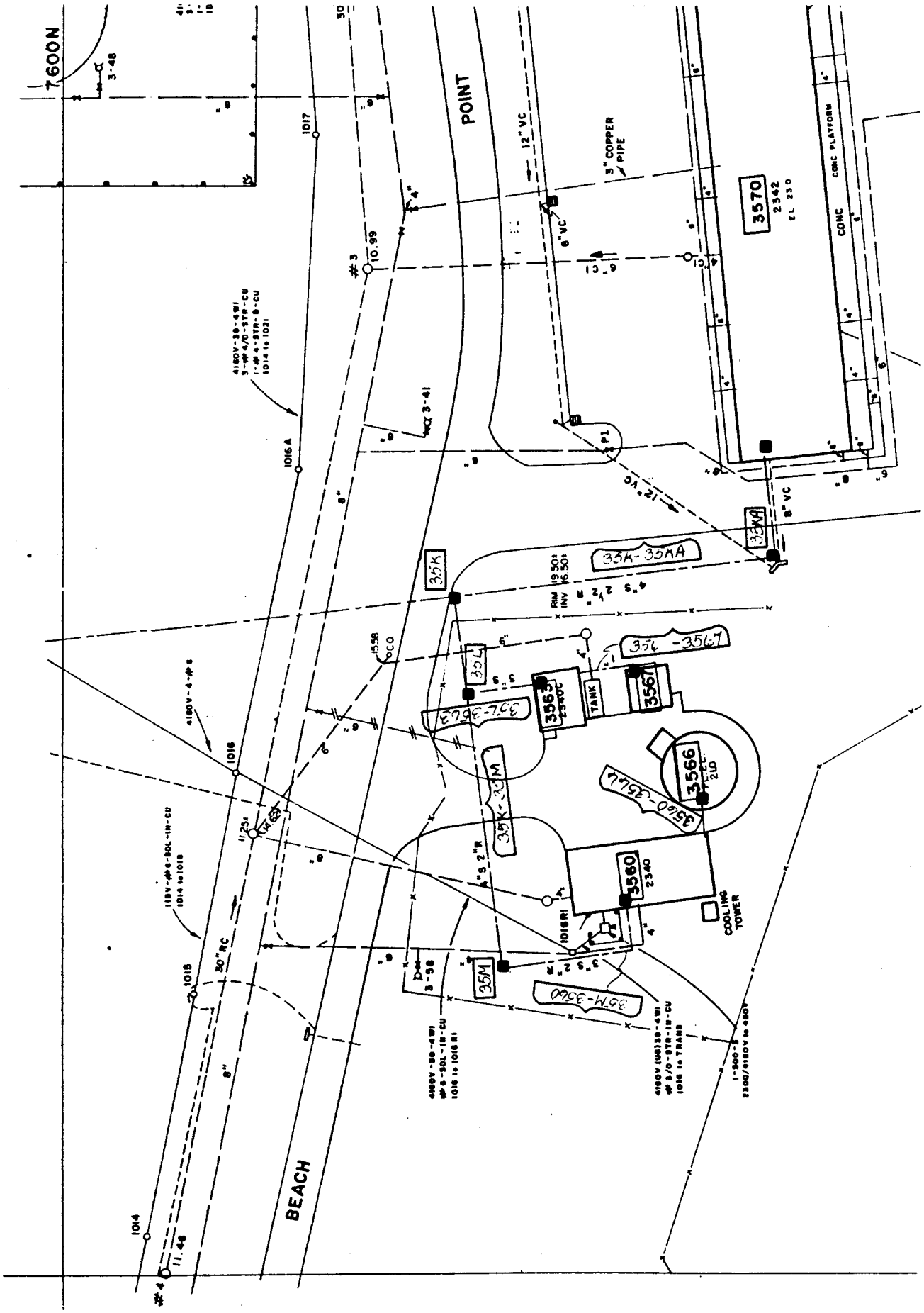


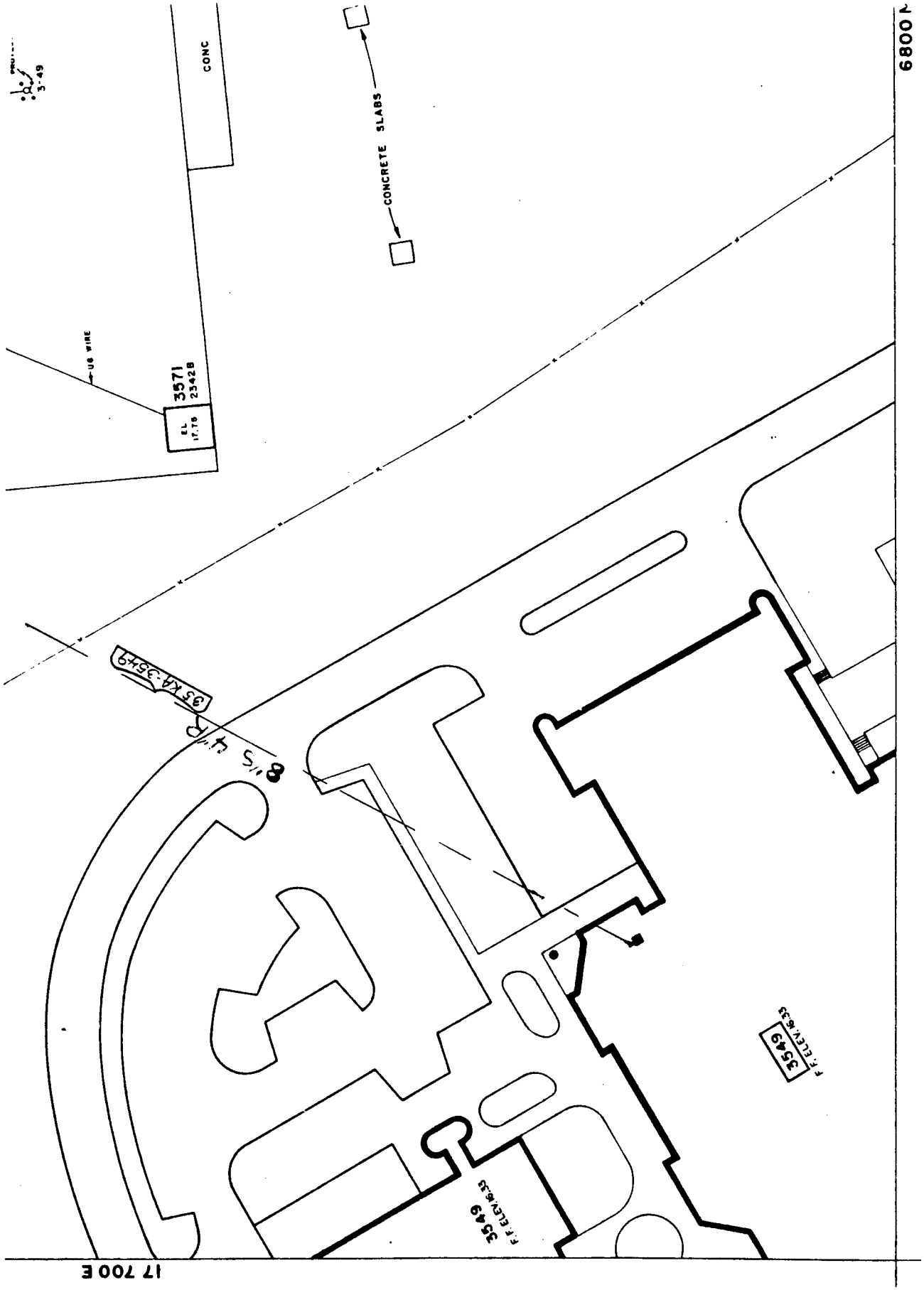
25Q-1


ROAD
3550
VENT LINE
STEEL TANK 72" D/X 60" LONG
10" CHEM SEWER
1012 RS1
1012
1013
1011 RI
1010 RS1
F39
F40
F41
F42
3552
35I-3552
35J-3546
35H-35J
35I-3550
35I
35J
35H
T3546
T3545
T3539
T3544
T3549
T3548
BP8
25Q-2

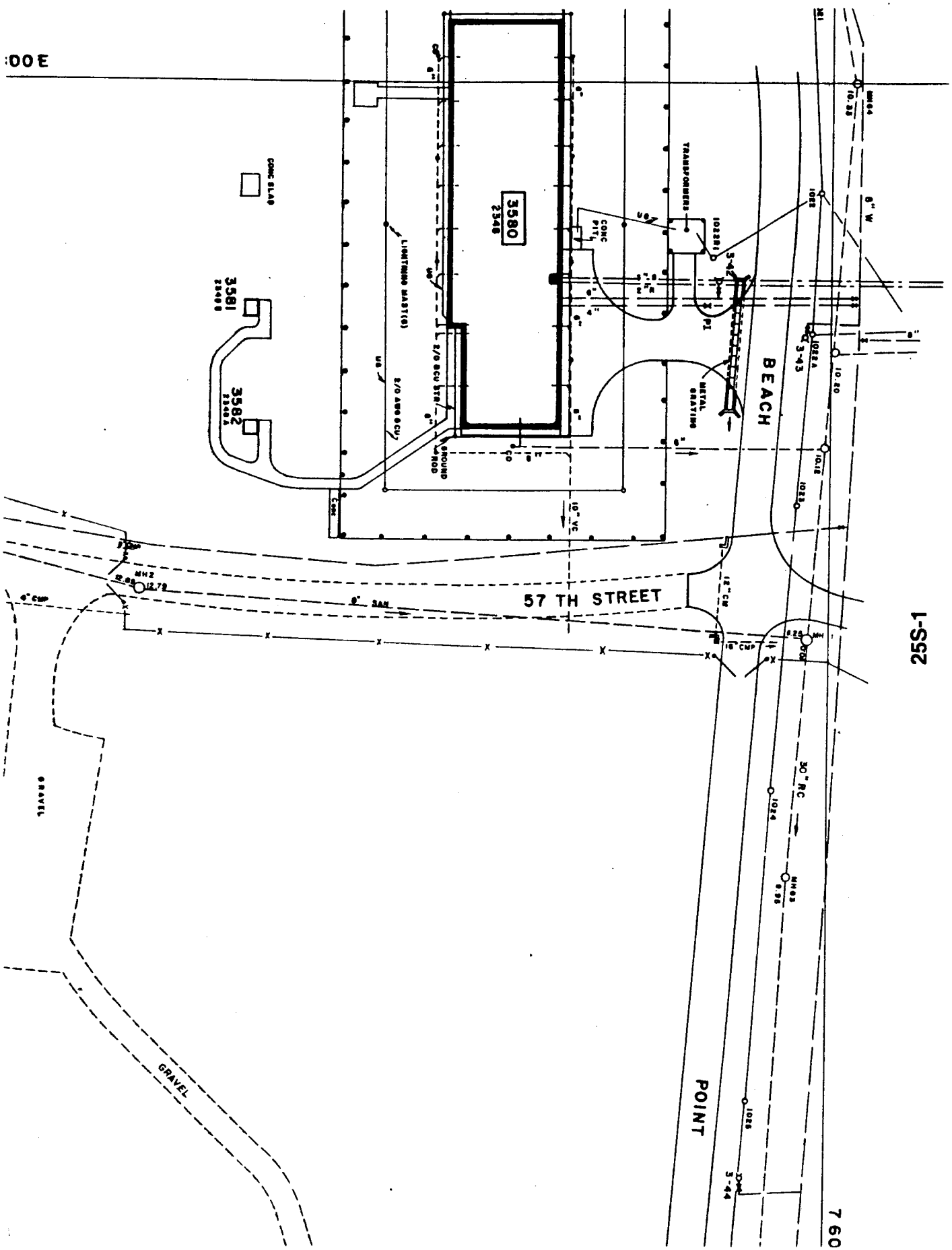

RICKETTS
POINT
ROAD
12" CMSM SEWER
T3520
T3521
T3523
T3525
T3526
T3528
T3530
T3531
T3519
T3510
NOTE A
NOTE B
NOTE C
NOTE D

25Q-3


7600N
POINT
BEACH
12" VC
3" COPPER PIPE
8" VC
3570
2342
EL 23.0
CONC
CONC PLATFORM
35K-35KA
35K
35KA
35L
35L-35L3
3563
TANK
3561
35L-35L7
3566
2.10
35M-35M
35M
35M-3560
3560
2340
COOLING TOWER
1016 R1
1016
1015
1014
1017
1016 A
#3
#4
10.99
11.48
11.25
15.58
30" RC
4160V-3Ø-4W1
3-#4/0-STR-CU
1-#4-STR-B-CU
1014 to 1021
4160V-4-#8
118V-#8-SOL-1W-CU
1014 to 1016
4160V-3Ø-4W1
#8-SOL-1W-CU
1016 to 1016 R1
4160V (UG)3Ø-4W1
#2/0-STR-1W-CU
1016 to TRANS
1-500-?
2300/4160V to 480V
25R-1

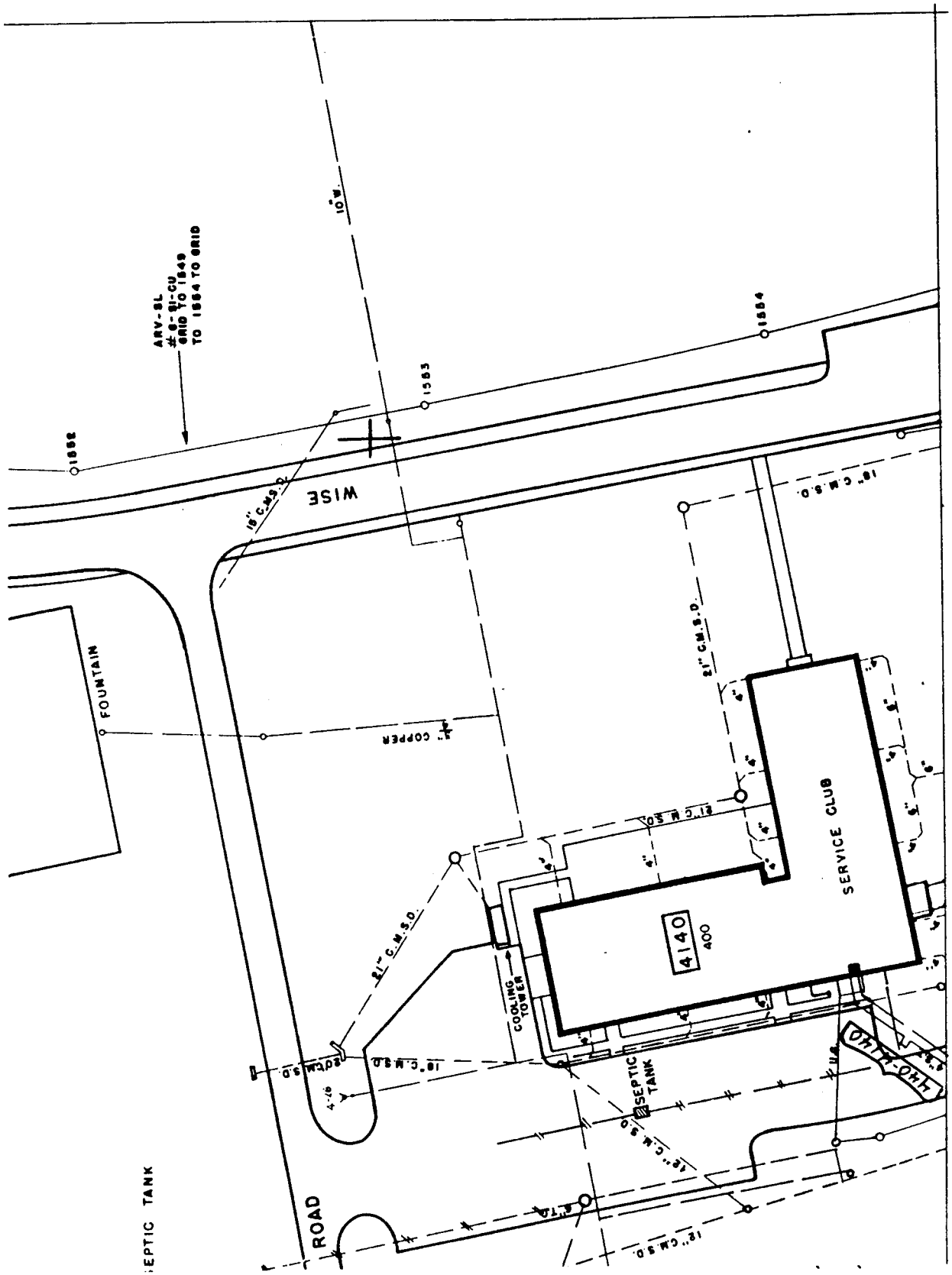

CONC
CONCRETE SLABS
UG WIRE
3571
23428
EL
17.70
3549
F.F. ELEV. 6.53
3549
F.F. ELEV. 6.53
17 700 E
6800 N

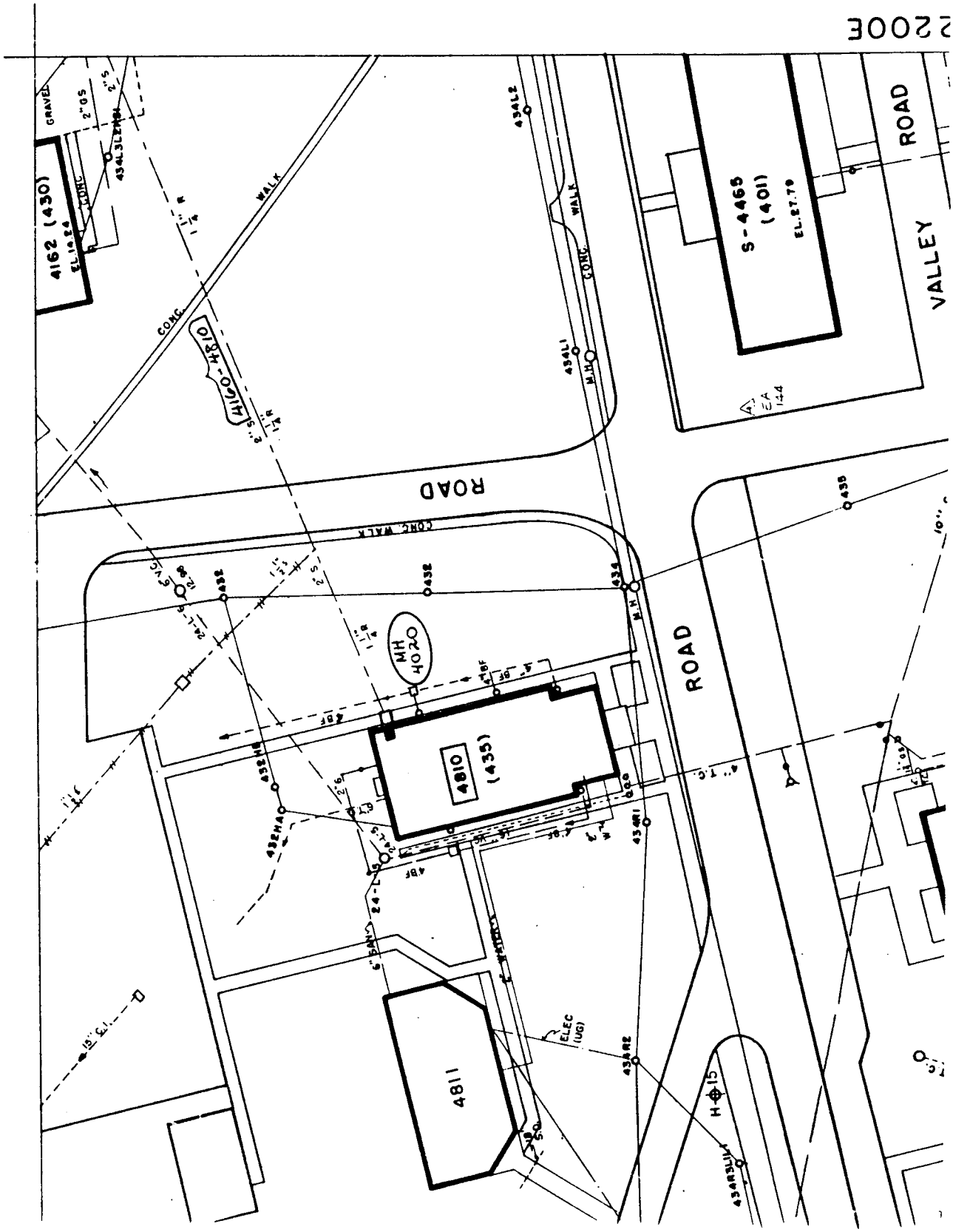
25R-3

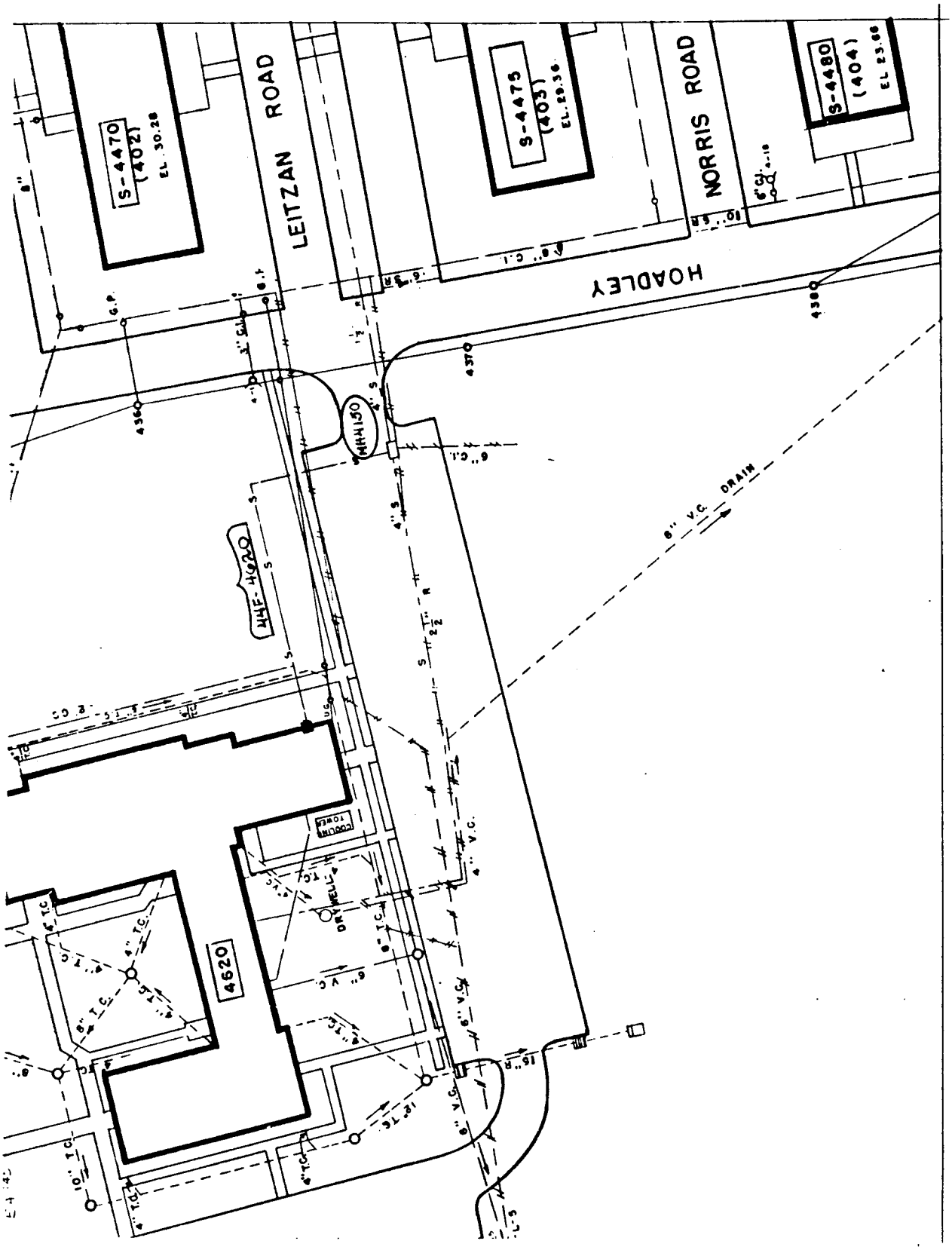

3580
2348
3581
3582
CONC SLAB
LIMESTONE MASTIC
TRANSFORMERS
CONC PIT
METAL BRACING
BEACH
POINT
57 TH STREET
GRAVEL
GRAVEL
30" RC
8" SAN
12" CMP
10" CMP
MH2
MH3
MH4
10.22
10.20
10.18
10.24
10.26
9.95
12.79
25S-1

Layout Chart for 4000 Area Quadrant Map Sheets

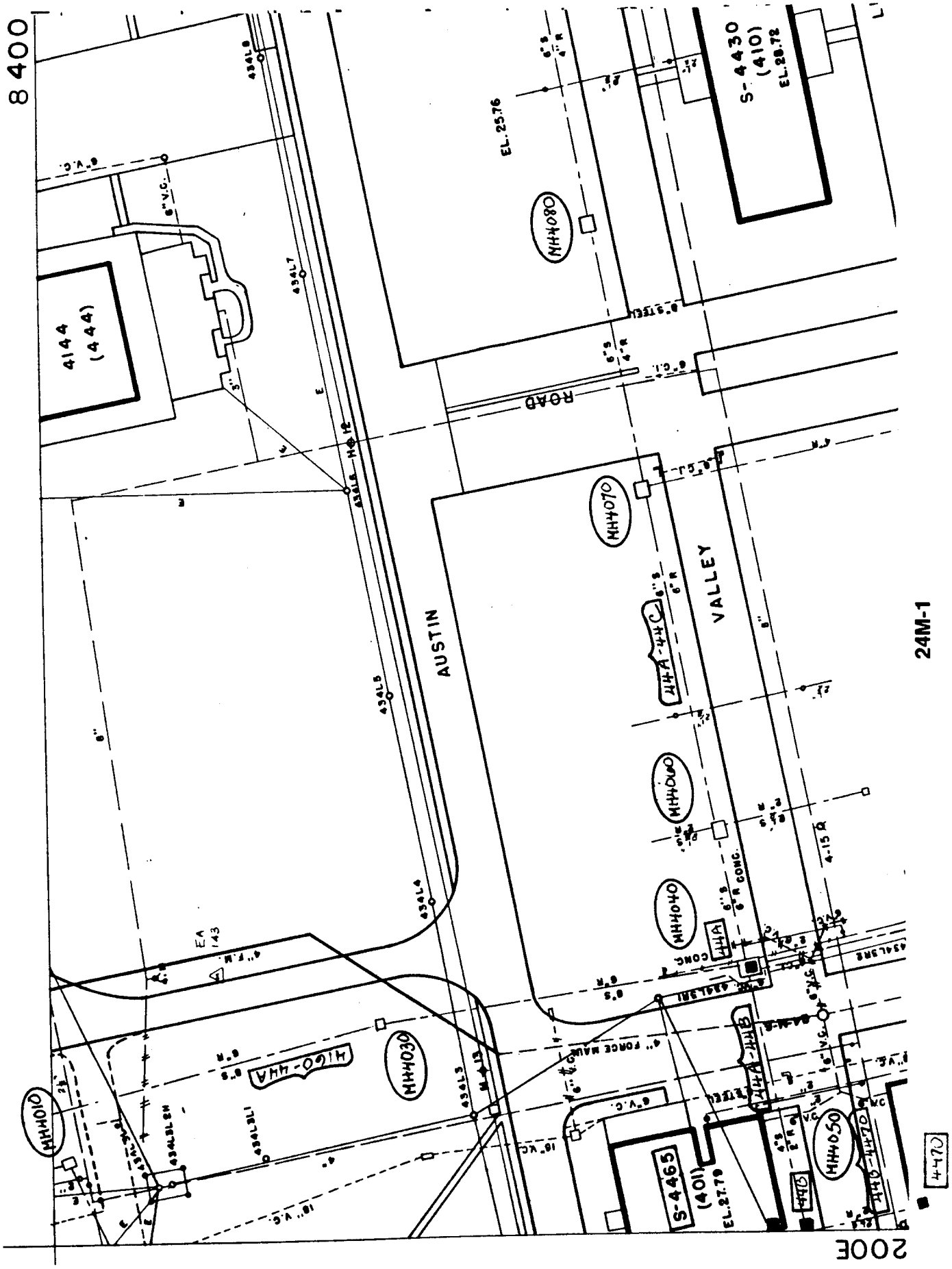
		23M-4		
24L-2	24M-1	24M-2	24N-1	24N-2
24L-4	24M-3	24M-4	24N-3	

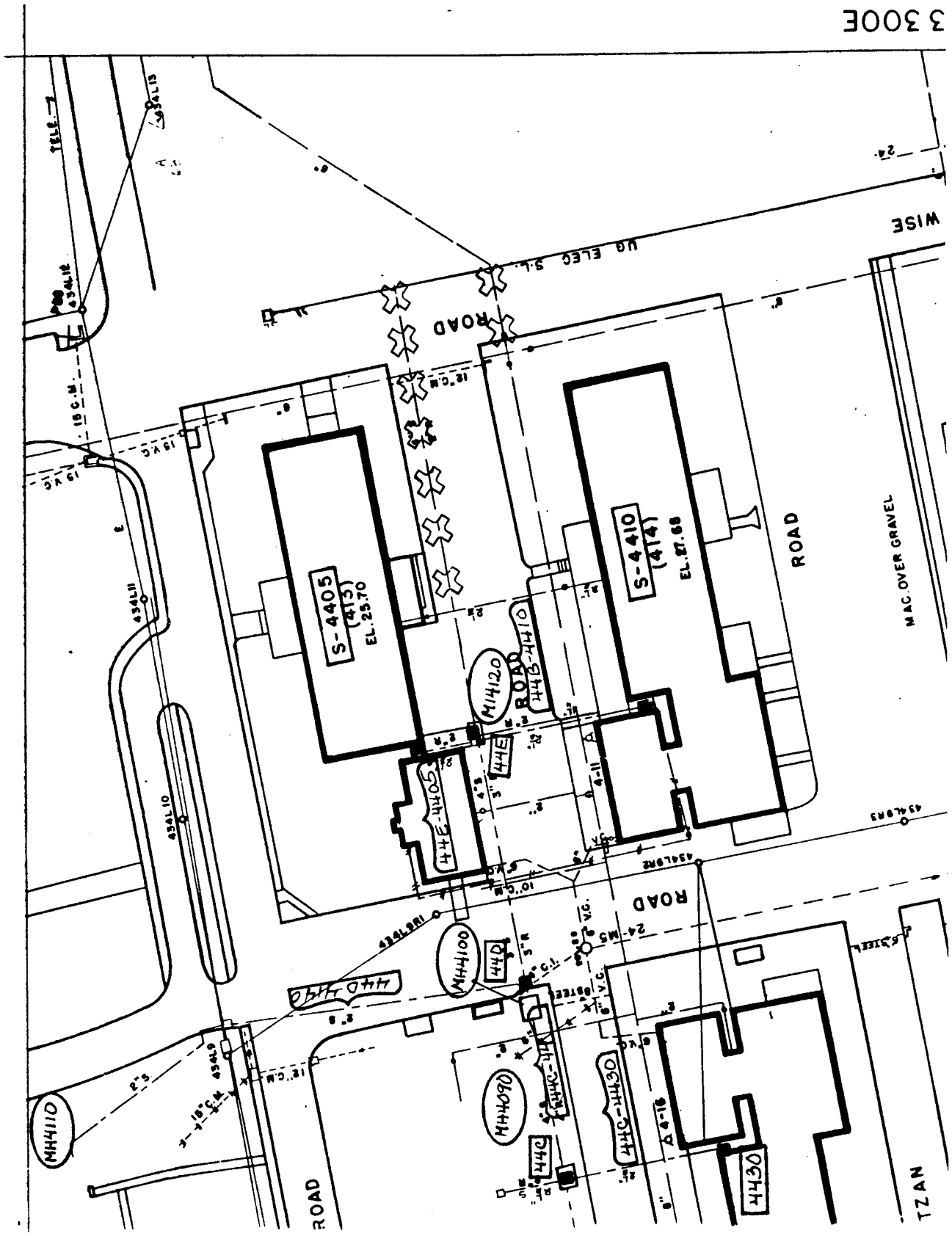

ARV-SL
#6-81-CU
GRID TO 1549
TO 1554 TO GRID
1552
1553
1554
10"W
WISE
18" C.M.S.D.
FOUNTAIN
4" COPPER
21" C.M.S.D.
18" C.M.S.D.
SERVICE CLUB
4140
400
COOLING TOWER
SEPTIC TANK
ROAD
SEPTIC TANK


4162 (430)
GRAVEL
CONC
WALK
CONC
MH 4020
4810
(435)
4811
ELEC (UG)
S-4465
(401)
EL.27.79
ROAD
VALLEY
ROAD
ROAD
CONC. WALK
CONC
WALK
434L2
434L1
M.H.
432
432
434
435
432HB
432HA
434H1
434R2
434R3L1
H 15
24-L-2
6" SAN
6" WATER
24L-2

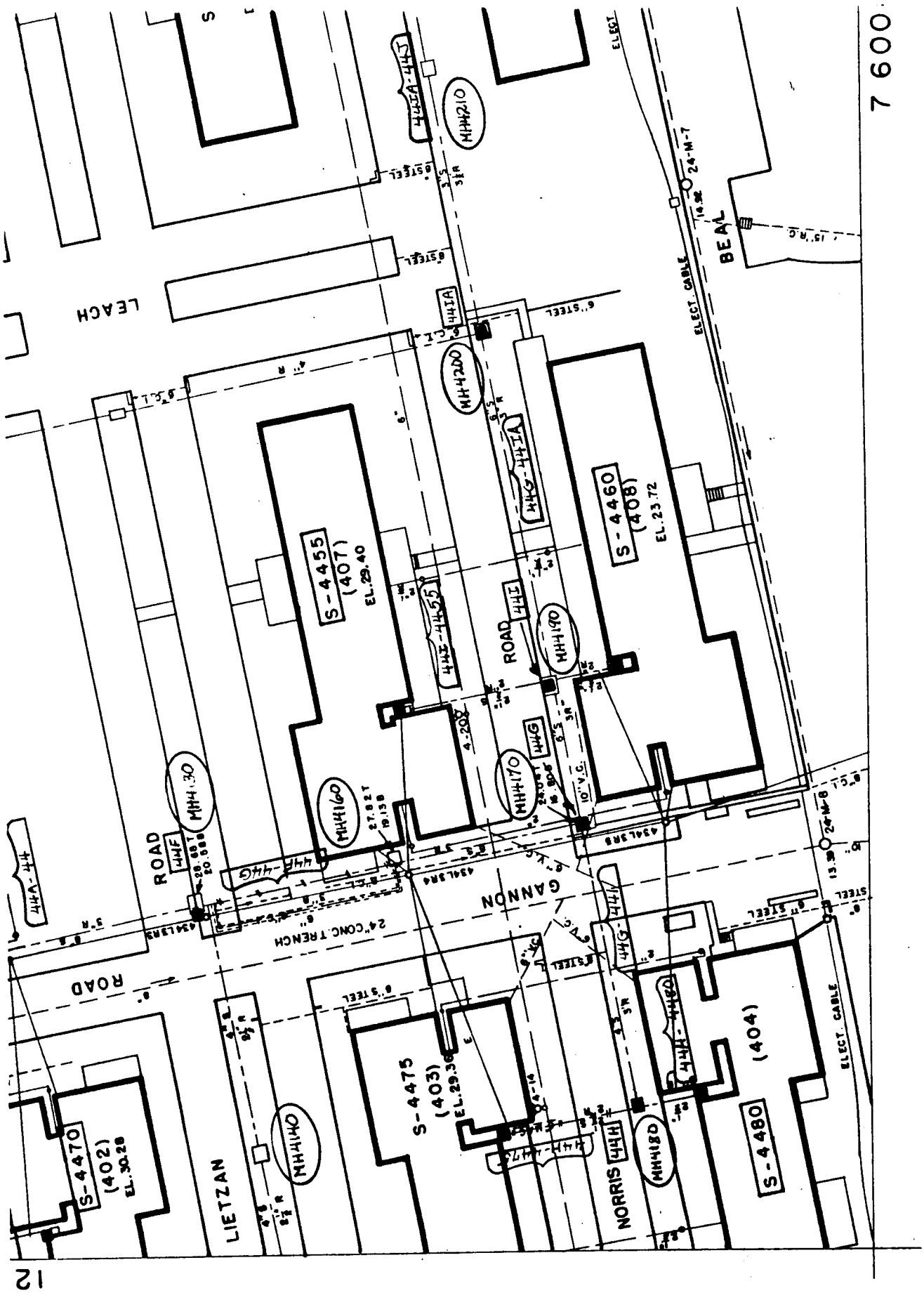

S-4470
(402)
EL. 30.28
LEITZAN ROAD
S-4475
(403)
EL. 28.36
NORRIS ROAD
S-4480
(404)
EL. 23.98
HOADLEY
MH-1150
4620
COOLING TOWER
DRY WELL
8" V.C. DRAIN

24L-4

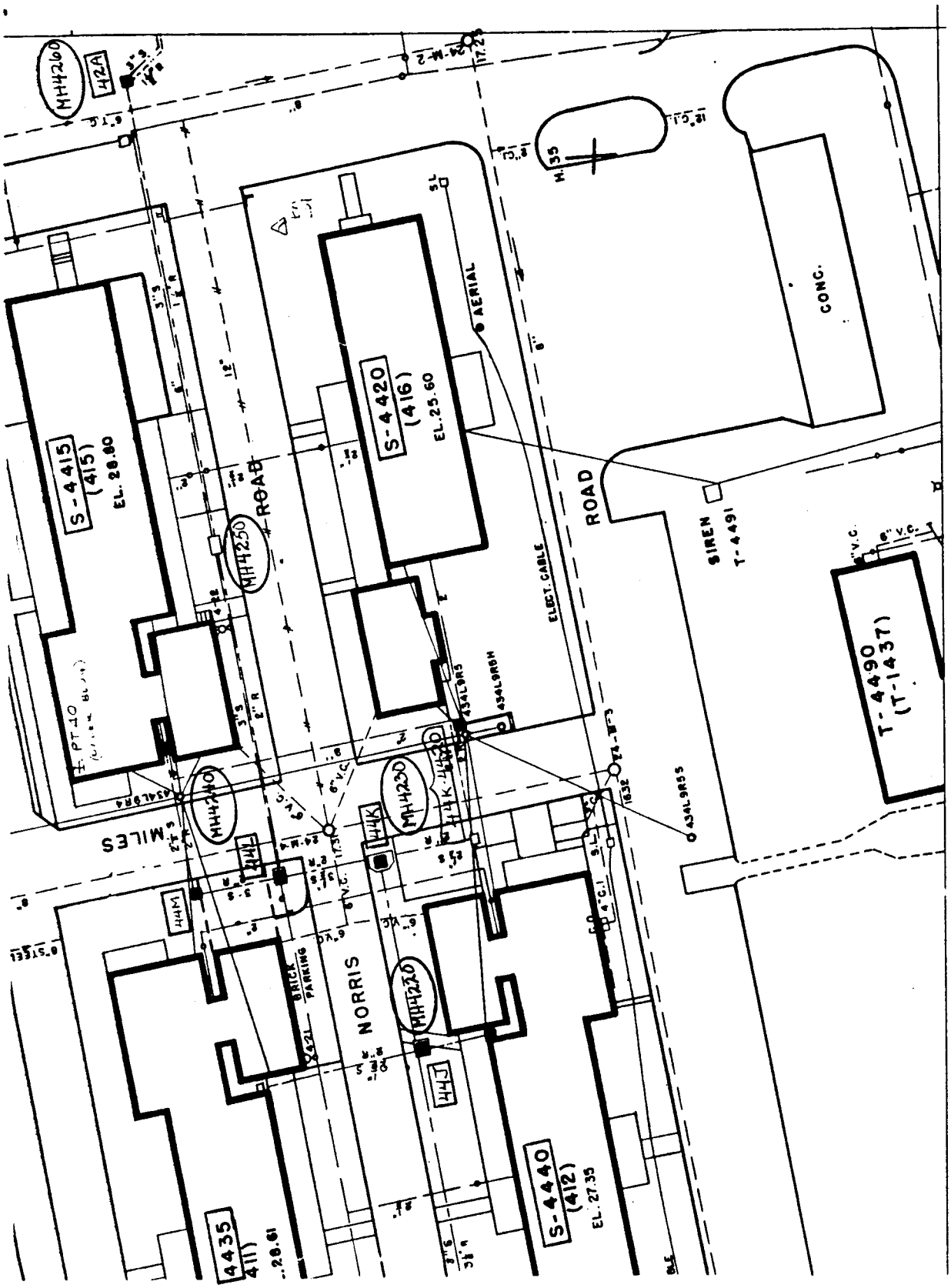

8400
2006
24M-1
4470
4144
(444)
S-4430
(410)
EL.28.72
S-4465
(401)
EL.27.79
EL.25.76
AUSTIN
VALLEY
ROAD
MH4010
MH4030
MH4040
MH4050
MH4060
MH4070
MH4080
H120-44A
44A-44C
44A-44B
434L8
434L7
434L6
434L5
434L4
434L3
434L2
434L1
434L8H
434L9R
434L9RI
EA 143
4" F.M.
4" FORCE MAIN
6" V.C.
6" R CONC.
4-15 Q


S-4405
(415)
EL. 25.70
S-4410
(414)
EL. 27.68
ROAD
ROAD
ROAD
ROAD
MAC. OVER GRAVEL
TZAN
WISE
UG ELEC S.L.
TELE.
MH4110
MH4120
MH4100
MH4090
MH4080
MH4070
MH4060
MH4050
MH4040
MH4030
MH4020
MH4010
4340.12
4341.11
4341.10
4341.9
4341.8
4341.13
4341.15
4341.16
4341.17
4341.18
4341.19
4341.20
4341.21
4341.22
4341.23
4341.24
4341.25
4341.26
4341.27
4341.28
4341.29
4341.30
4341.31
4341.32
4341.33
4341.34
4341.35
4341.36
4341.37
4341.38
4341.39
4341.40
4341.41
4341.42
4341.43
4341.44
4341.45
4341.46
4341.47
4341.48
4341.49
4341.50
4341.51
4341.52
4341.53
4341.54
4341.55
4341.56
4341.57
4341.58
4341.59
4341.60
4341.61
4341.62
4341.63
4341.64
4341.65
4341.66
4341.67
4341.68
4341.69
4341.70
4341.71
4341.72
4341.73
4341.74
4341.75
4341.76
4341.77
4341.78
4341.79
4341.80
4341.81
4341.82
4341.83
4341.84
4341.85
4341.86
4341.87
4341.88
4341.89
4341.90
4341.91
4341.92
4341.93
4341.94
4341.95
4341.96
4341.97
4341.98
4341.99
4341.100
4341.101
4341.102
4341.103
4341.104
4341.105
4341.106
4341.107
4341.108
4341.109
4341.110
4341.111
4341.112
4341.113
4341.114
4341.115
4341.116
4341.117
4341.118
4341.119
4341.120
4341.121
4341.122
4341.123
4341.124
4341.125
4341.126
4341.127
4341.128
4341.129
4341.130
4341.131
4341.132
4341.133
4341.134
4341.135
4341.136
4341.137
4341.138
4341.139
4341.140
4341.141
4341.142
4341.143
4341.144
4341.145
4341.146
4341.147
4341.148
4341.149
4341.150
4341.151
4341.152
4341.153
4341.154
4341.155
4341.156
4341.157
4341.158
4341.159
4341.160
4341.161
4341.162
4341.163
4341.164
4341.165
4341.166
4341.167
4341.168
4341.169
4341.170
4341.171
4341.172
4341.173
4341.174
4341.175
4341.176
4341.177
4341.178
4341.179
4341.180
4341.181
4341.182
4341.183
4341.184
4341.185
4341.186
4341.187
4341.188
4341.189
4341.190
4341.191
4341.192
4341.193
4341.194
4341.195
4341.196
4341.197
4341.198
4341.199
4341.200
4341.201
4341.202
4341.203
4341.204
4341.205
4341.206
4341.207
4341.208
4341.209
4341.210
4341.211
4341.212
4341.213
4341.214
4341.215
4341.216
4341.217
4341.218
4341.219
4341.220
4341.221
4341.222
4341.223
4341.224
4341.225
4341.226
4341.227
4341.228
4341.229
4341.230
4341.231
4341.232
4341.233
4341.234
4341.235
4341.236
4341.237
4341.238
4341.239
4341.240
4341.241
4341.242
4341.243
4341.244
4341.245
4341.246
4341.247
4341.248
4341.249
4341.250
4341.251
4341.252
4341.253
4341.254
4341.255
4341.256
4341.257
4341.258
4341.259
4341.260
4341.261
4341.262
4341.263
4341.264
4341.265
4341.266
4341.267
4341.268
4341.269
4341.270
4341.271
4341.272
4341.273
4341.274
4341.275
4341.276
4341.277
4341.278
4341.279
4341.280
4341.281
4341.282
4341.283
4341.284
4341.285
4341.286
4341.287
4341.288
4341.289
4341.290
4341.291
4341.292
4341.293
4341.294
4341.295
4341.296
4341.297
4341.298
4341.299
4341.300
4341.301
4341.302
4341.303
4341.304
4341.305
4341.306
4341.307
4341.308
4341.309
4341.310
4341.311
4341.312
4341.313
4341.314
4341.315
4341.316
4341.317
4341.318
4341.319
4341.320
4341.321
4341.322
4341.323
4341.324
4341.325
4341.326
4341.327
4341.328
4341.329
4341.330
4341.331
4341.332
4341.333
4341.334
4341.335
4341.336
4341.337
4341.338
4341.339
4341.340
4341.341
4341.342
4341.343
4341.344
4341.345
4341.346
4341.347
4341.348
4341.349
4341.350
4341.351
4341.352
4341.353
4341.354
4341.355
4341.356
4341.357
4341.358
4341.359
4341.360
4341.361
4341.362
4341.363
4341.364
4341.365
4341.366
4341.367
4341.368
4341.369
4341.370
4341.371
4341.372
4341.373
4341.374
4341.375
4341.376
4341.377
4341.378
4341.379
4341.380
4341.381
4341.382
4341.383
4341.384
4341.385
4341.386
4341.387
4341.388
4341.389
4341.390
4341.391
4341.392
4341.393
4341.394
4341.395
4341.396
4341.397
4341.398
4341.399
4341.400
4341.401
4341.402
4341.403
4341.404
4341.405
4341.406
4341.407
4341.408
4341.409
4341.410
4341.411
4341.412
4341.413
4341.414
4341.415
4341.416
4341.417
4341.418
4341.419
4341.420
4341.421
4341.422
4341.423
4341.424
4341.425
4341.426
4341.427
4341.428
4341.429
4341.430
4341.431
4341.432
4341.433
4341.434
4341.435
4341.436
4341.437
4341.438
4341.439
4341.440
4341.441
4341.442
4341.443
4341.444
4341.445
4341.446
4341.447
4341.448
4341.449
4341.450
4341.451
4341.452
4341.453
4341.454
4341.455
4341.456
4341.457
4341.458
4341.459
4341.460
4341.461
4341.462
4341.463
4341.464
4341.465
4341.466
4341.467
4341.468
4341.469
4341.470
4341.471
4341.472
4341.473
4341.474
4341.475
4341.476
4341.477
4341.478
4341.479
4341.480
4341.481
4341.482
4341.483
4341.484
4341.485
4341.486
4341.487
4341.488
4341.489
4341.490
4341.491
4341.492
4341.493
4341.494
4341.495
4341.496
4341.497
4341.498
4341.499
4341.500
4341.501
4341.502
4341.503
4341.504
4341.505
4341.506
4341.507
4341.508
4341.509
4341.510
4341.511
4341.512
4341.513
4341.514
4341.515
4341.516
4341.517
4341.518
4341.519
4341.520
4341.521
4341.522
4341.523
4341.524
4341.525
4341.526
4341.527
4341.528
4341.529
4341.530
4341.531
4341.532
4341.533
4341.534
4341.535
4341.536
4341.537
4341.538
4341.539
4341.540
4341.541
4341.542
4341.543
4341.544
4341.545
4341.546
4341.547
4341.548
4341.549
4341.550
4341.551
4341.552
4341.553
4341.554
4341.555
4341.556
4341.557
4341.558
4341.559
4341.560
4341.561
4341.562
4341.563
4341.564
4341.565
4341.566
4341.567
4341.568
4341.569
4341.570
4341.571
4341.572
4341.573
4341.574
4341.575
4341.576
4341.577
4341.578
4341.579
4341.580
4341.581
4341.582
4341.583
4341.584
4341.585
4341.586
4341.587
4341.588
4341.589
4341.590
4341.591
4341.592
4341.593
4341.594
4341.595
4341.596
4341.597
4341.598
4341.599
4341.600
4341.601
4341.602
4341.603
4341.604
4341.605
4341.606
4341.607
4341.608
4341.609
4341.610
4341.611
4341.612
4341.613
4341.614
4341.615
4341.616
4341.617
4341.618
4341.619
4341.620
4341.621
4341.622
4341.623
4341.624
4341.625
4341.626
4341.627
4341.628
4341.629
4341.630
4341.631
4341.632
4341.633
4341.634
4341.635
4341.636
4341.637
4341.638
4341.639
4341.640
4341.641
4341.642
4341.643
4341.644
4341.645
4341.646
4341.647
4341.648
4341.649
4341.650
4341.651
4341.652
4341.653
4341.654
4341.655
4341.656
4341.657
4341.658
4341.659
4341.660
4341.661
4341.662
4341.663
4341.664
4341.665
4341.666
4341.667
4341.668
4341.669
4341.670
4341.671
4341.672
4341.673
4341.674
4341.675
4341.676
4341.677
4341.678
4341.679
4341.680
4341.681
4341.682
4341.683
4341.684
4341.685
4341.686
4341.687
4341.688
4341.689
4341.690
4341.691
4341.692
4341.693
4341.694
4341.695
4341.696
4341.697
4341.698
4341.699
4341.700
4341.701
4341.702
4341.703
4341.704
4341.705
4341.706
4341.707
4341.708
4341.709
4341.710
4341.711
4341.712
4341.713
4341.714
4341.715
4341.716
4341.717
4341.718
4341.719
4341.720
4341.721
4341.722
4341.723
4341.724
4341.725
4341.726
4341.727
4341.728
4341.729
4341.730
4341.731
4341.732
4341.733
4341.734
4341.735
4341.736
4341.737
4341.738
4341.739
4341.740
4341.741
4341.742
4341.743
4341.744
4341.745
4341.746
4341.747
4341.748
4341.749
4341.750
4341.751
4341.752
4341.753
4341.754
4341.755
4341.756
4341.757
4341.758
4341.759
4341.760
4341.761
4341.762
4341.763
4341.764
4341.765
4341.766
4341.767
4341.768
4341.769
4341.770
4341.771
4341.772
4341.773
4341.774
4341.775
4341.776
4341.777
4341.778
4341.779
4341.780
4341.781
4341.782
4341.783
4341.784
4341.785
4341.786
4341.787
4341.788
4341.789
4341.790
4341.791
4341.792
4341.793
4341.794
4341.795
4341.796
4341.797
4341.798
4341.799
4341.800
4341.801
4341.802
4341.803
4341.804
4341.805
4341.806
4341.807
4341.808
4341.809
4341.810
4341.811
4341.812
4341.813
4341.814
4341.815
4341.816
4341.817
4341.818
4341.819
4341.820
4341.821
4341.822
4341.823
4341.824
4341.825
4341.826
4341.827
4341.828
4341.829
4341.830
4341.831
4341.832
4341.833
4341.834
4341.835
4341.836
4341.837
4341.838
4341.839
4341.840
4341.841
4341.842
4341.843
4341.844
4341.845
4341.846
4341.847
4341.848
4341.849
4341.850
4341.851
4341.852
4341.853
4341.854
4341.855
4341.856
4341.857
4341.858
4341.859
4341.860
4341.861
4341.862
4341.863
4341.864
4341.865
4341.866
4341.867
4341.868
4341.869
4341.870
4341.871
4341.872
4341.873
4341.874
4341.875
4341.876
4341.877
4341.878
4341.879
4341.880
4341.881
4341.882
4341.883
4341.884
4341.885
4341.886
4341.887
4341.888
4341.889
4341.890
4341.891
4341.892
4341.893
4341.894
4341.895
4341.896
4341.897
4341.898
4341.899
4341.900
4341.901
4341.902
4341.903
4341.904
4341.905
4341.906
4341.907
4341.908
4341.909
4341.910
4341.911
4341.912
4341.913
4341.914
4341.915
4341.916
4341.917
4341.918
4341.919
4341.920
4341.921
4341.922
4341.923
4341.924
4341.925
4341.926
4341.927
4341.928
4341.929
4341.930
4341.931
4341.932
4341.933
4341.934
4341.935
4341.936
4341.937
4341.938
4341.939
4341.940
4341.941
4341.942
4341.943
4341.944
4341.945
4341.946
4341.947
4341.948
4341.949
4341.950
4341.951
4341.952
4341.953
4341.954
4341.955
4341.956
4341.957
4341.958
4341.959
4341.960
4341.961
4341.962
4341.963
4341.964
4341.965
4341.966
4341.967
4341.968
4341.969
4341.970
4341.971
4341.972
4341.973
4341.974
4341.975
4341.976
4341.977
4341.978
4341.979
4341.980
4341.981
4341.982
4341.983
4341.984
4341.985
4341.986
4341.987
4341.988
4341.989
4341.990
4341.991
4341.992
4341.993
4341.994
4341.995
4341.996
4341.997
4341.998
4341.999
4341.1000

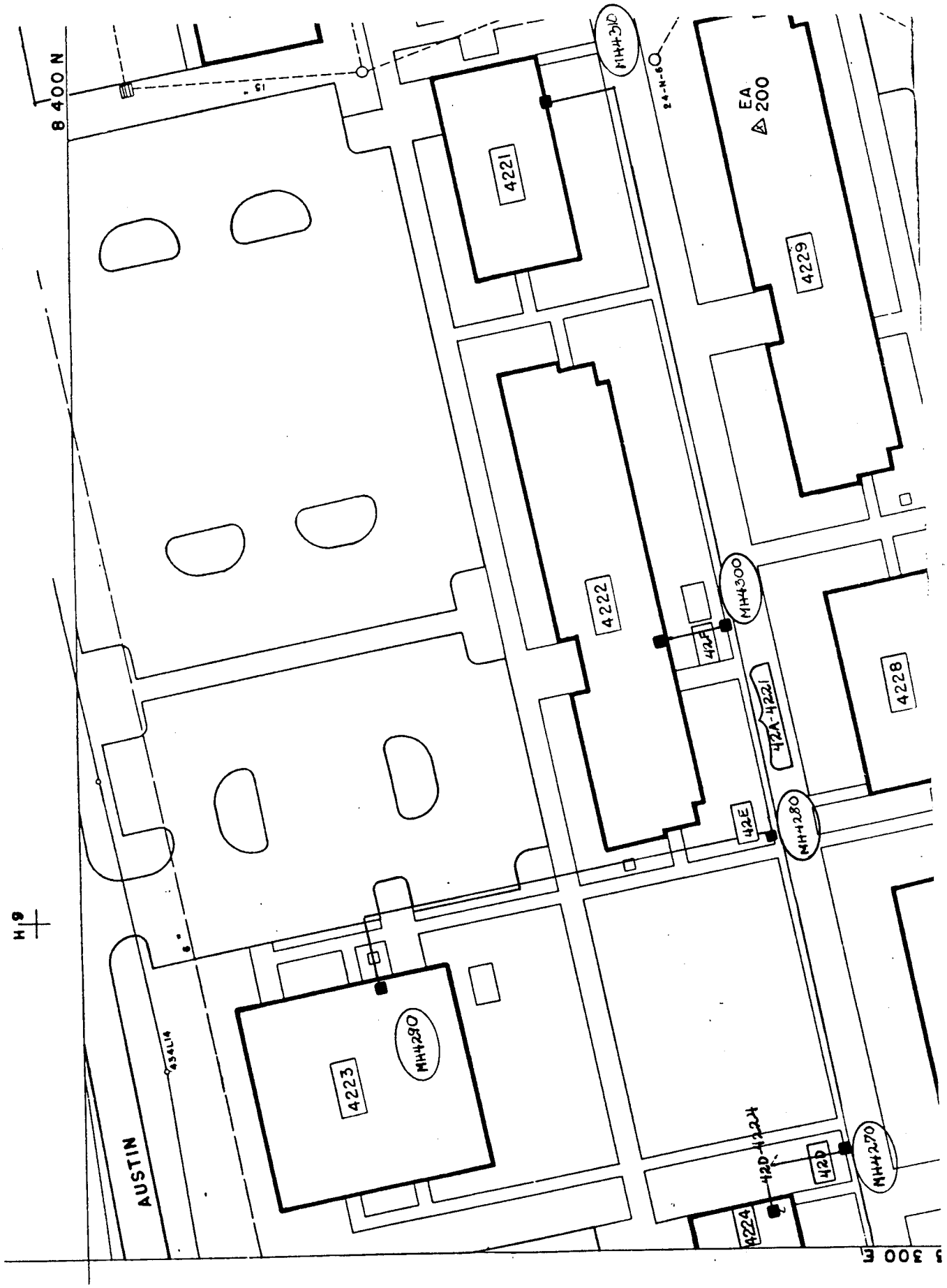
24M-2


LEACH
BEAL
ROAD
GANNON
LIETZAN
NORRIS
S-4455 (407) EL. 29.40
S-4460 (408) EL. 23.72
S-4470 (402) EL. 30.28
S-4475 (403) EL. 29.36
S-4480 (404)
MH4130
MH4160
MH4170
MH4200
MH4210
MH4140
MH4180
24"CONC. TRENCH
ELECT. CABLE
7 600

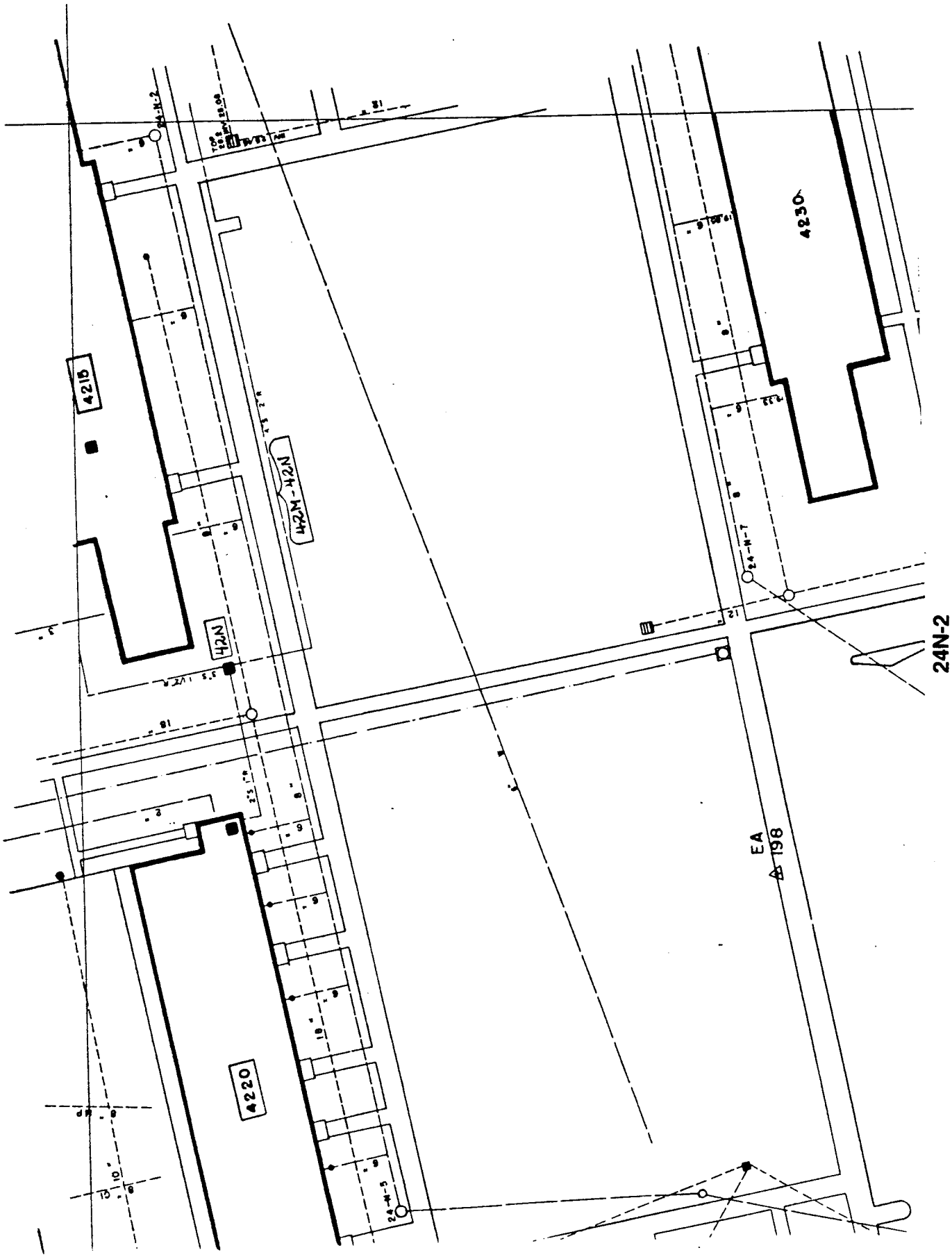
24M-3

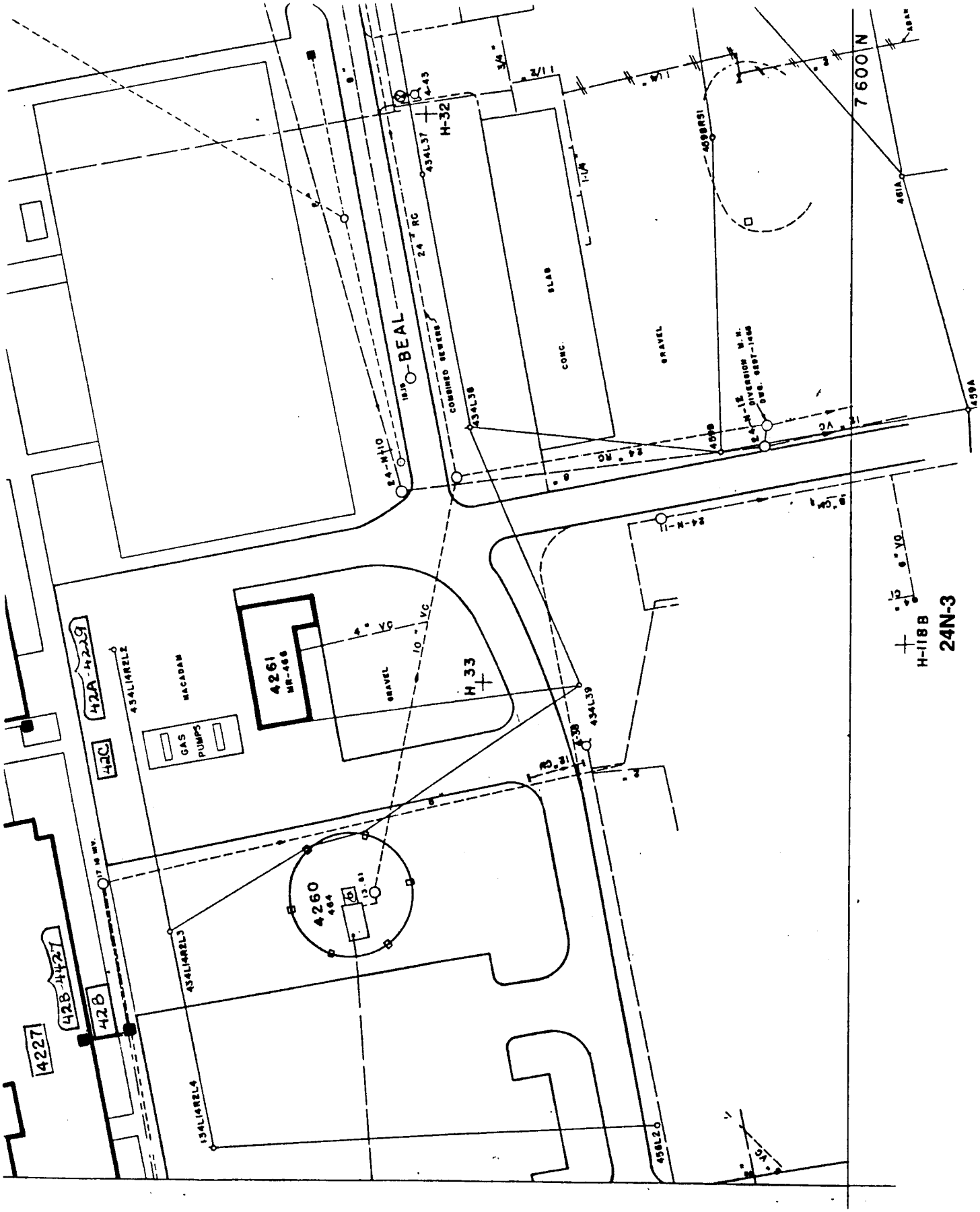

S-4415
(415)
EL. 28.80
S-4420
(416)
EL. 25.60
S-4440
(412)
EL. 27.35
4435
(411)
T-4490
(T-1437)
CONC.
ROAD
ROAD
NORRIS
MILES
AERIAL
SIREN
T-4491
ELECT. CABLE
BRICK PARKING
MH4210
MH4250
MH4240
MH4230
MH4220
4LA
4LM
4LL
4LK
4LJ
4LH
M135
4341.9R55
4341.9R84
4341.9R85
4341.9R86
1632

24M-4


8 400 N
AUSTIN
4223
MH4290
4222
4221
MH4310
24-N-6
EA
200
4229
4228
MH4300
42F
42A-4221
42E
MH4280
42D-4224
42D
MH4270
4224
5 300 E

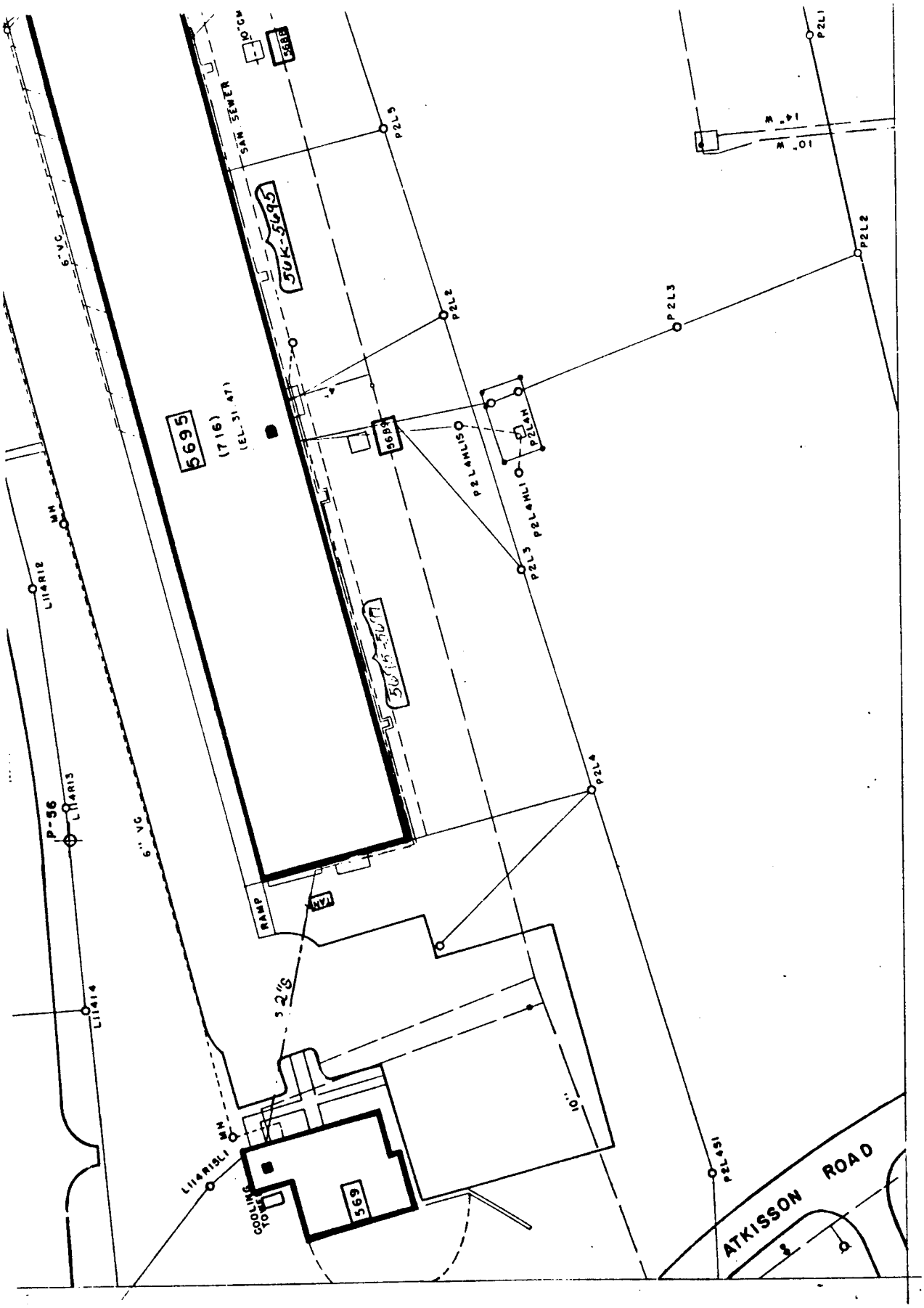
24N-1


4215
4230
42N-4-2N
42N
4220
EA
198
24N-2

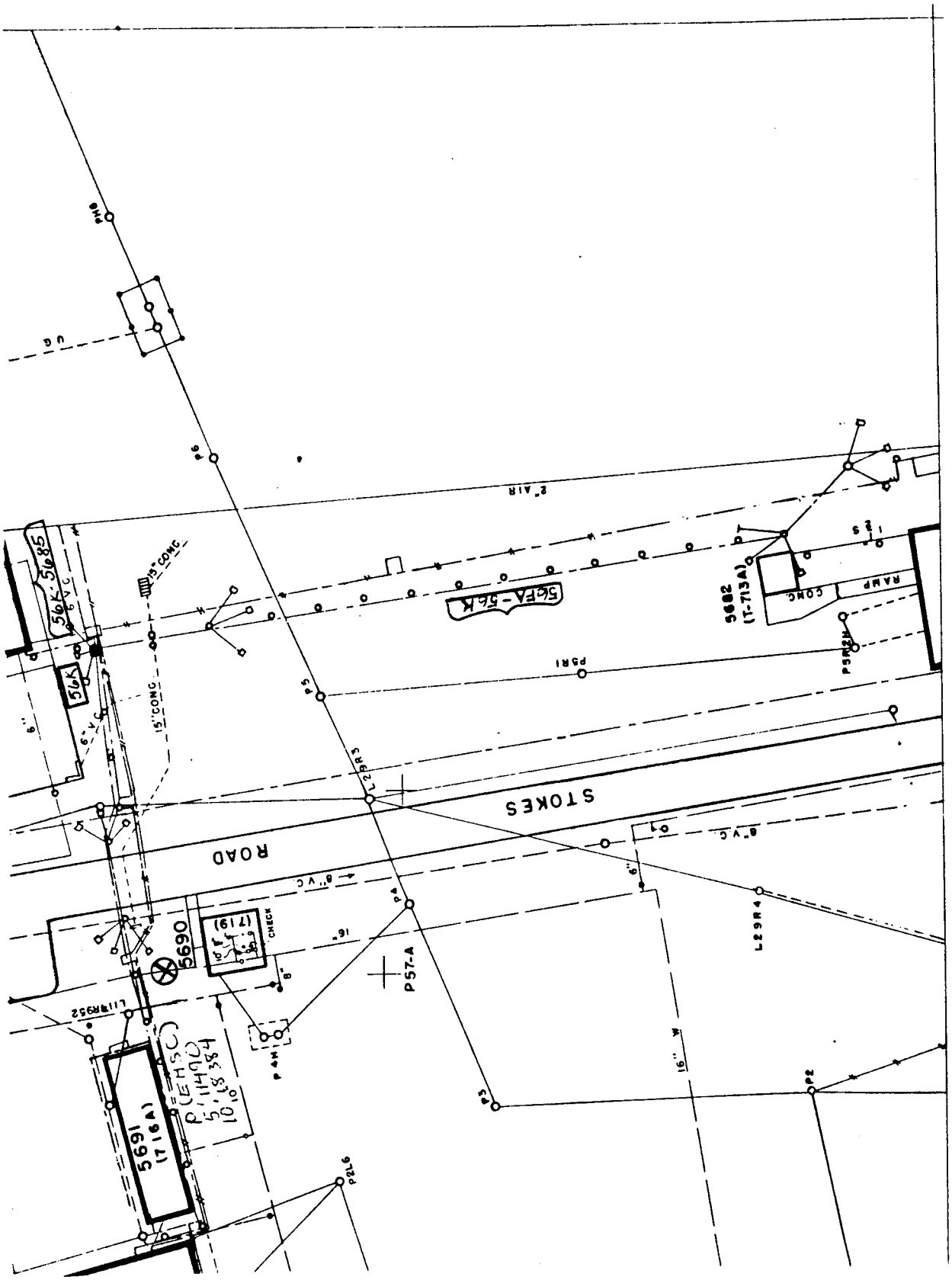

BEAL
7600 N
H-32
H-33
H-118B
24N-3
4261
MR-466
4260
464
CONC.
SLAB
GRAVEL
MACADAM
GAS
PUMPS
COMBINED SEWERS
DIVERSION M.H.
4227
428
42C
42A
459A
461A
4598R51
434L37
434L38
434L39
434L14R2L2
434L14R2L3
434L14R2L4
458L2

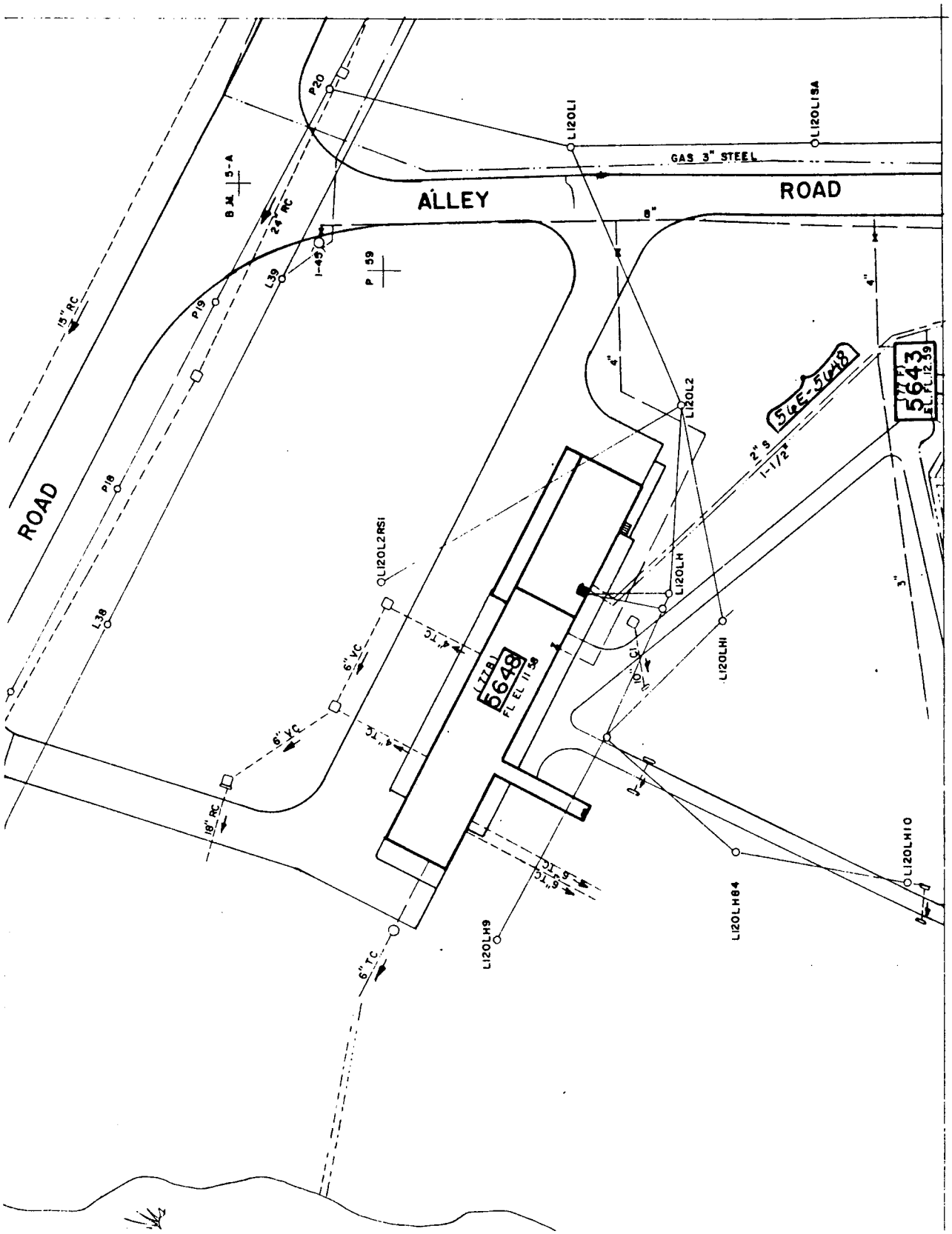
Layout Chart for 5000 Area Quadrant Map Sheets

				17L-1					
17J-3	17J-4		17K-4	17L-3					
	18J-2	18K-1	18K-2	18L-1	18L-2				
		18K-3		18L-3	18L-4	18M-3	18M-4		
		19K-1	19K-2	19L-1	19L-2	19M-1	19M-2	19N-1	19N-2
		19K-3	19K-4	19L-3		19M-3	19M-4	19N-3	19N-4
				20L-1	20L-2	20M-1	20M-2	20N-1	20N-2
				20L-3	20L-4	20M-3	20M-4	20N-3	20N-4
			21K-2	21L-1	21L-2	21M-1	21M-2		
			21K-4	21L-3	21L-4	21M-3			

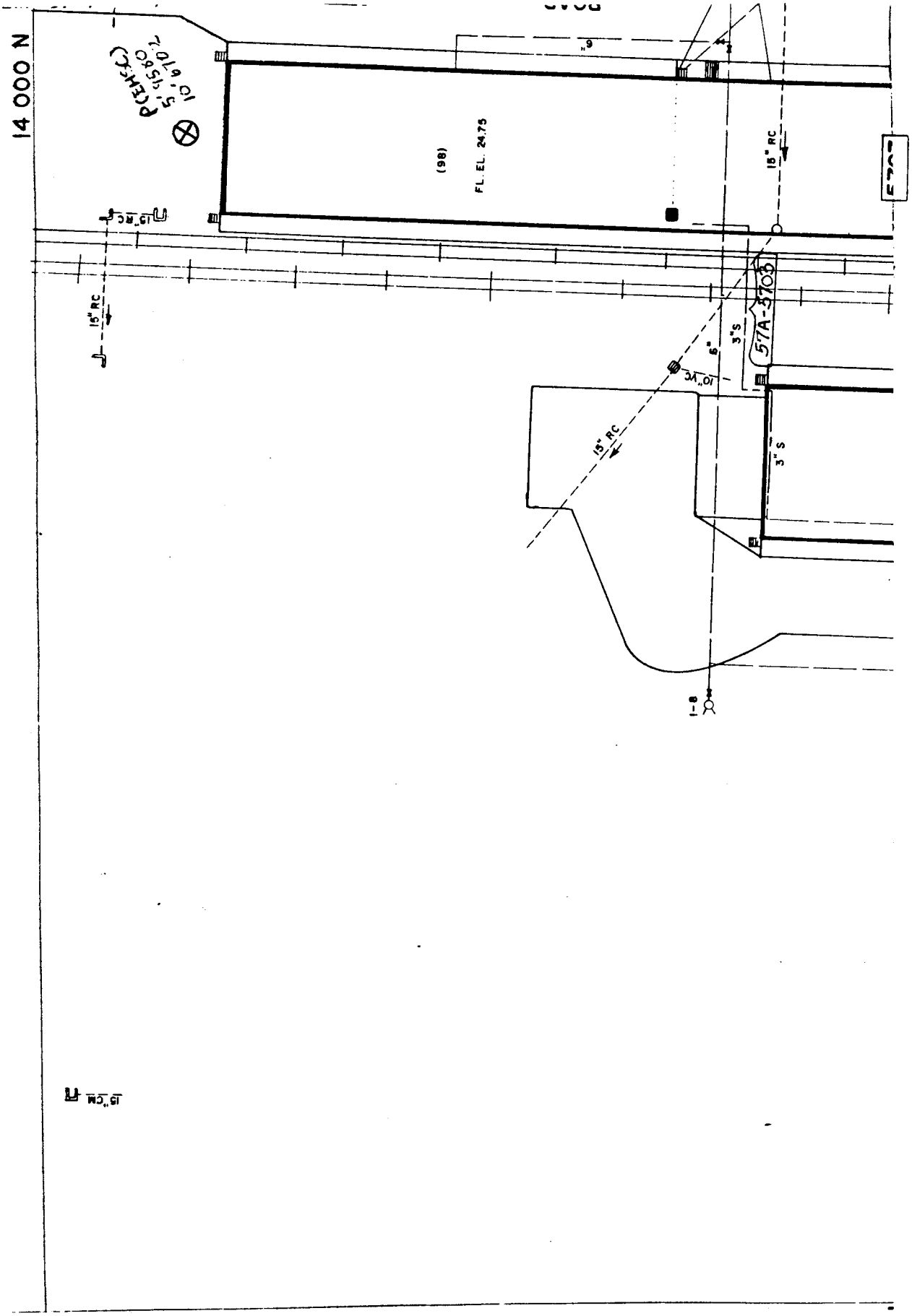

5695
(716)
(EL-31.47)
SAN SEWER
6" VC
6" VC
P-56
L114R12
L114R13
L11414
L114R15.1
MH
RAMP
32"G
COOLING TOWER
569
ATKISSON ROAD
P2L1
P2L2
P2L3
P2L4
P2L5
P2L451
P2L4H
P2L4H1.1
P2L4H1.5
10" CM
14" W
10" W
10"

17J-3

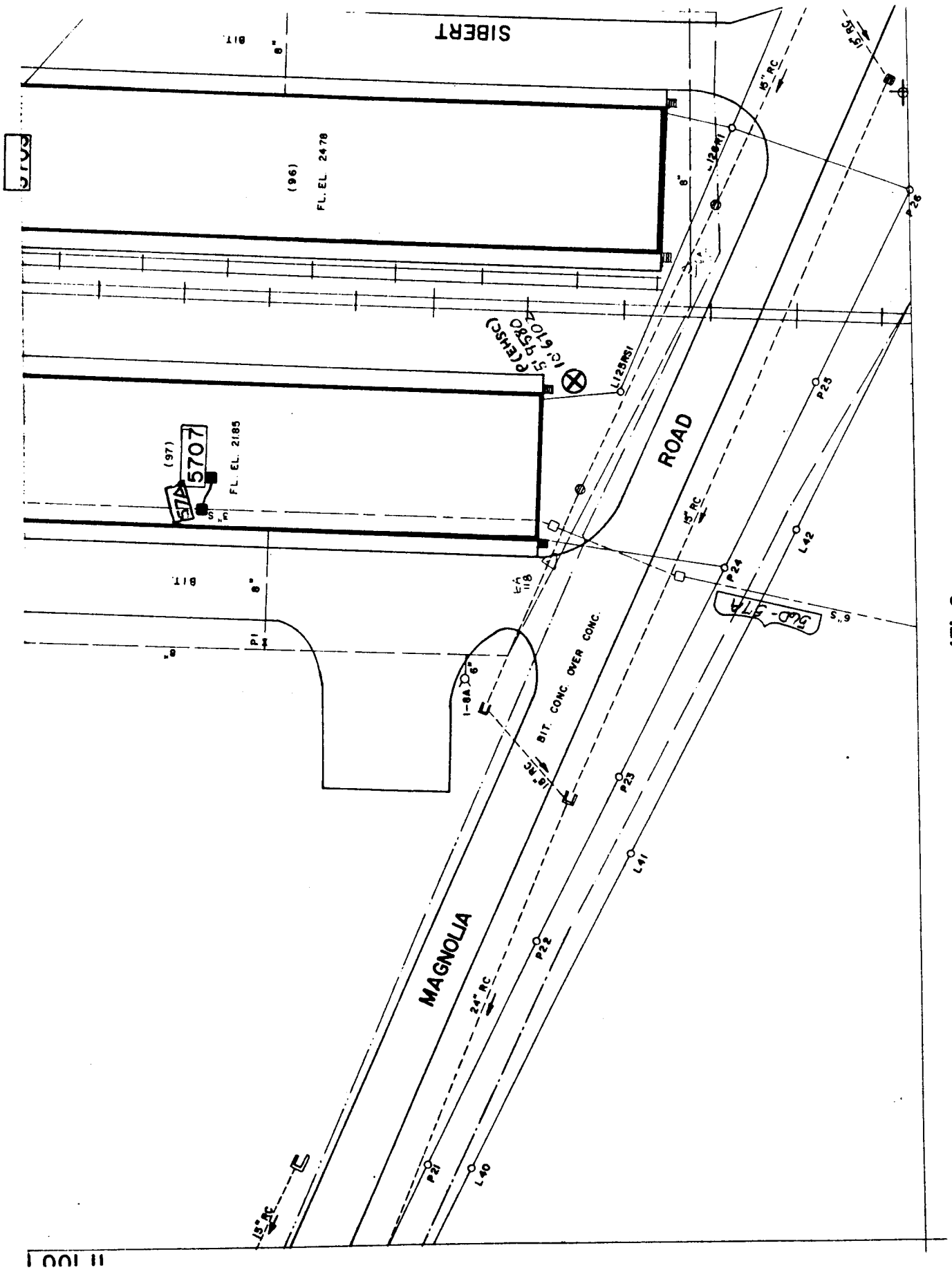

STOKES
ROAD
5691
(1716A)
5690
(719)
CHECK
5682
(T-713A)
RAMP
CONC
56A
56K-56M
56FA-56K
P57-A
P5R1
P4W1
P2
P3
P4
P5
P6
P7
P8
P9
P7L6
L29R4
L2P3R3
LIIRR952
15" CONC
2" AIR
16" W
8" V C
6" V C
U G


ROAD
ALLEY
ROAD
GAS 3" STEEL
L120L1
L120L1SA
P20
P19
P18
L39
L38
I-49
P 59
B.M. 5-A
24" RC
15" RC
18" RC
6" YC
6" TC
L120L2RS1
L120L2
L120LH
L120LH1
L120LH9
L120LH84
L120LH10
5648
FL EL 11.58
5643
EL. FL. 12.39
5GE-5648
2" S
1-1/2"
8"
4"
3"

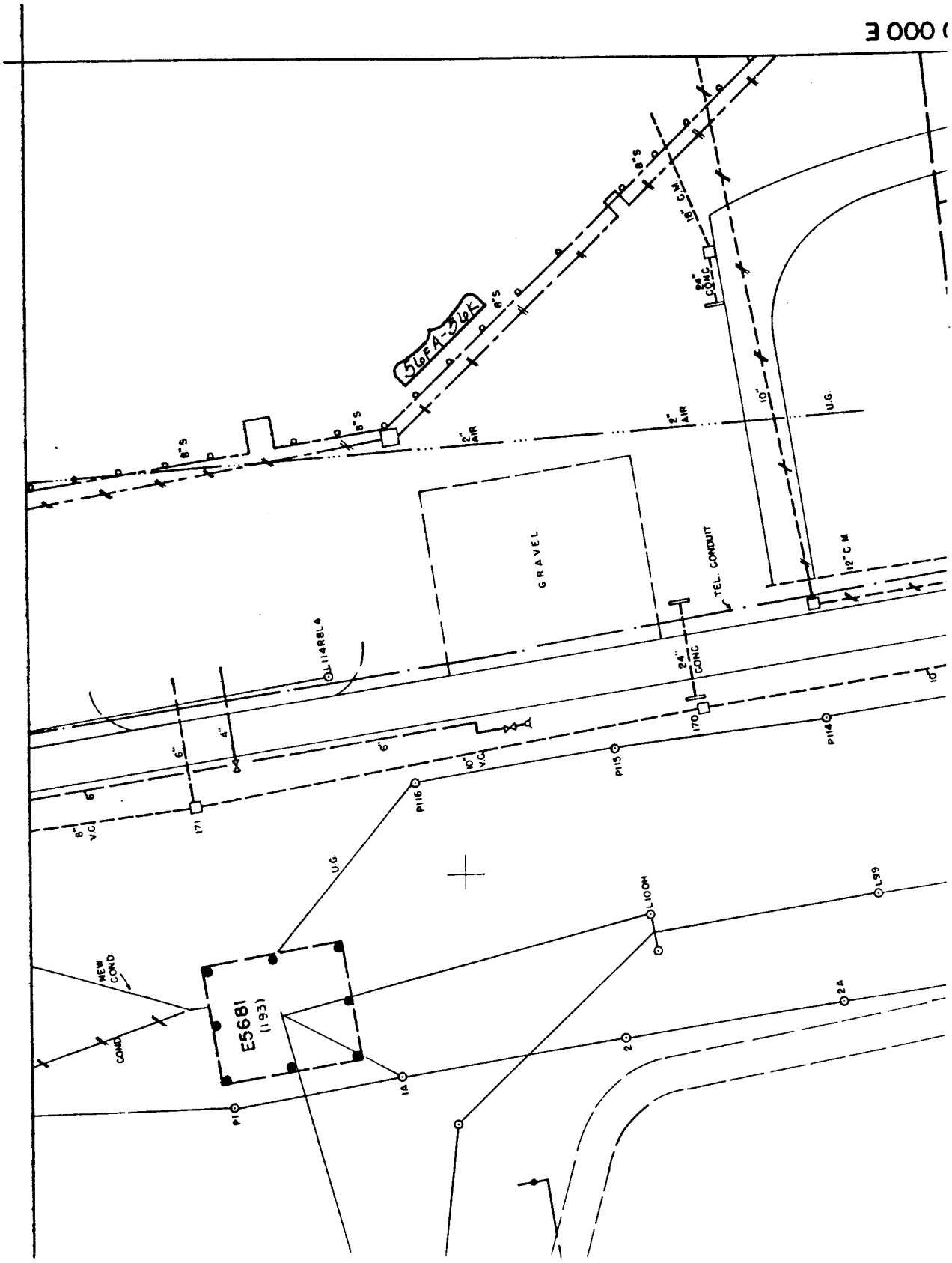
17K-4


14 000 N
PCEMKC
S1,1560
10,670.2
15" RC
15" RC
15" RC
15" RC
15" RC
(98)
FL. EL. 24.75
9"
6"
3"S
3" S
57A-3703
1-8

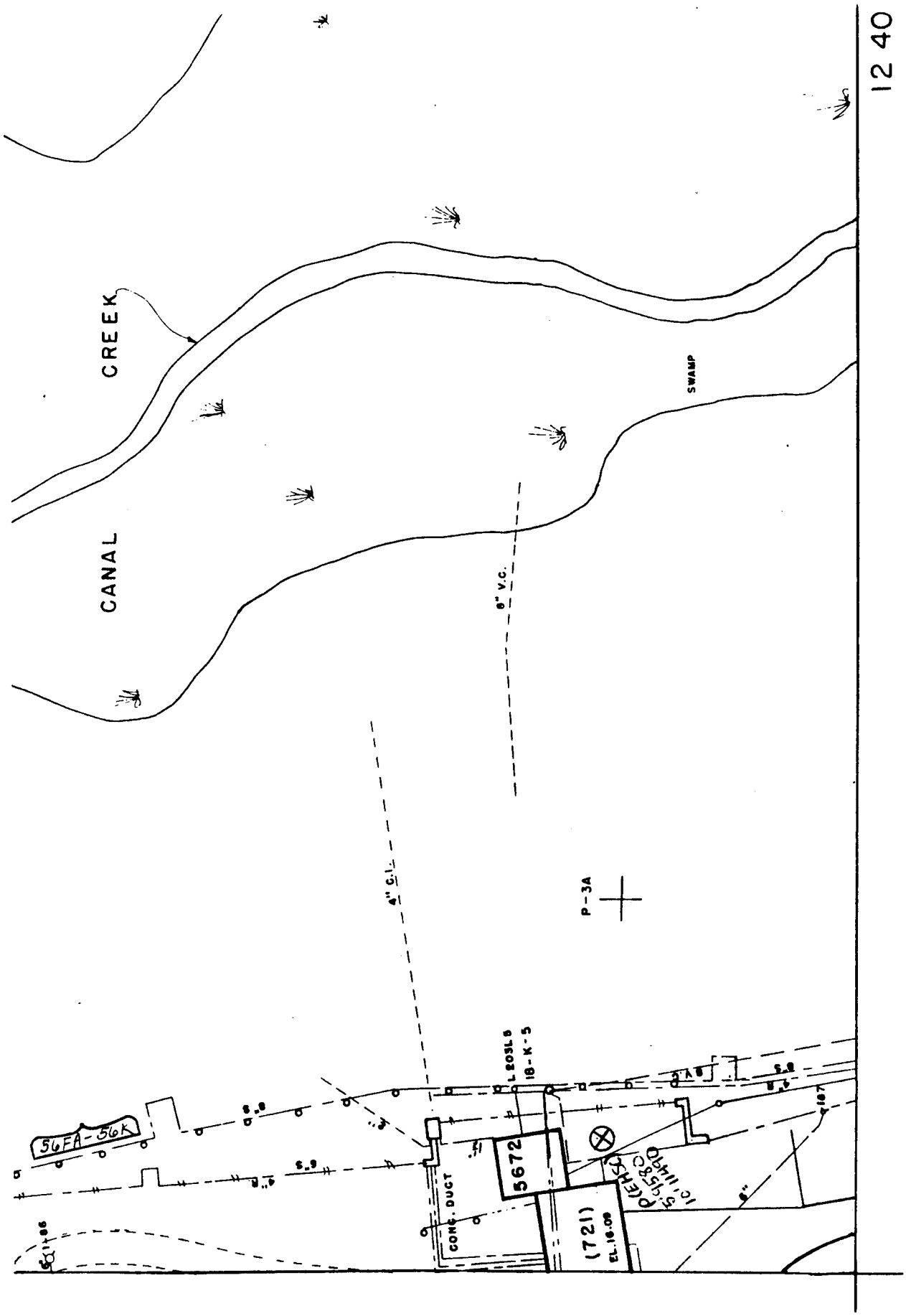
17L-1

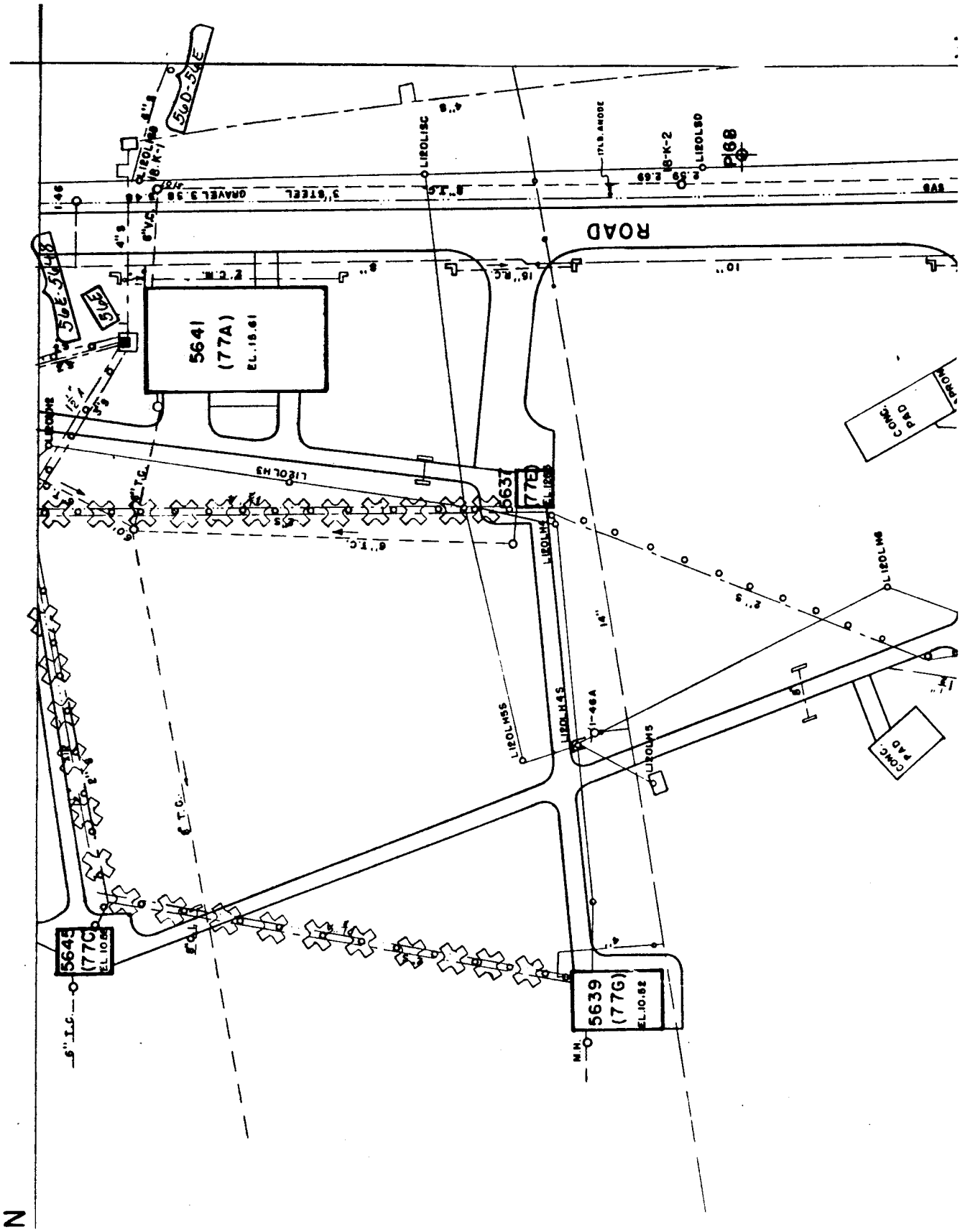

SIBERT
(96)
FL. EL. 2478
(97)
5707
FL. EL. 2185
ROAD
MAGNOLIA
BIT. CONC. OVER CONC.
15" RC
24" RC
13" RC
P21
P22
P23
P24
P25
P26
L40
L41
L42
L128RS1
1-9A
P1

17L-3

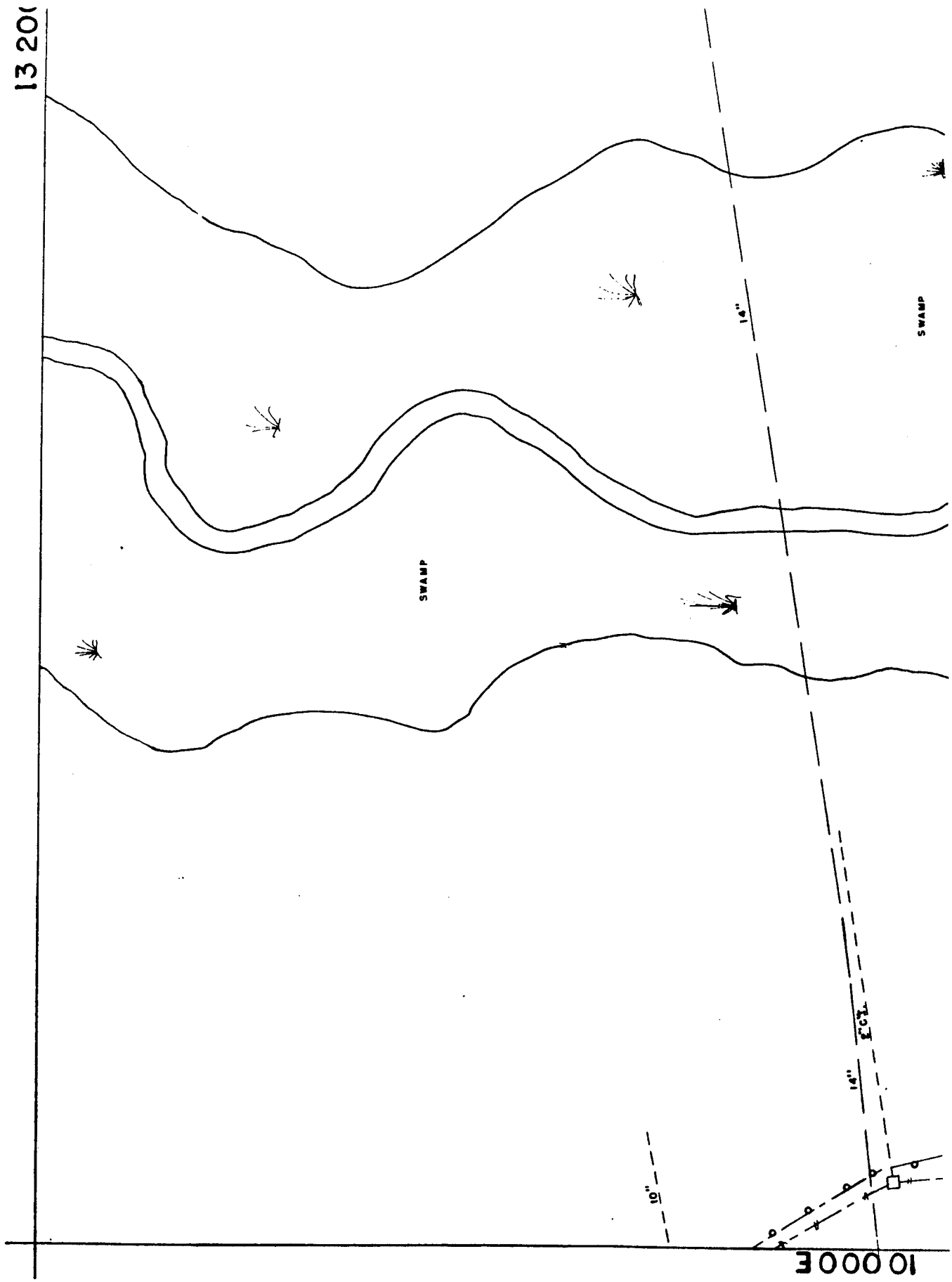

3 000 (
5 to A-3 to K
8"S
8"S
8"S
18" C.M.
24" CONC.
10"
U.G.
2" AIR
2" AIR
GRAVEL
TEL. CONDUIT
12" C.M.
L148BL4
24" CONC
170
P114
10"
6"
4"
6"
6"
10" V.C.
P115
8" V.C.
171
P116
U.G.
L100M
L99
NEW COND.
COND.
E5681
(193)
2A
2
1A
P1

18J-2

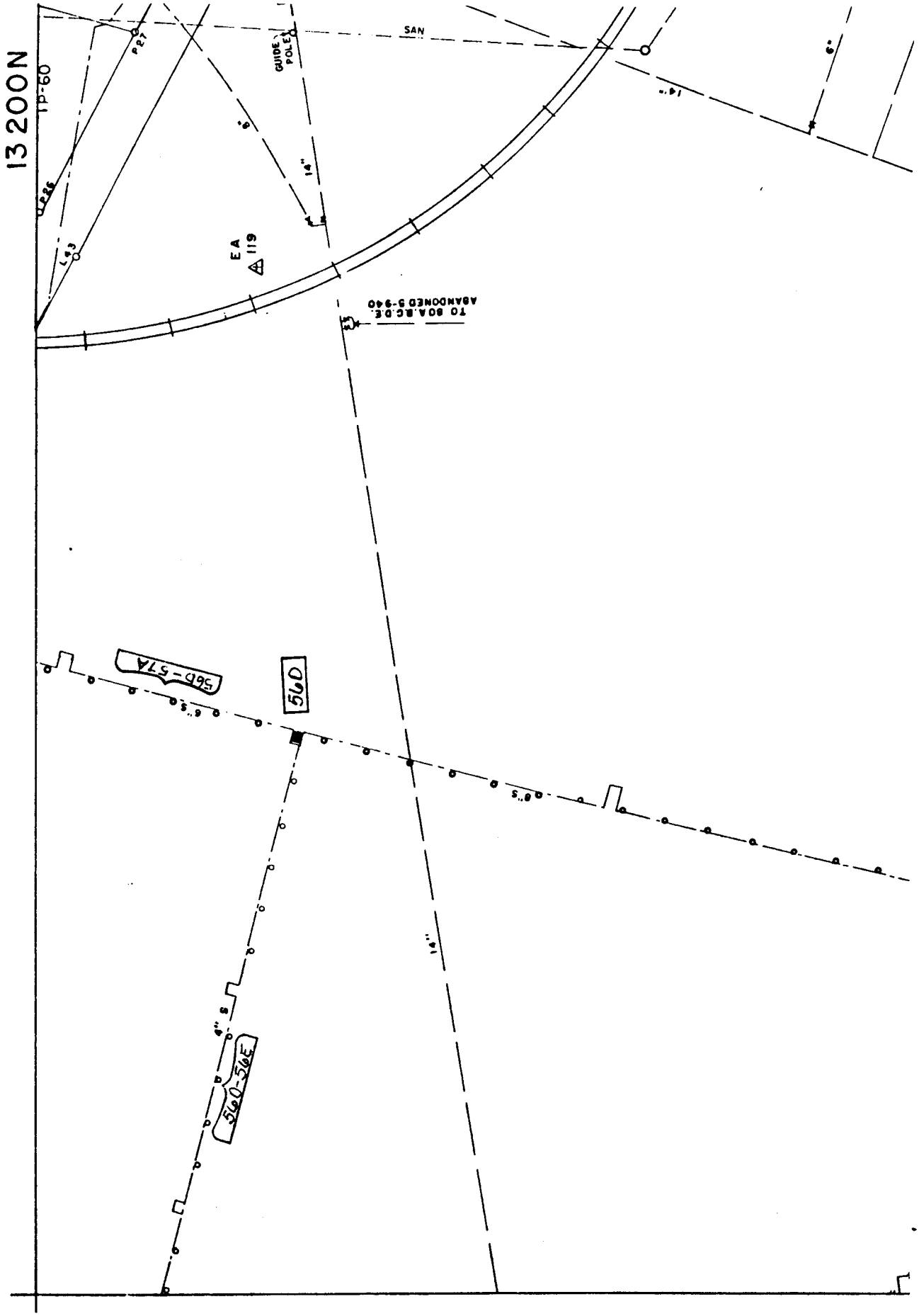

CANAL
CREEK
SWAMP
8" V.C.
4" C.I.
P-3A
56FA-56K
5672
(721)
EL. 18.00
CONC. DUCT
L. 8OSLB
18-K-5
12 40


N
ROAD
5641
(77A)
EL. 15.61
5637
(77E)
5645
(77C)
EL. 10.85
5639
(77G)
EL. 10.52
CONC. PAD
CONC. PAD
L120LH3
L120LH4
L120LH4S
L120LH5S
L120LH5
L120LH6
L120LS6
L120LS8
L120LS9
L120LS10
L120LS11
L120LS12
L120LS13
L120LS14
L120LS15
L120LS16
L120LS17
L120LS18
L120LS19
L120LS20
L120LS21
L120LS22
L120LS23
L120LS24
L120LS25
L120LS26
L120LS27
L120LS28
L120LS29
L120LS30
L120LS31
L120LS32
L120LS33
L120LS34
L120LS35
L120LS36
L120LS37
L120LS38
L120LS39
L120LS40
L120LS41
L120LS42
L120LS43
L120LS44
L120LS45
L120LS46
L120LS47
L120LS48
L120LS49
L120LS50
L120LS51
L120LS52
L120LS53
L120LS54
L120LS55
L120LS56
L120LS57
L120LS58
L120LS59
L120LS60
L120LS61
L120LS62
L120LS63
L120LS64
L120LS65
L120LS66
L120LS67
L120LS68
L120LS69
L120LS70
L120LS71
L120LS72
L120LS73
L120LS74
L120LS75
L120LS76
L120LS77
L120LS78
L120LS79
L120LS80
L120LS81
L120LS82
L120LS83
L120LS84
L120LS85
L120LS86
L120LS87
L120LS88
L120LS89
L120LS90
L120LS91
L120LS92
L120LS93
L120LS94
L120LS95
L120LS96
L120LS97
L120LS98
L120LS99
L120LS100
L120LS101
L120LS102
L120LS103
L120LS104
L120LS105
L120LS106
L120LS107
L120LS108
L120LS109
L120LS110
L120LS111
L120LS112
L120LS113
L120LS114
L120LS115
L120LS116
L120LS117
L120LS118
L120LS119
L120LS120
L120LS121
L120LS122
L120LS123
L120LS124
L120LS125
L120LS126
L120LS127
L120LS128
L120LS129
L120LS130
L120LS131
L120LS132
L120LS133
L120LS134
L120LS135
L120LS136
L120LS137
L120LS138
L120LS139
L120LS140
L120LS141
L120LS142
L120LS143
L120LS144
L120LS145
L120LS146
L120LS147
L120LS148
L120LS149
L120LS150
L120LS151
L120LS152
L120LS153
L120LS154
L120LS155
L120LS156
L120LS157
L120LS158
L120LS159
L120LS160
L120LS161
L120LS162
L120LS163
L120LS164
L120LS165
L120LS166
L120LS167
L120LS168
L120LS169
L120LS170
L120LS171
L120LS172
L120LS173
L120LS174
L120LS175
L120LS176
L120LS177
L120LS178
L120LS179
L120LS180
L120LS181
L120LS182
L120LS183
L120LS184
L120LS185
L120LS186
L120LS187
L120LS188
L120LS189
L120LS190
L120LS191
L120LS192
L120LS193
L120LS194
L120LS195
L120LS196
L120LS197
L120LS198
L120LS199
L120LS200
L120LS201
L120LS202
L120LS203
L120LS204
L120LS205
L120LS206
L120LS207
L120LS208
L120LS209
L120LS210
L120LS211
L120LS212
L120LS213
L120LS214
L120LS215
L120LS216
L120LS217
L120LS218
L120LS219
L120LS220
L120LS221
L120LS222
L120LS223
L120LS224
L120LS225
L120LS226
L120LS227
L120LS228
L120LS229
L120LS230
L120LS231
L120LS232
L120LS233
L120LS234
L120LS235
L120LS236
L120LS237
L120LS238
L120LS239
L120LS240
L120LS241
L120LS242
L120LS243
L120LS244
L120LS245
L120LS246
L120LS247
L120LS248
L120LS249
L120LS250
L120LS251
L120LS252
L120LS253
L120LS254
L120LS255
L120LS256
L120LS257
L120LS258
L120LS259
L120LS260
L120LS261
L120LS262
L120LS263
L120LS264
L120LS265
L120LS266
L120LS267
L120LS268
L120LS269
L120LS270
L120LS271
L120LS272
L120LS273
L120LS274
L120LS275
L120LS276
L120LS277
L120LS278
L120LS279
L120LS280
L120LS281
L120LS282
L120LS283
L120LS284
L120LS285
L120LS286
L120LS287
L120LS288
L120LS289
L120LS290
L120LS291
L120LS292
L120LS293
L120LS294
L120LS295
L120LS296
L120LS297
L120LS298
L120LS299
L120LS300
L120LS301
L120LS302
L120LS303
L120LS304
L120LS305
L120LS306
L120LS307
L120LS308
L120LS309
L120LS310
L120LS311
L120LS312
L120LS313
L120LS314
L120LS315
L120LS316
L120LS317
L120LS318
L120LS319
L120LS320
L120LS321
L120LS322
L120LS323
L120LS324
L120LS325
L120LS326
L120LS327
L120LS328
L120LS329
L120LS330
L120LS331
L120LS332
L120LS333
L120LS334
L120LS335
L120LS336
L120LS337
L120LS338
L120LS339
L120LS340
L120LS341
L120LS342
L120LS343
L120LS344
L120LS345
L120LS346
L120LS347
L120LS348
L120LS349
L120LS350
L120LS351
L120LS352
L120LS353
L120LS354
L120LS355
L120LS356
L120LS357
L120LS358
L120LS359
L120LS360
L120LS361
L120LS362
L120LS363
L120LS364
L120LS365
L120LS366
L120LS367
L120LS368
L120LS369
L120LS370
L120LS371
L120LS372
L120LS373
L120LS374
L120LS375
L120LS376
L120LS377
L120LS378
L120LS379
L120LS380
L120LS381
L120LS382
L120LS383
L120LS384
L120LS385
L120LS386
L120LS387
L120LS388
L120LS389
L120LS390
L120LS391
L120LS392
L120LS393
L120LS394
L120LS395
L120LS396
L120LS397
L120LS398
L120LS399
L120LS400
L120LS401
L120LS402
L120LS403
L120LS404
L120LS405
L120LS406
L120LS407
L120LS408
L120LS409
L120LS410
L120LS411
L120LS412
L120LS413
L120LS414
L120LS415
L120LS416
L120LS417
L120LS418
L120LS419
L120LS420
L120LS421
L120LS422
L120LS423
L120LS424
L120LS425
L120LS426
L120LS427
L120LS428
L120LS429
L120LS430
L120LS431
L120LS432
L120LS433
L120LS434
L120LS435
L120LS436
L120LS437
L120LS438
L120LS439
L120LS440
L120LS441
L120LS442
L120LS443
L120LS444
L120LS445
L120LS446
L120LS447
L120LS448
L120LS449
L120LS450
L120LS451
L120LS452
L120LS453
L120LS454
L120LS455
L120LS456
L120LS457
L120LS458
L120LS459
L120LS460
L120LS461
L120LS462
L120LS463
L120LS464
L120LS465
L120LS466
L120LS467
L120LS468
L120LS469
L120LS470
L120LS471
L120LS472
L120LS473
L120LS474
L120LS475
L120LS476
L120LS477
L120LS478
L120LS479
L120LS480
L120LS481
L120LS482
L120LS483
L120LS484
L120LS485
L120LS486
L120LS487
L120LS488
L120LS489
L120LS490
L120LS491
L120LS492
L120LS493
L120LS494
L120LS495
L120LS496
L120LS497
L120LS498
L120LS499
L120LS500
L120LS501
L120LS502
L120LS503
L120LS504
L120LS505
L120LS506
L120LS507
L120LS508
L120LS509
L120LS510
L120LS511
L120LS512
L120LS513
L120LS514
L120LS515
L120LS516
L120LS517
L120LS518
L120LS519
L120LS520
L120LS521
L120LS522
L120LS523
L120LS524
L120LS525
L120LS526
L120LS527
L120LS528
L120LS529
L120LS530
L120LS531
L120LS532
L120LS533
L120LS534
L120LS535
L120LS536
L120LS537
L120LS538
L120LS539
L120LS540
L120LS541
L120LS542
L120LS543
L120LS544
L120LS545
L120LS546
L120LS547
L120LS548
L120LS549
L120LS550
L120LS551
L120LS552
L120LS553
L120LS554
L120LS555
L120LS556
L120LS557
L120LS558
L120LS559
L120LS560
L120LS561
L120LS562
L120LS563
L120LS564
L120LS565
L120LS566
L120LS567
L120LS568
L120LS569
L120LS570
L120LS571
L120LS572
L120LS573
L120LS574
L120LS575
L120LS576
L120LS577
L120LS578
L120LS579
L120LS580
L120LS581
L120LS582
L120LS583
L120LS584
L120LS585
L120LS586
L120LS587
L120LS588
L120LS589
L120LS590
L120LS591
L120LS592
L120LS593
L120LS594
L120LS595
L120LS596
L120LS597
L120LS598
L120LS599
L120LS600
L120LS601
L120LS602
L120LS603
L120LS604
L120LS605
L120LS606
L120LS607
L120LS608
L120LS609
L120LS610
L120LS611
L120LS612
L120LS613
L120LS614
L120LS615
L120LS616
L120LS617
L120LS618
L120LS619
L120LS620
L120LS621
L120LS622
L120LS623
L120LS624
L120LS625
L120LS626
L120LS627
L120LS628
L120LS629
L120LS630
L120LS631
L120LS632
L120LS633
L120LS634
L120LS635
L120LS636
L120LS637
L120LS638
L120LS639
L120LS640
L120LS641
L120LS642
L120LS643
L120LS644
L120LS645
L120LS646
L120LS647
L120LS648
L120LS649
L120LS650
L120LS651
L120LS652
L120LS653
L120LS654
L120LS655
L120LS656
L120LS657
L120LS658
L120LS659
L120LS660
L120LS661
L120LS662
L120LS663
L120LS664
L120LS665
L120LS666
L120LS667
L120LS668
L120LS669
L120LS670
L120LS671
L120LS672
L120LS673
L120LS674
L120LS675
L120LS676
L120LS677
L120LS678
L120LS679
L120LS680
L120LS681
L120LS682
L120LS683
L120LS684
L120LS685
L120LS686
L120LS687
L120LS688
L120LS689
L120LS690
L120LS691
L120LS692
L120LS693
L120LS694
L120LS695
L120LS696
L120LS697
L120LS698
L120LS699
L120LS700
L120LS701
L120LS702
L120LS703
L120LS704
L120LS705
L120LS706
L120LS707
L120LS708
L120LS709
L120LS710
L120LS711
L120LS712
L120LS713
L120LS714
L120LS715
L120LS716
L120LS717
L120LS718
L120LS719
L120LS720
L120LS721
L120LS722
L120LS723
L120LS724
L120LS725
L120LS726
L120LS727
L120LS728
L120LS729
L120LS730
L120LS731
L120LS732
L120LS733
L120LS734
L120LS735
L120LS736
L120LS737
L120LS738
L120LS739
L120LS740
L120LS741
L120LS742
L120LS743
L120LS744
L120LS745
L120LS746
L120LS747
L120LS748
L120LS749
L120LS750
L120LS751
L120LS752
L120LS753
L120LS754
L120LS755
L120LS756
L120LS757
L120LS758
L120LS759
L120LS760
L120LS761
L120LS762
L120LS763
L120LS764
L120LS765
L120LS766
L120LS767
L120LS768
L120LS769
L120LS770
L120LS771
L120LS772
L120LS773
L120LS774
L120LS775
L120LS776
L120LS777
L120LS778
L120LS779
L120LS780
L120LS781
L120LS782
L120LS783
L120LS784
L120LS785
L120LS786
L120LS787
L120LS788
L120LS789
L120LS790
L120LS791
L120LS792
L120LS793
L120LS794
L120LS795
L120LS796
L120LS797
L120LS798
L120LS799
L120LS800
L120LS801
L120LS802
L120LS803
L120LS804
L120LS805
L120LS806
L120LS807
L120LS808
L120LS809
L120LS810
L120LS811
L120LS812
L120LS813
L120LS814
L120LS815
L120LS816
L120LS817
L120LS818
L120LS819
L120LS820
L120LS821
L120LS822
L120LS823
L120LS824
L120LS825
L120LS826
L120LS827
L120LS828
L120LS829
L120LS830
L120LS831
L120LS832
L120LS833
L120LS834
L120LS835
L120LS836
L120LS837
L120LS838
L120LS839
L120LS840
L120LS841
L120LS842
L120LS843
L120LS844
L120LS845
L120LS846
L120LS847
L120LS848
L120LS849
L120LS850
L120LS851
L120LS852
L120LS853
L120LS854
L120LS855
L120LS856
L120LS857
L120LS858
L120LS859
L120LS860
L120LS861
L120LS862
L120LS863
L120LS864
L120LS865
L120LS866
L120LS867
L120LS868
L120LS869
L120LS870
L120LS871
L120LS872
L120LS873
L120LS874
L120LS875
L120LS876
L120LS877
L120LS878
L120LS879
L120LS880
L120LS881
L120LS882
L120LS883
L120LS884
L120LS885
L120LS886
L120LS887
L120LS888
L120LS889
L120LS890
L120LS891
L120LS892
L120LS893
L120LS894
L120LS895
L120LS896
L120LS897
L120LS898
L120LS899
L120LS900
L120LS901
L120LS902
L120LS903
L120LS904
L120LS905
L120LS906
L120LS907
L120LS908
L120LS909
L120LS910
L120LS911
L120LS912
L120LS913
L120LS914
L120LS915
L120LS916
L120LS917
L120LS918
L120LS919
L120LS920
L120LS921
L120LS922
L120LS923
L120LS924
L120LS925
L120LS926
L120LS927
L120LS928
L120LS929
L120LS930
L120LS931
L120LS932
L120LS933
L120LS934
L120LS935
L120LS936
L120LS937
L120LS938
L120LS939
L120LS940
L120LS941
L120LS942
L120LS943
L120LS944
L120LS945
L120LS946
L120LS947
L120LS948
L120LS949
L120LS950
L120LS951
L120LS952
L120LS953
L120LS954
L120LS955
L120LS956
L120LS957
L120LS958
L120LS959
L120LS960
L120LS961
L120LS962
L120LS963
L120LS964
L120LS965
L120LS966
L120LS967
L120LS968
L120LS969
L120LS970
L120LS971
L120LS972
L120LS973
L120LS974
L120LS975
L120LS976
L120LS977
L120LS978
L120LS979
L120LS980
L120LS981
L120LS982
L120LS983
L120LS984
L120LS985
L120LS986
L120LS987
L120LS988
L120LS989
L120LS990
L120LS991
L120LS992
L120LS993
L120LS994
L120LS995
L120LS996
L120LS997
L120LS998
L120LS999
L120LS1000

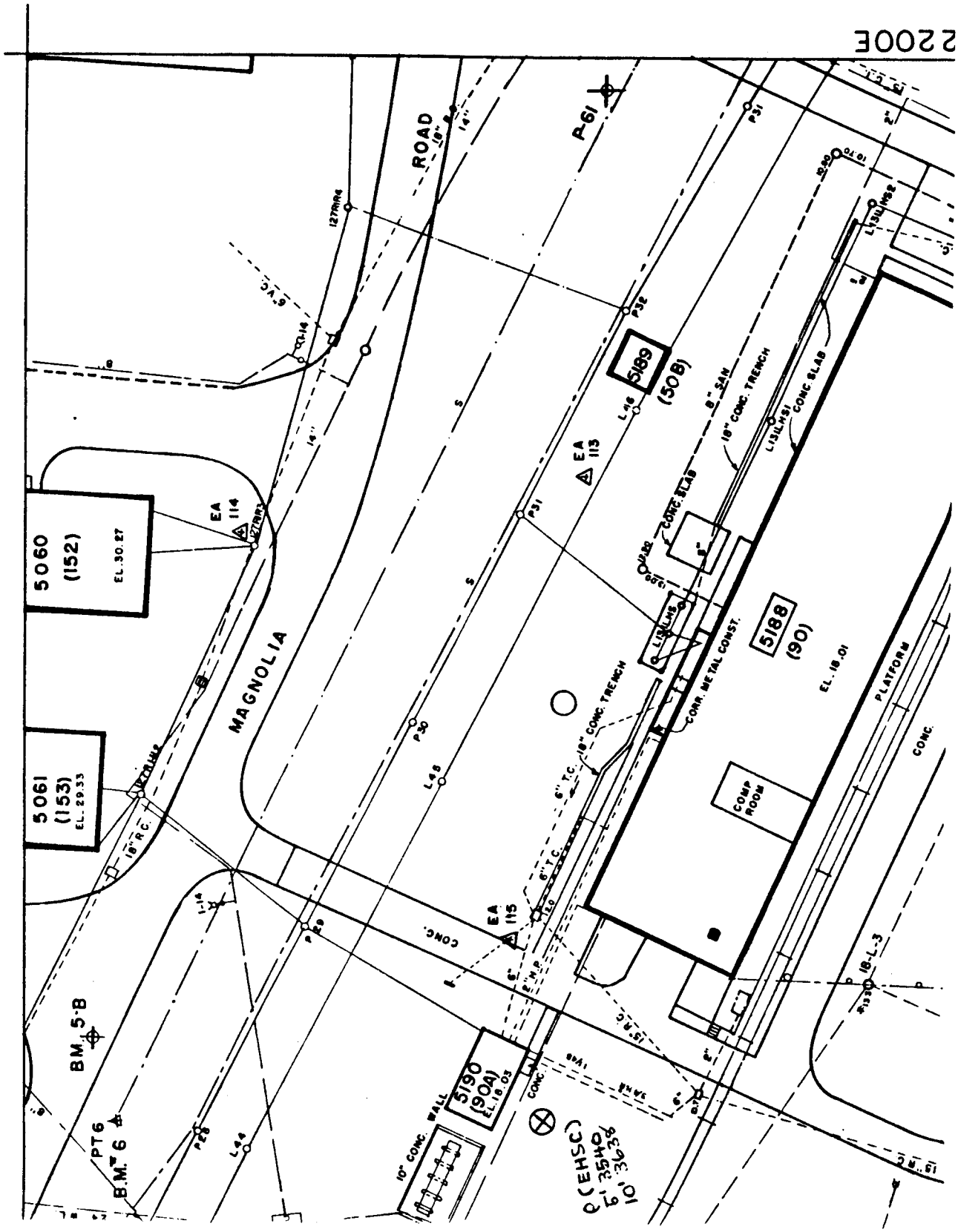
18K-2

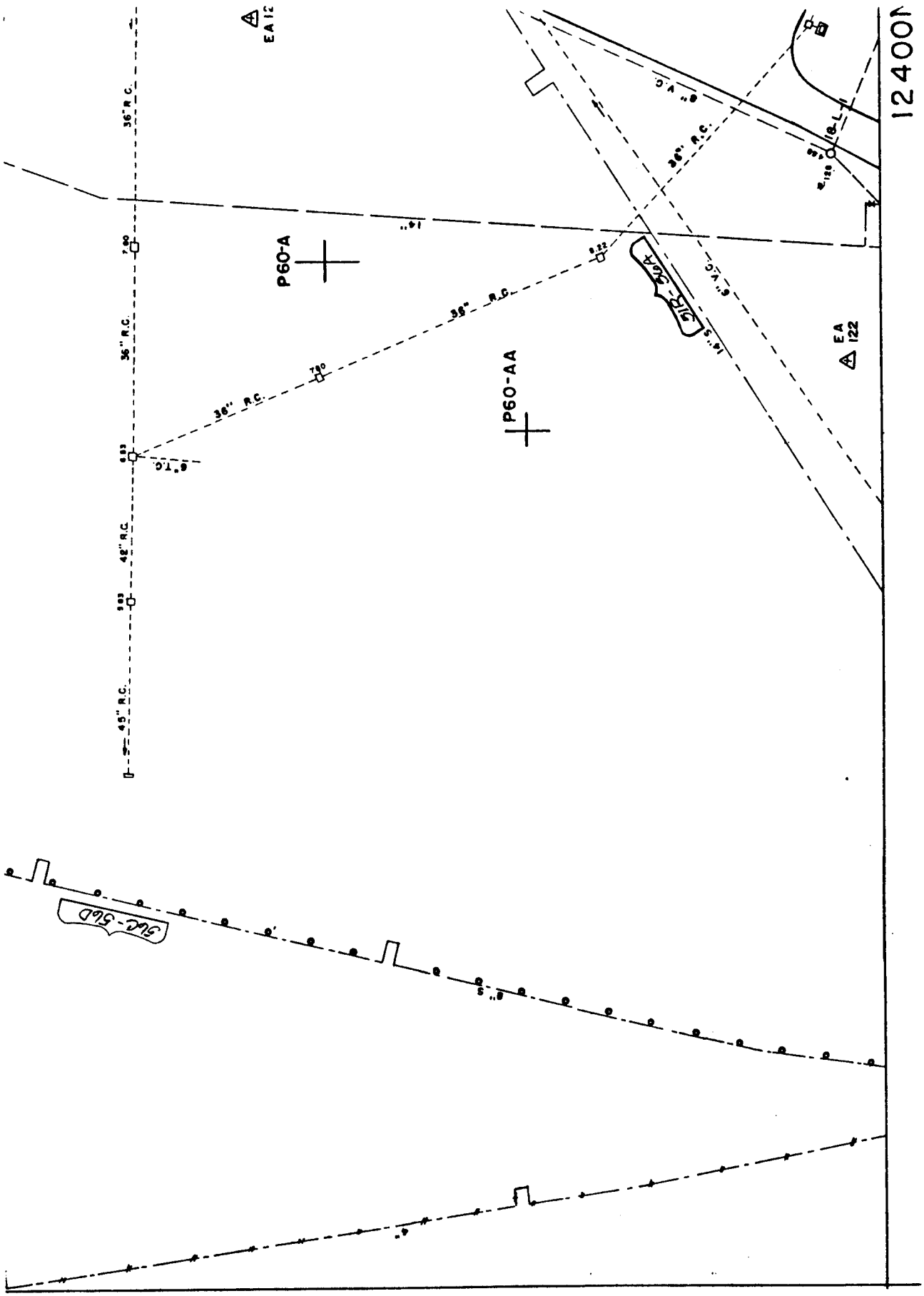


18K-3

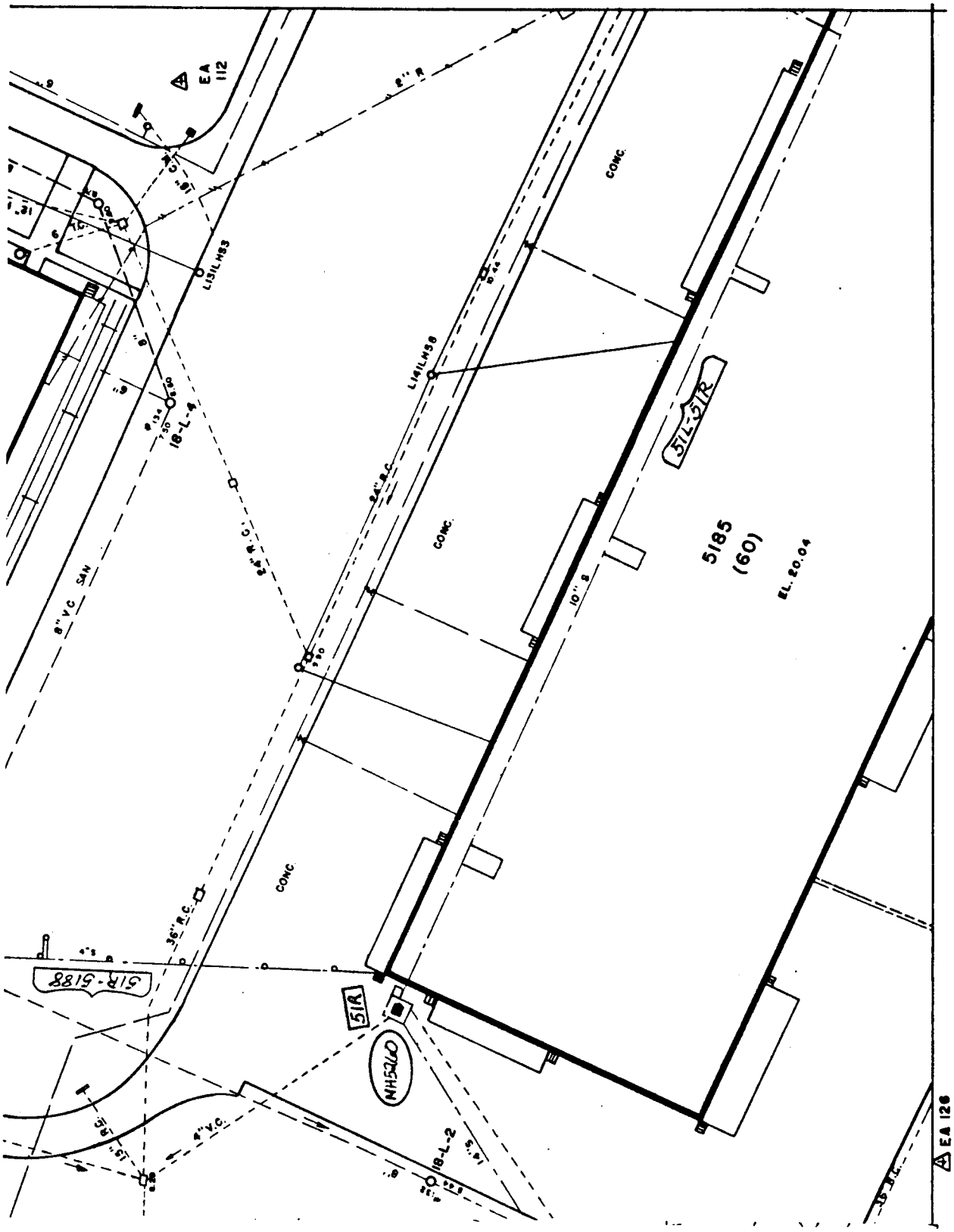

13 200N
TP-60
P27
P26
L43
GUIDE POLE
SAN
14"
8"
EA 119
TO 80A.B.C.D.E. ABANDONED 5-940
56b-57A
56D
6"S
8"S
14"
4" S
56D-56E
6"

18L-1

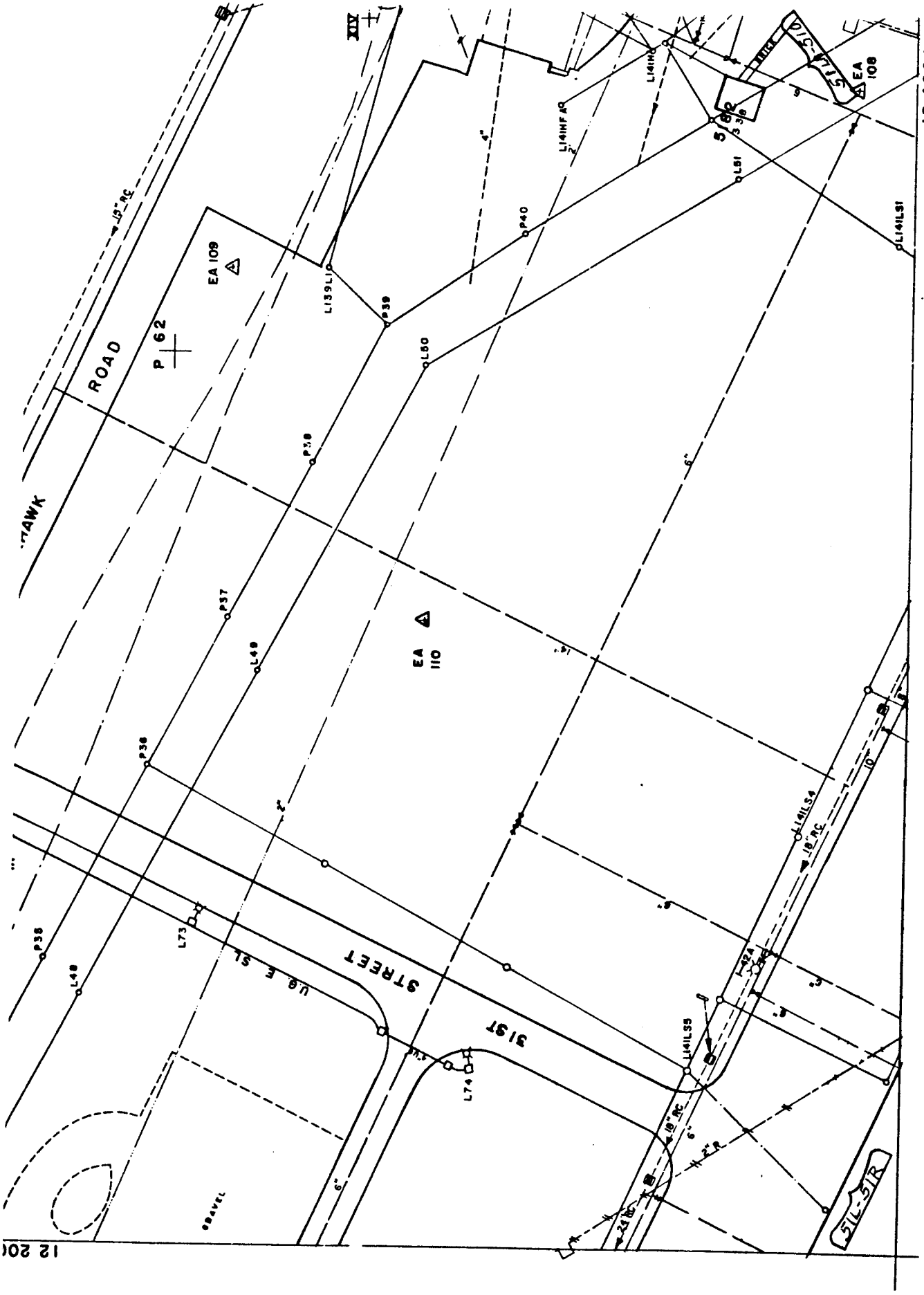

MAGNOLIA
ROAD
5060
(152)
EL. 30.27
5061
(153)
EL. 29.33
5189
(508)
5188
(90)
EL. 18.01
5190
(904)
EL. 18.03
COMP ROOM
PLATFORM
CONC.
CONC. SLAB
CORR. METAL CONST.
8" SAN
18" CONC. TRENCH
CONC. WALL
BM 5-B
BM 6
PT 6
EA 113
EA 114
EA 115
P-61
18L-2

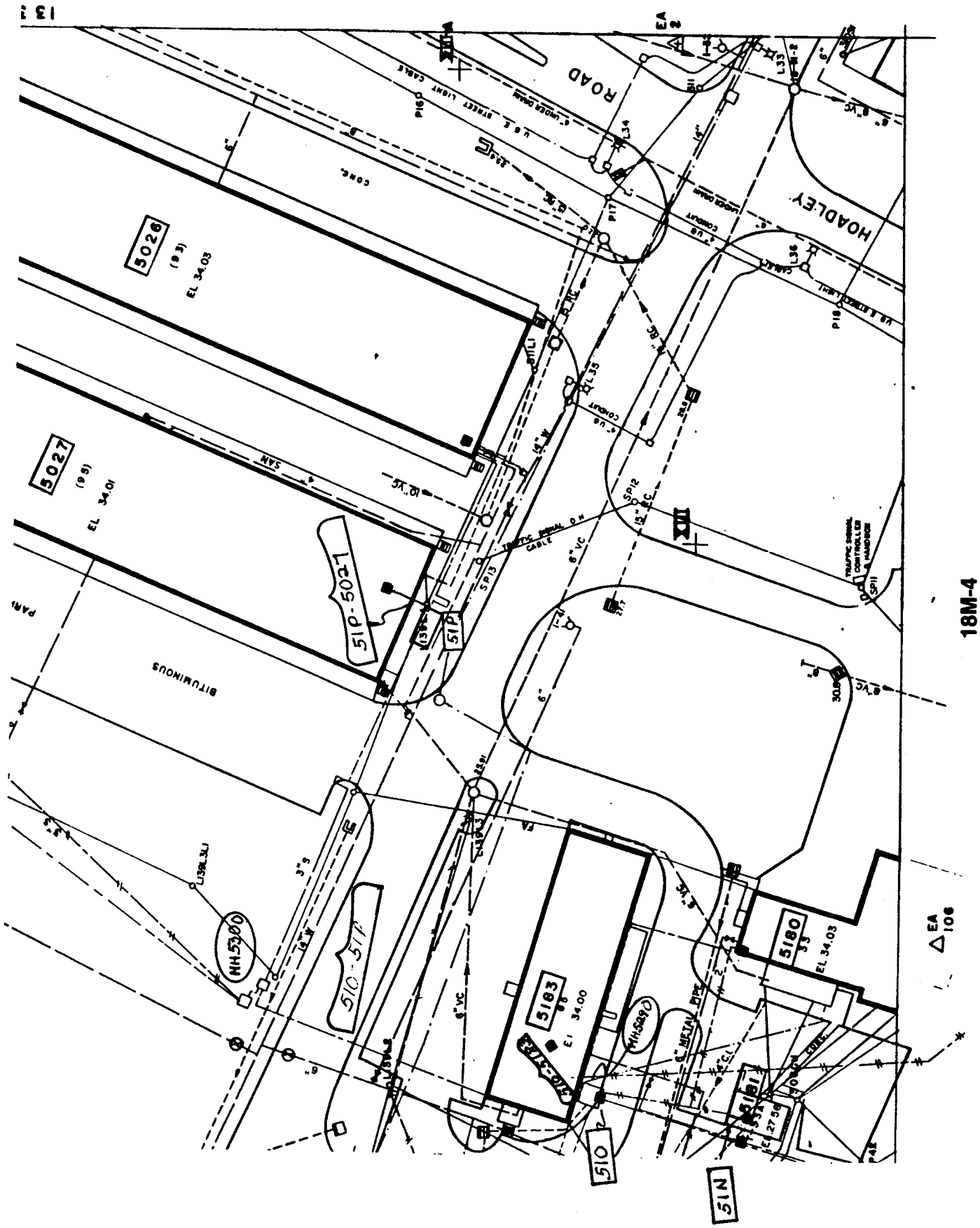

124001
EA 122
P60-A
P60-AA
36" R.C.
48" R.C.
45" R.C.
14"
18"
6" V.C.
6" T.C.
18-L
SLC-5bA
SLC-5bB

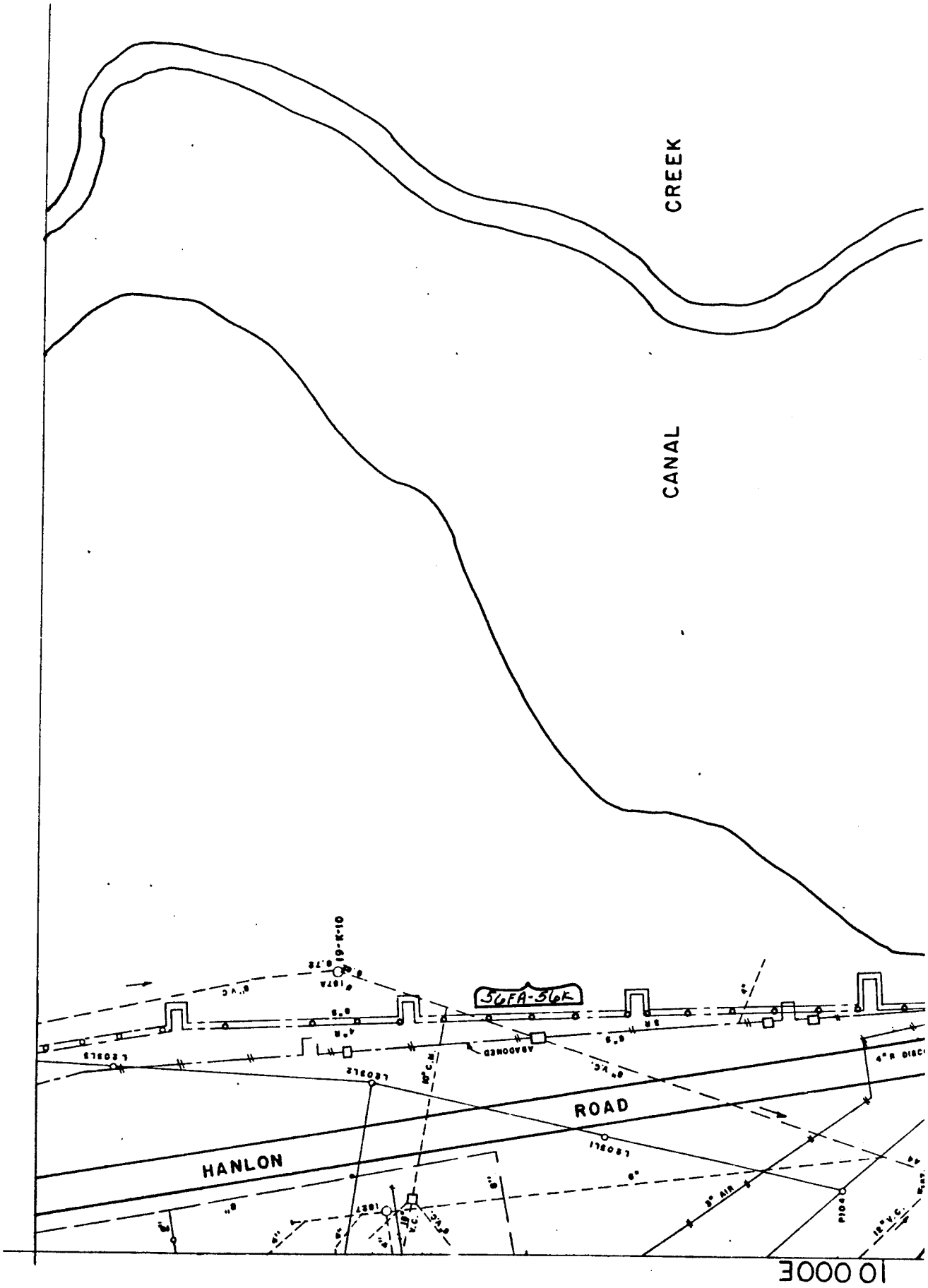
18L-3


EA 112
CONC.
CONC.
CONC.
5185
(60)
EL. 20.04
51L-51R
L141L438
L131L433
18-L-4
8" V.C. SAN
51R
NH5240
18-L-2
51R-5188
EA 126

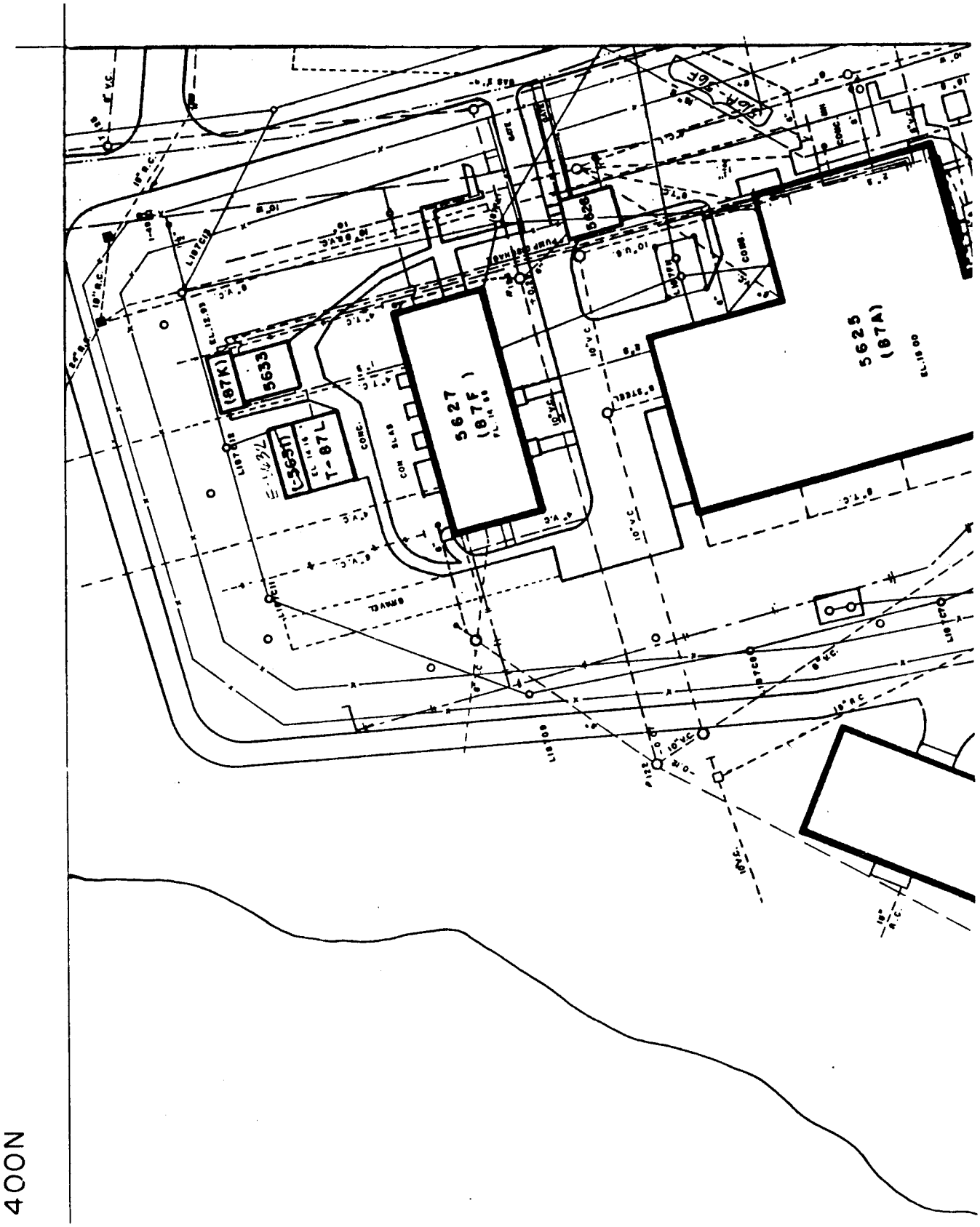
18L-4

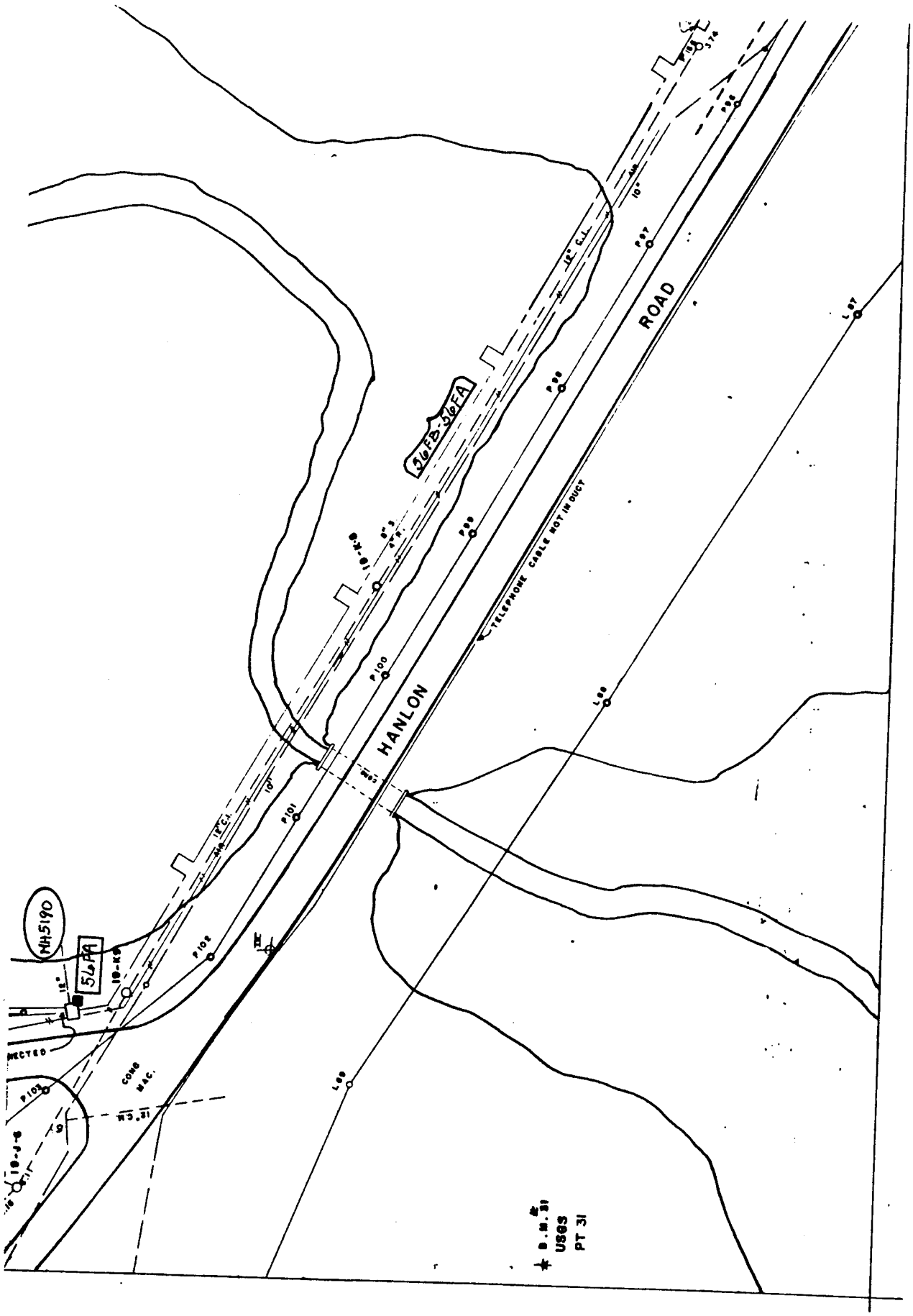

12 400 N
12 200
EA 108
EA 109
EA 110
P 62
ROAD
31ST
STREET
GRAVEL
5TL-5TR
18M-3

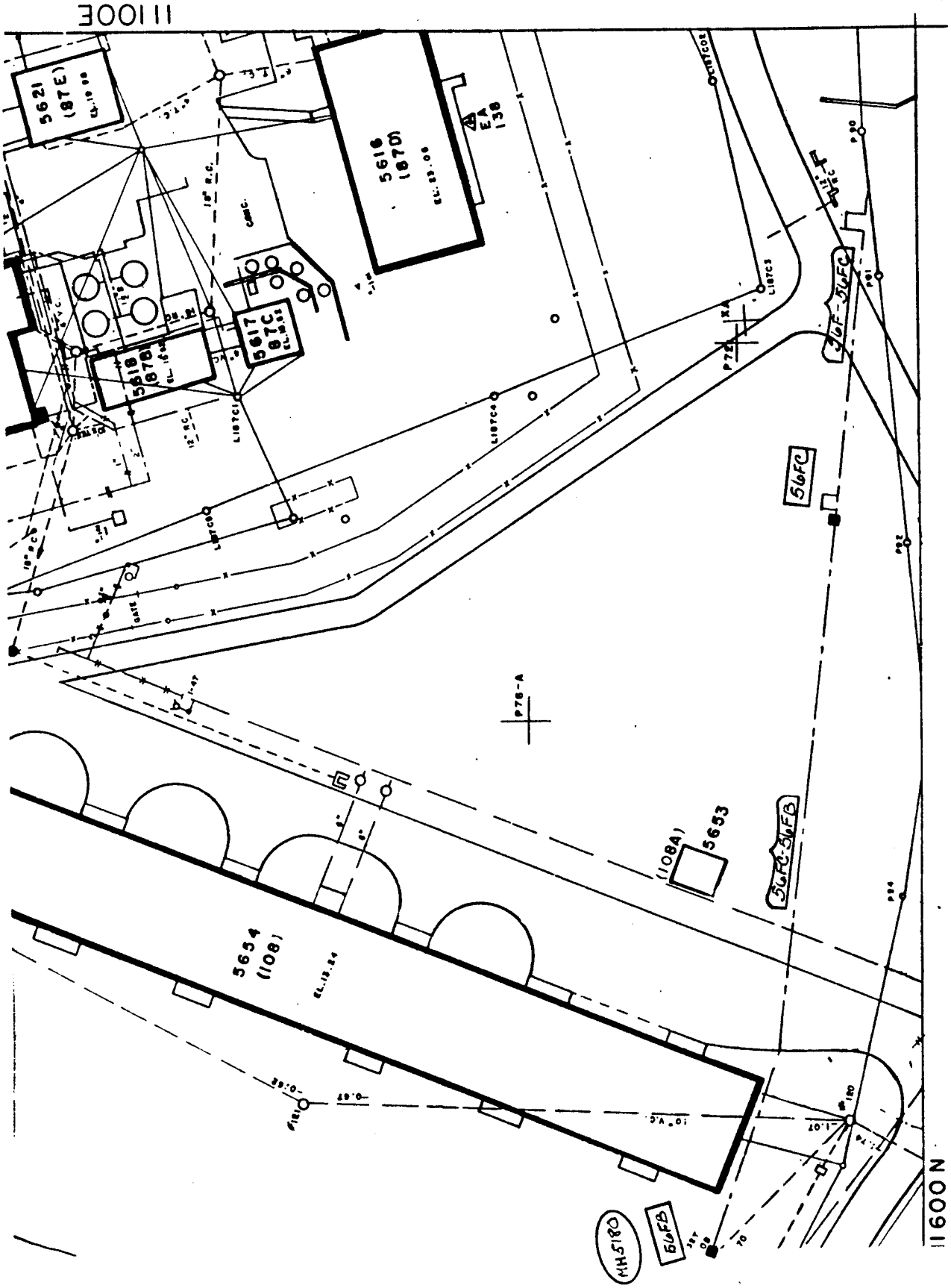

ROAD
HOADLEY
5026
EL 34.03
5027
EL 34.01
BITUMINOUS
510-510P
510P-502L
5183
EL 34.00
5180
EL 34.03
510
51N
EA 106
18M-4


CREEK
CANAL
HANLON
ROAD
36FA-36K
ABANDONED
LEOSELL
LEOSELS
19K-61
1087A
1087
P104
10 000E

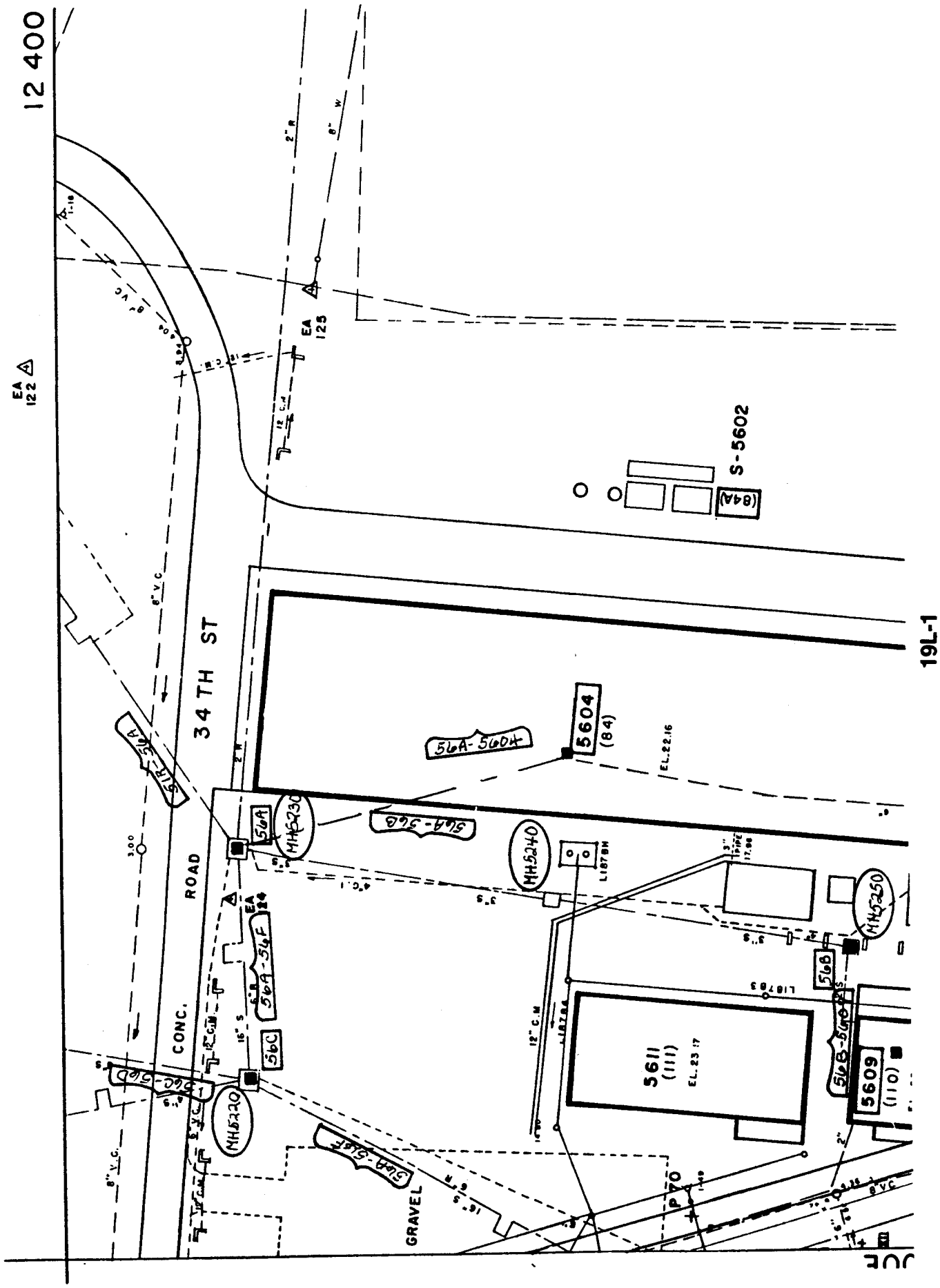
19K-1

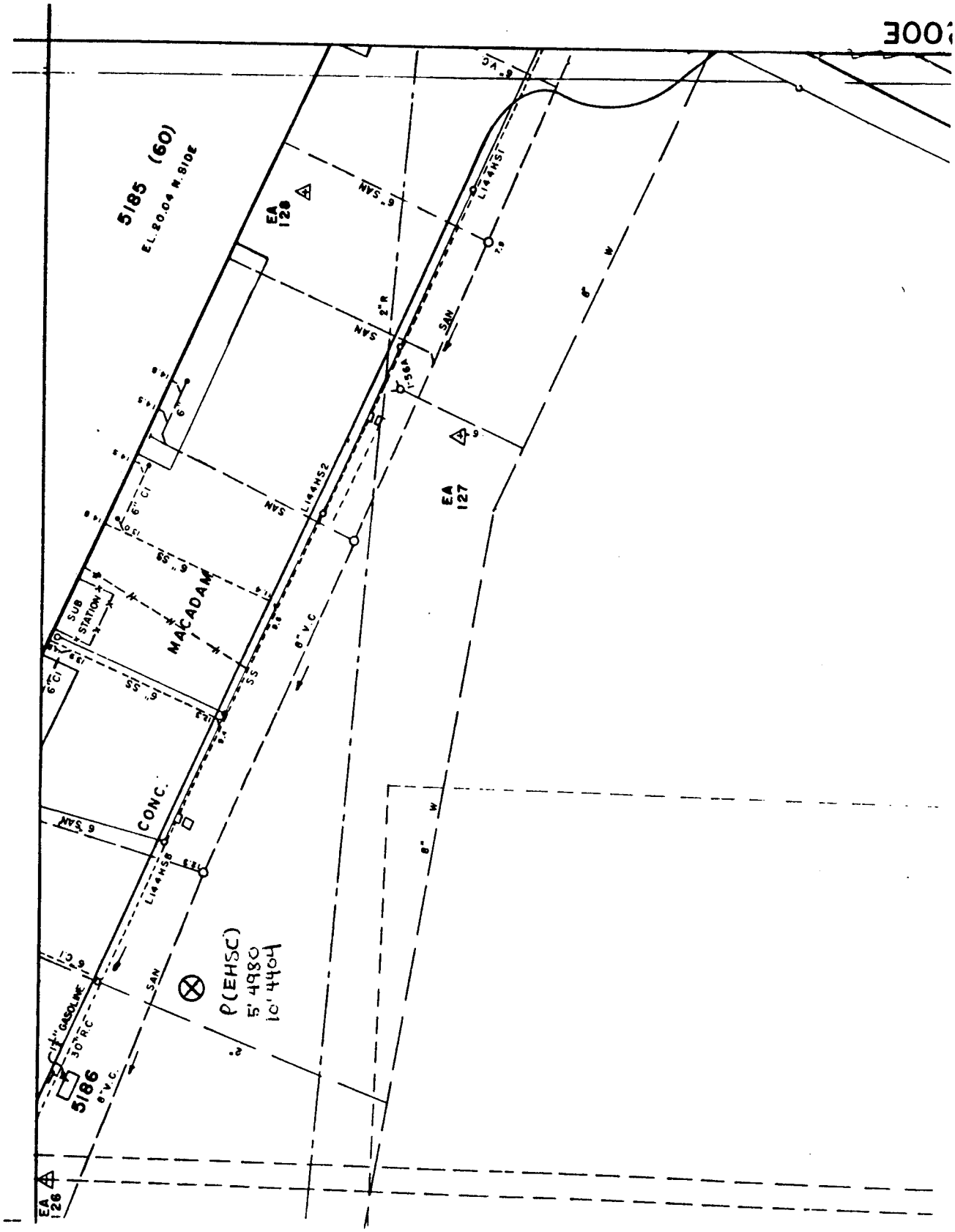

400N
19K-2
5627
(87F)
5625
(87A)
5633
(87K)
T-87L
5628


HANLON
ROAD
TELEPHONE CABLE NOT IN DUCT
36FB-36FA
NH5190
51-PA
CONC MAC.
B.M. 31
USGS
PT 31

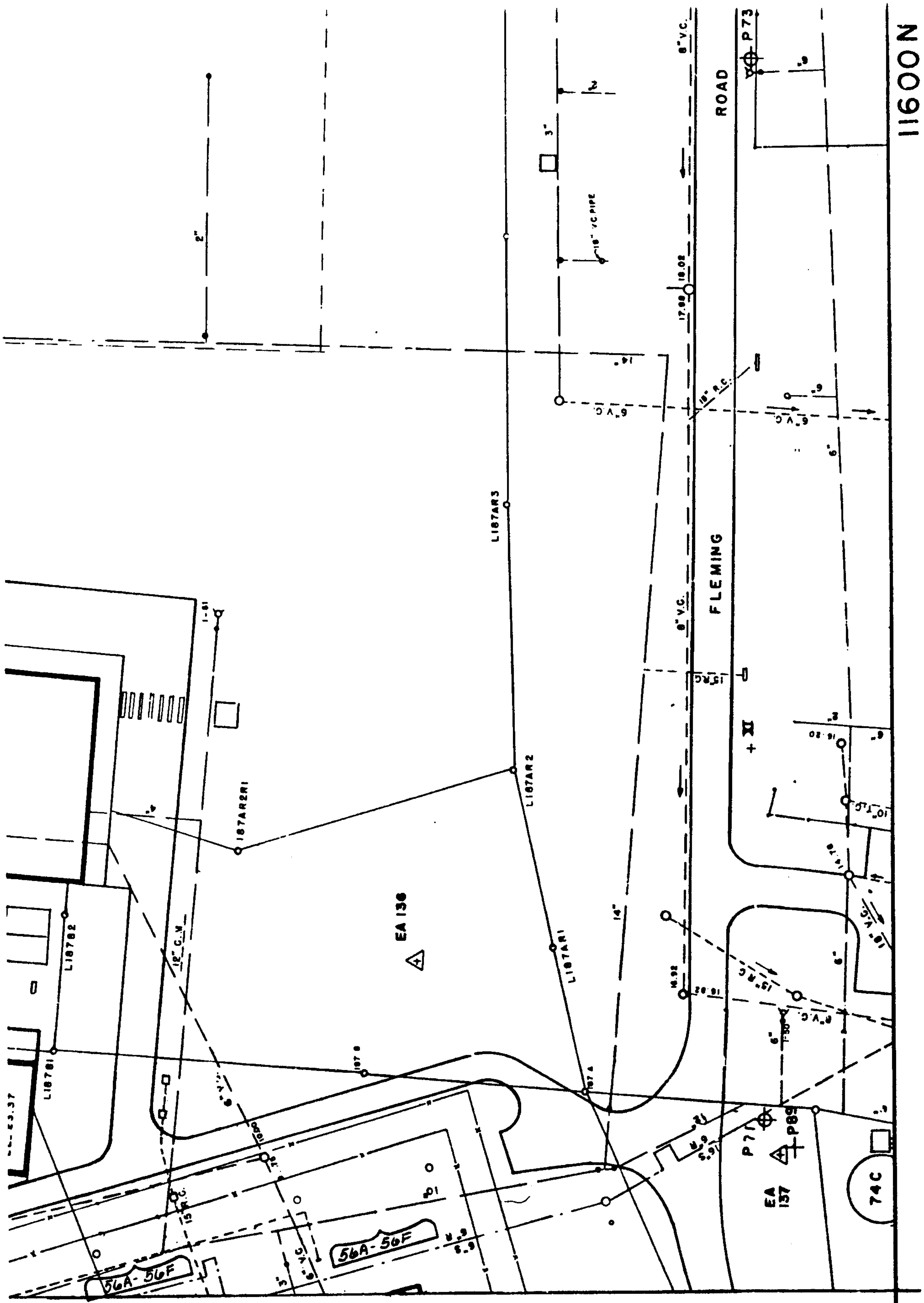

11100E
5621
(87E)
5616
(87D)
EA
138
5618
(87B)
5617
87C
5634
(108)
(108A)
5633
56FC
56FB
56F-56FC
56FD-56FB
MH5180
11600N

19K-4

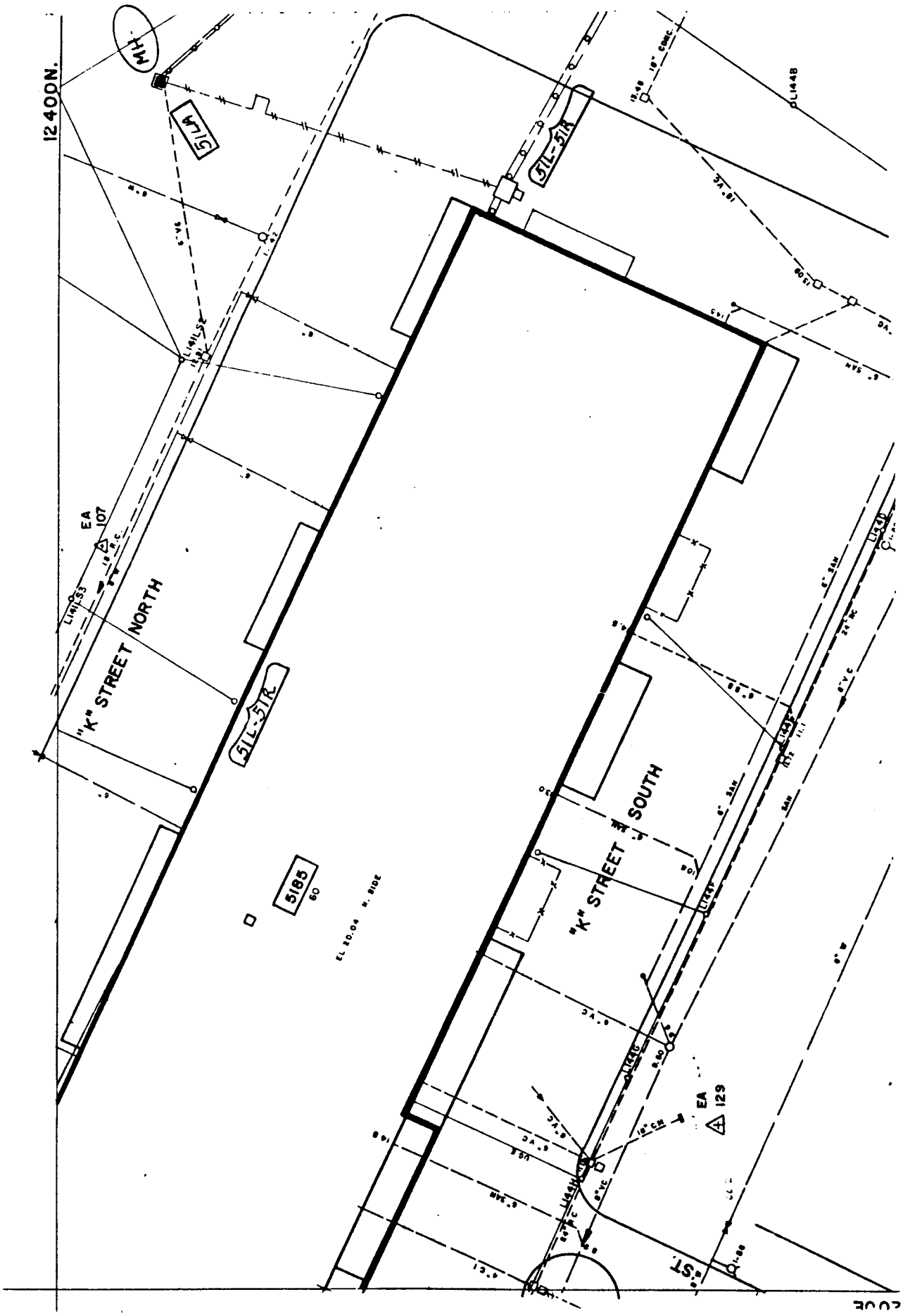

12 400
EA 122
EA 125
S-5602
(84A)
34TH ST
ROAD
CONC.
GRAVEL
5604
(84)
56A-5604
MH5230
56A-56B
MH5240
MH5250
56A
56B
56B-5609
5611
(111)
5609
(110)
56A-56F
56C
56C-56D
MH5220
56A-56E
EA 24
19L-1


5185 (60)
EL. 20.04 N. SIDE
EA 128
EA 127
EA 126
MACADAM
CONC.
SUB STATION
SAN
L14HS1
L14HS2
L14HS8
P(EHSC)
5' 4980
10' 4404
5186
GASOLINE
30" R.C.
8" V.C.
6" CI
6" SS
6" W

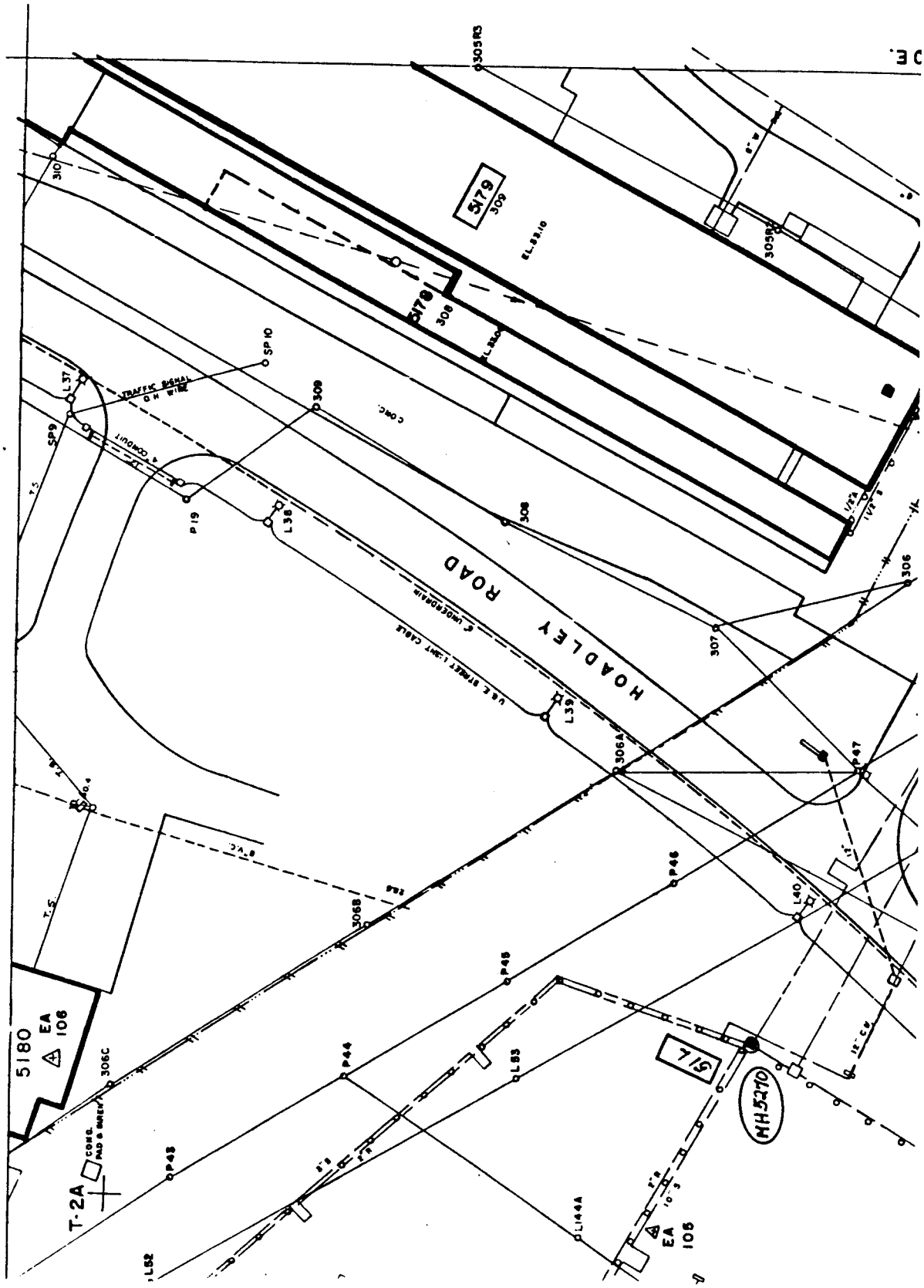
19L-2


FLEMING
ROAD
11600N
EA 136
EA 137
74C
P73
P89
P71
L187AR3
L187AR2
L187AR1
187AR2R1
L187B2
L187B1
187 A
187 B
56A-56F
56A-56F
8" V.C.
6" V.C.
18" V.C. PIPE
18" R.C.
15" R.C.
12" C.V.
10" T.C.
14"
6"
3"
2"
18.02
17.98
16.92
16.20

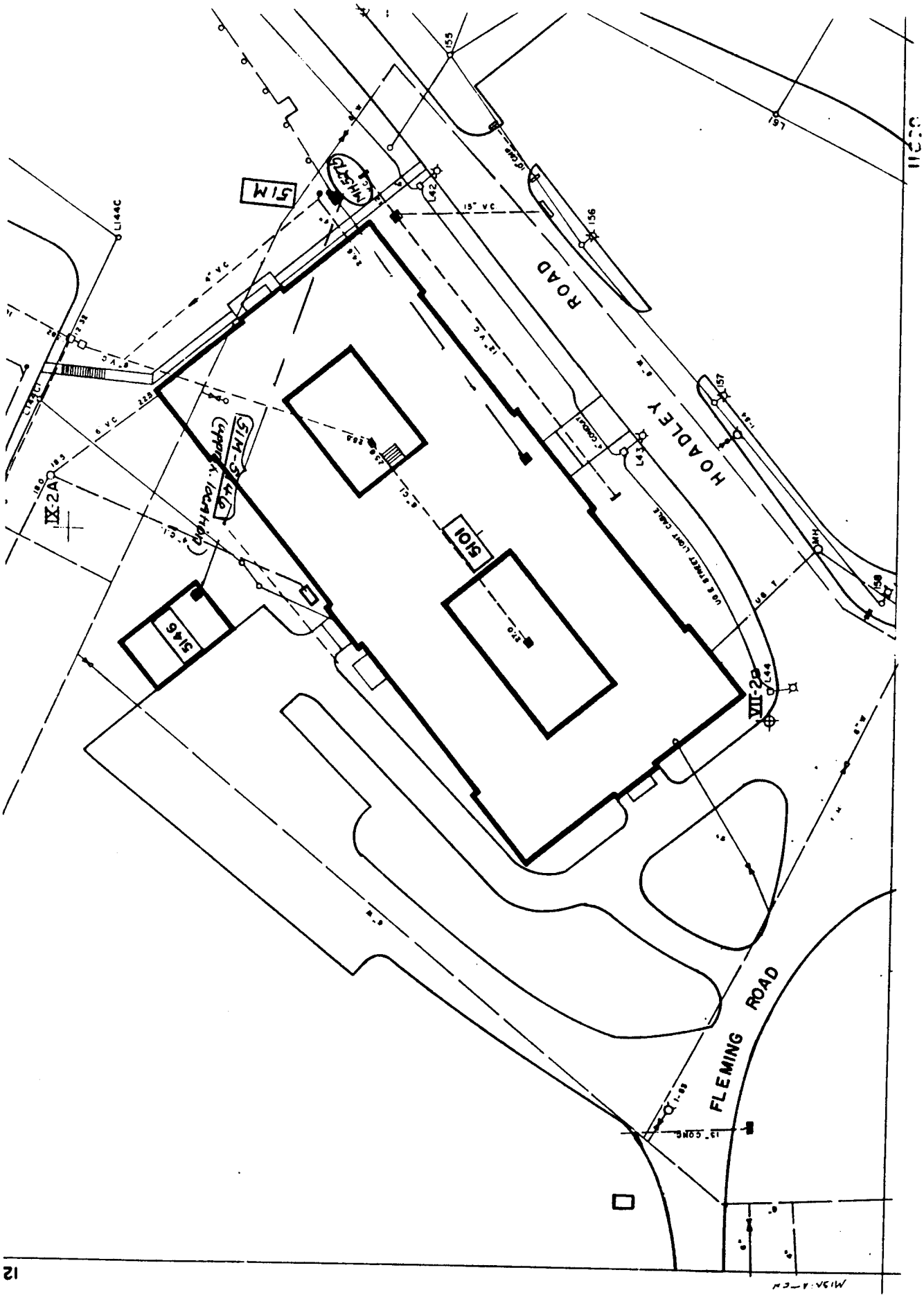
19L-3


12400N.
"K" STREET NORTH
"K" STREET SOUTH
EA 107
EA 129
5185
60
5IL-5IR
5ILA
MH
L1448
ST.

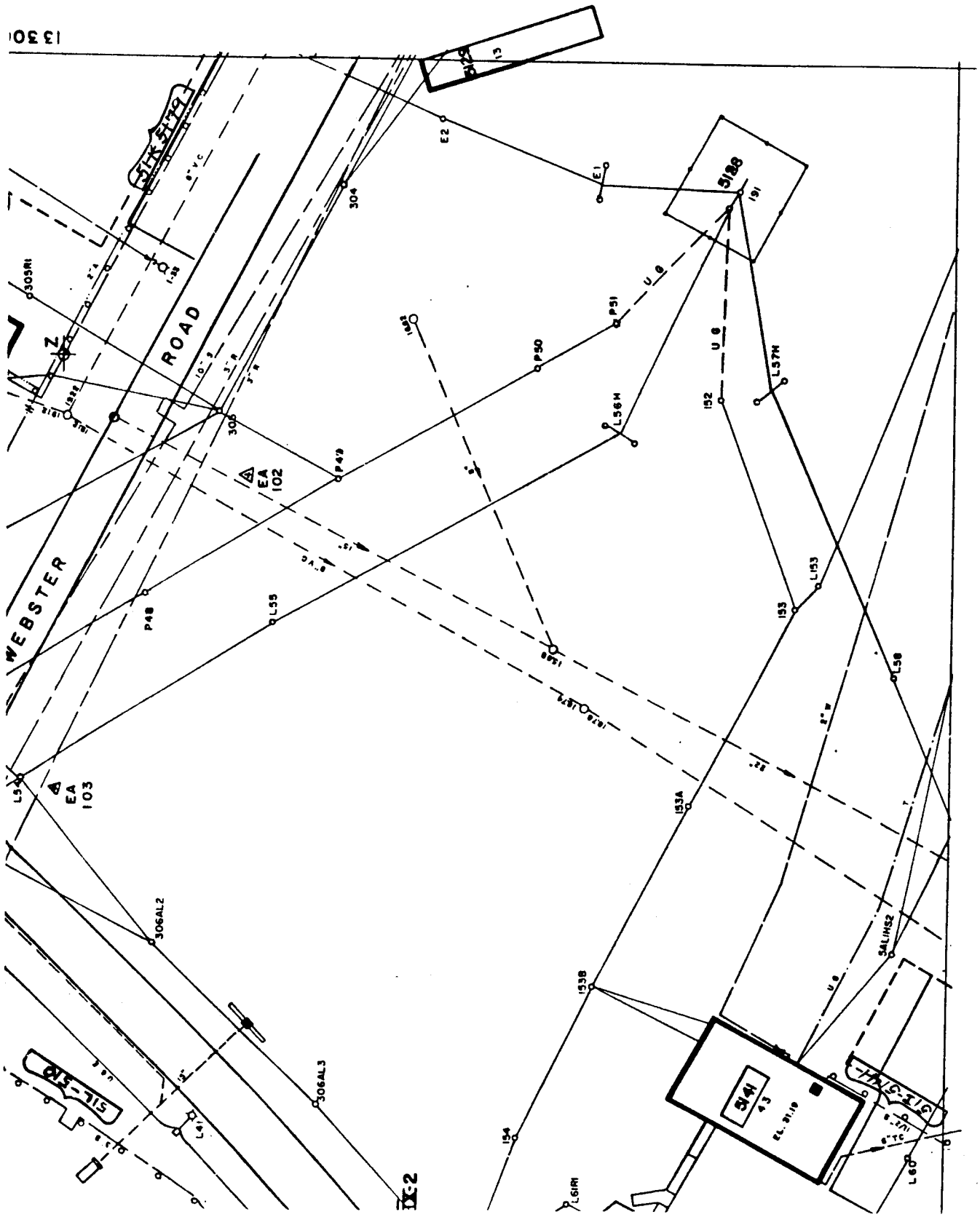
19M-1


HOADLEY ROAD
5179
309
5178
308
TRAFFIC SIGNAL
O.H. WIRE
SP10
SP9
L37
P19
L38
L39
306A
306B
306C
307
306
P47
P46
P45
P44
L40
L83
L144A
L52
P43
T-2A
5180
EA
106
EA
105
MH5210
305R5
305B
310

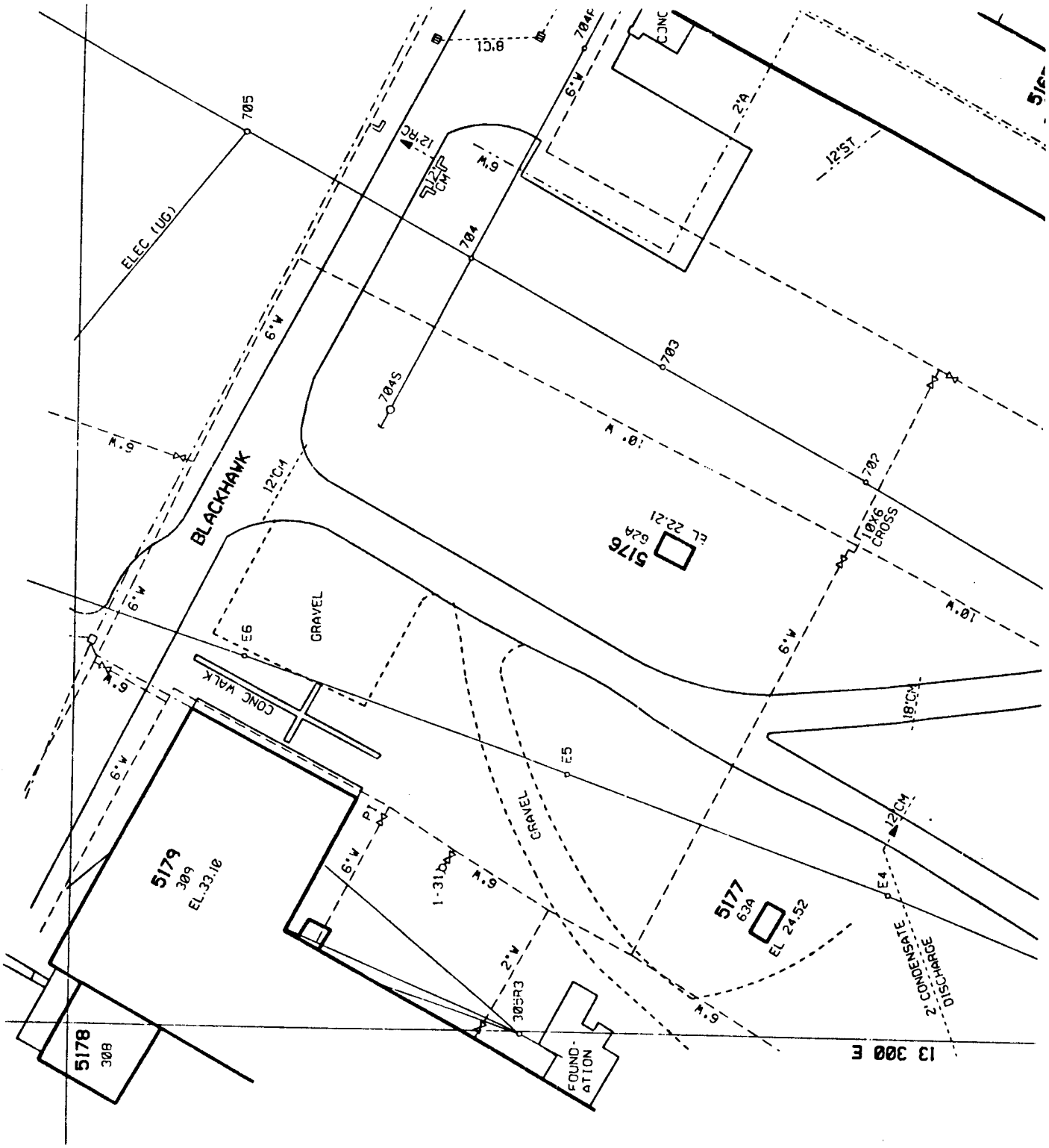
19M-2


HOADLEY ROAD
FLEMING ROAD
5101
5146
5IM
5IM-5IH
VII-2B
IX-2A
L44C
L42
L44
L47
L57
L56
L55
L58
L97
15" VC
12" VC
6" VC
15" CONC
12" CONC
UG 6 STREET LIGHT CABLE
MH
MH5IM

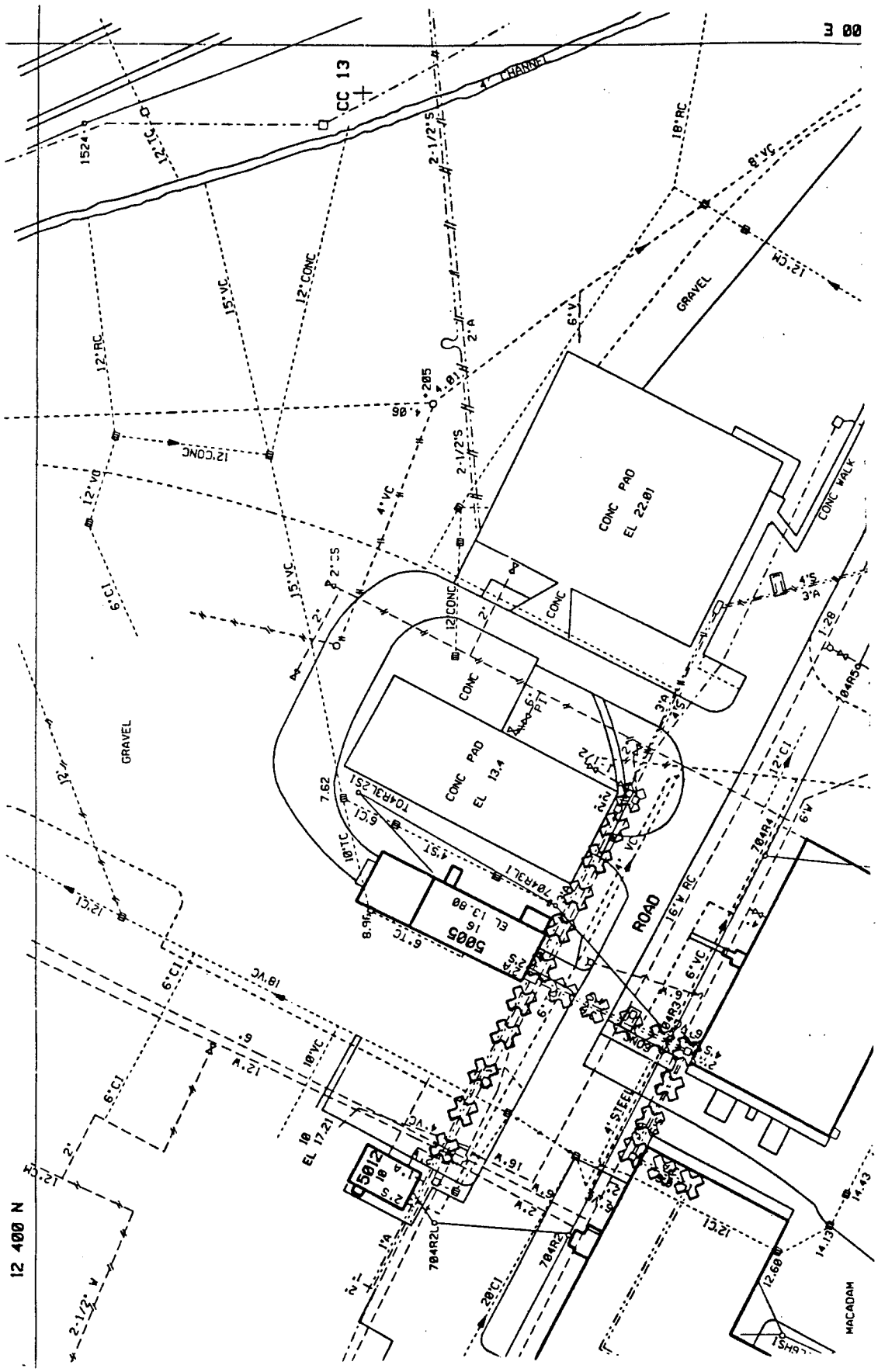
19M-3


WEBSTER
ROAD
EA 102
EA 103
5141
5188
SITE 5172
SITE 5170
SITE 5171
13 30

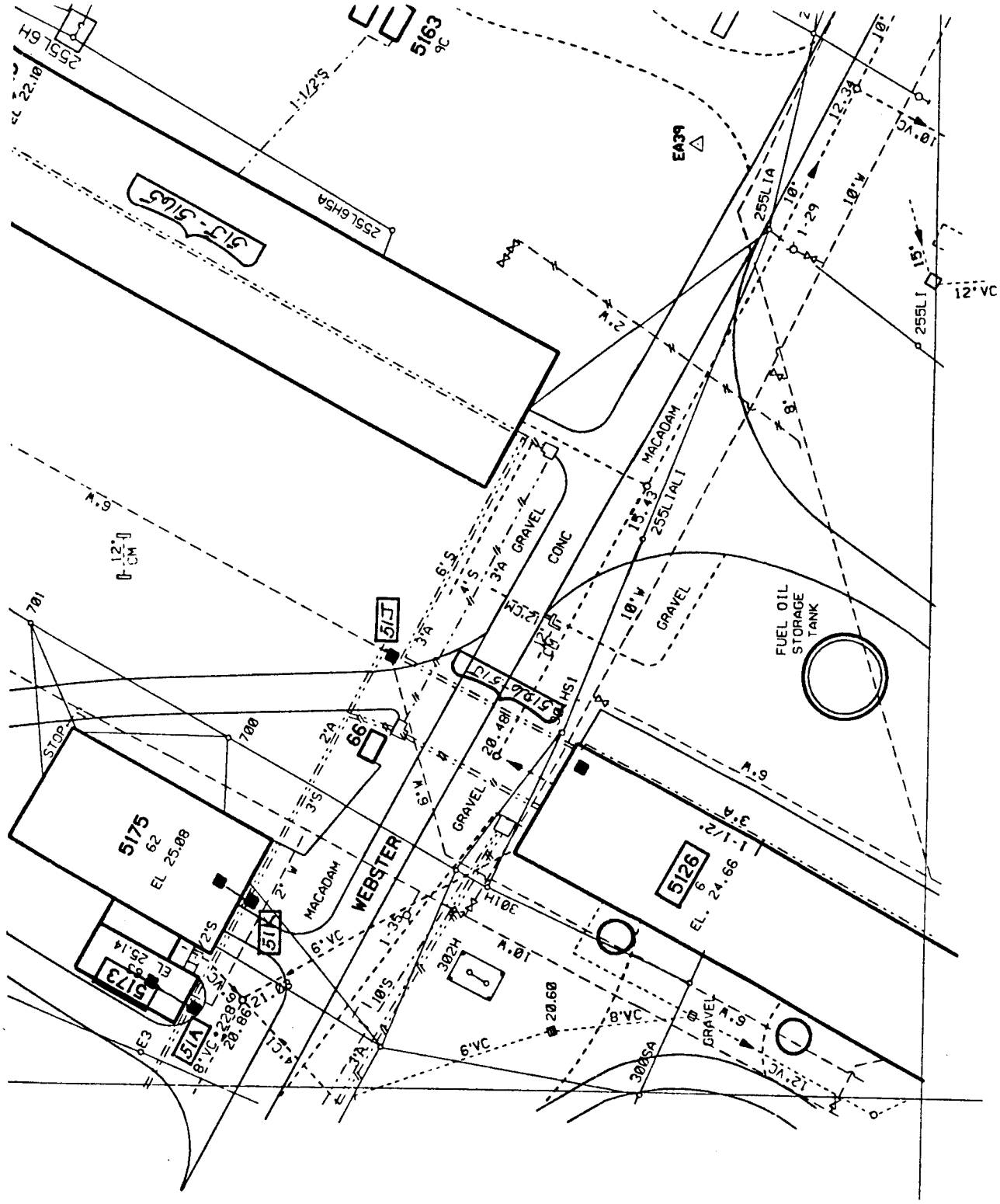
19M-4


5176
63A
EL 22.21
5177
63A
EL 24.52
5179
309
EL.33.18
5178
308
BLACKHAWK
GRAVEL
CONC WALK
ELEC (UG)
FOUND-ATION
2' CONDENSATE DISCHARGE
10X6 CROSS
13 300 E

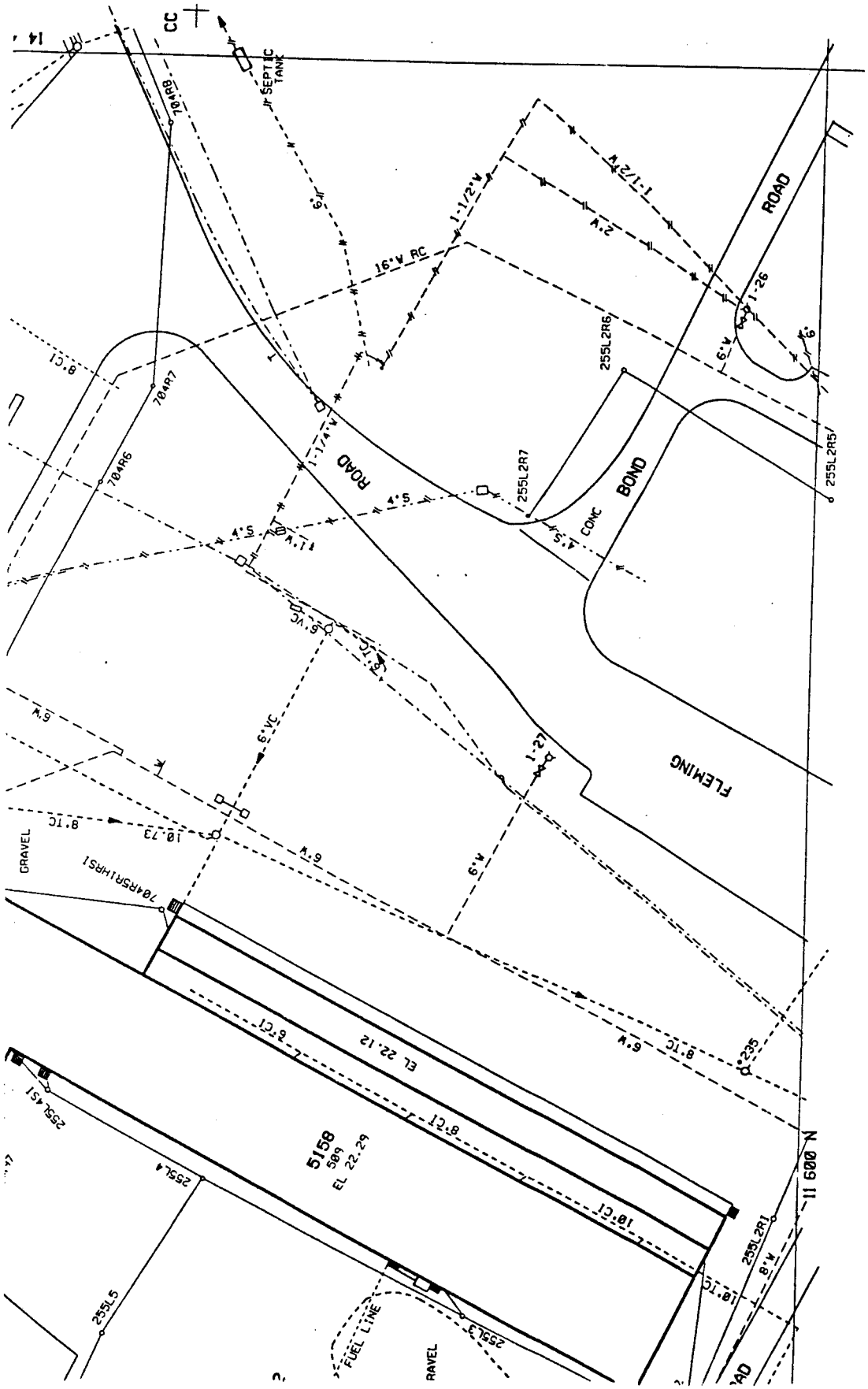
19N-1


3 00
CC 13
CHANNEL
GRAVEL
CONC PAD
EL 22.01
CONC WALK
CONC PAD
EL 13.4
CONC
5005
EL 13.80
ROAD
5012
EL 17.21
MACADAM
12 400 N

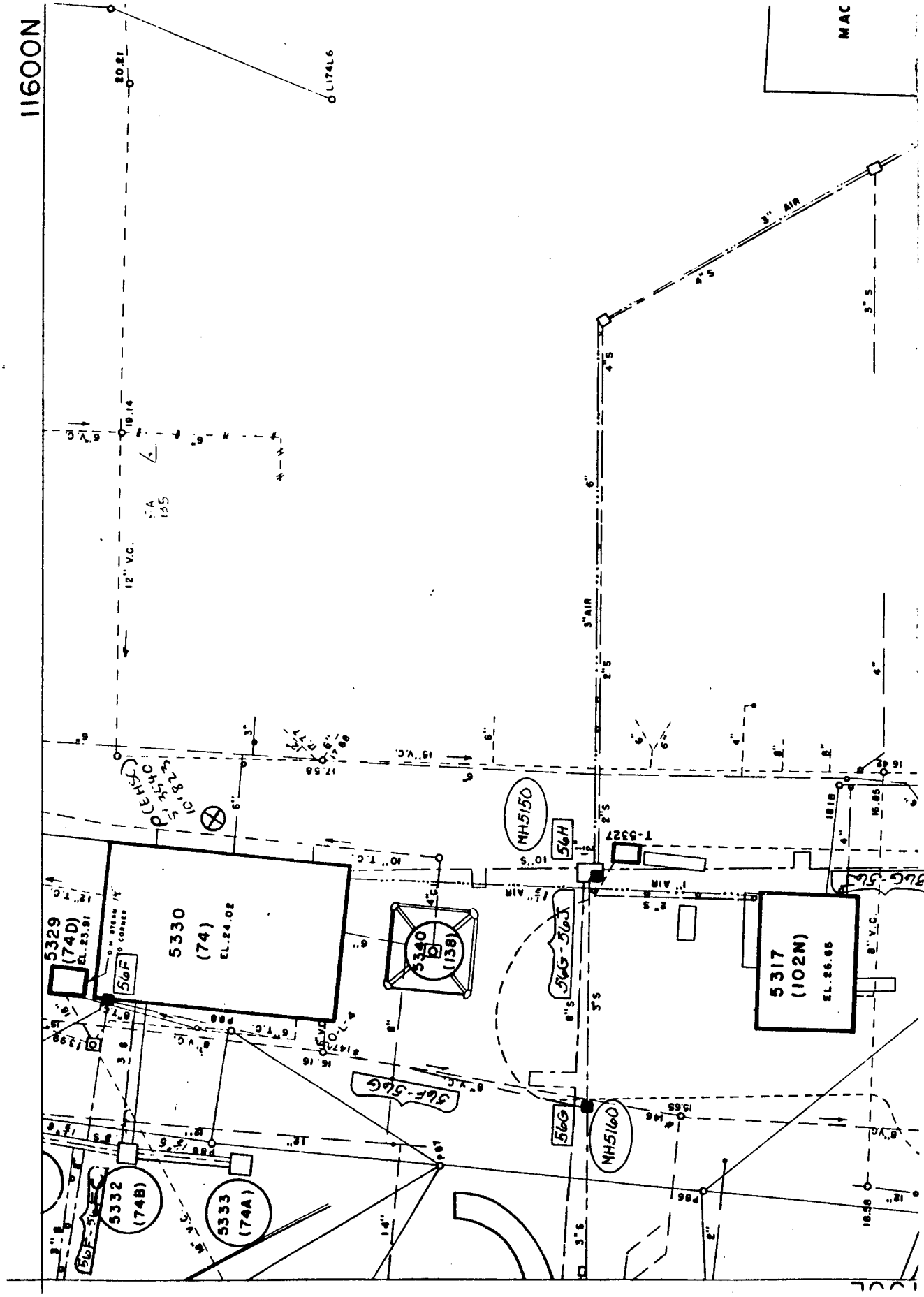
19N-2


5163
9C
EA39
255L 6H
255L 6H5A
51T-51AG
255L 1A
255L 1AL 1
MACADAM
GRAVEL
CONC
FUEL OIL STORAGE TANK
5175
62
EL 25.08
5173
51A
51K
51J
66
WEBSTER
5126
6
EL. 24.66
302H
300SA
STOP
700
701
12'VC

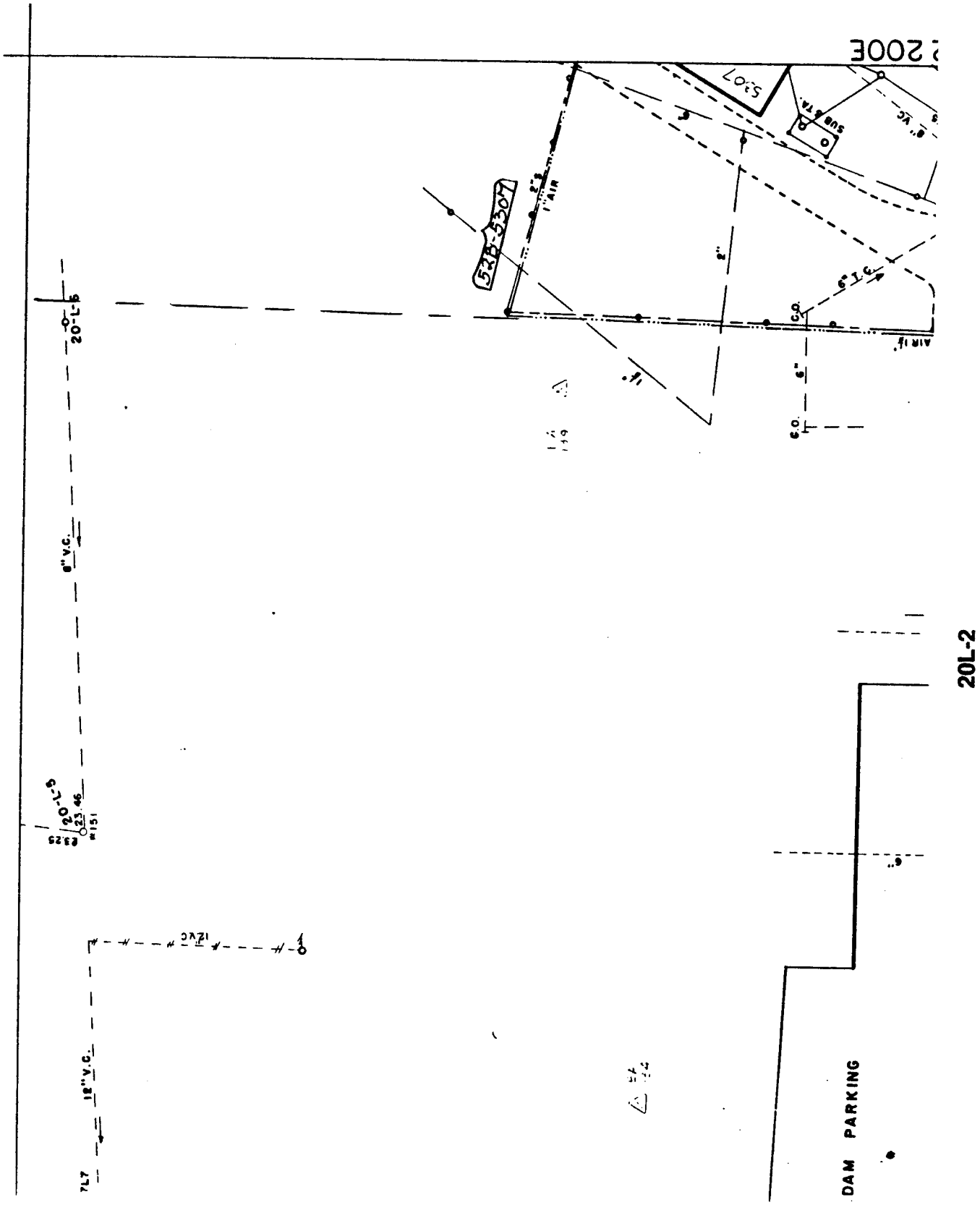
19N-3

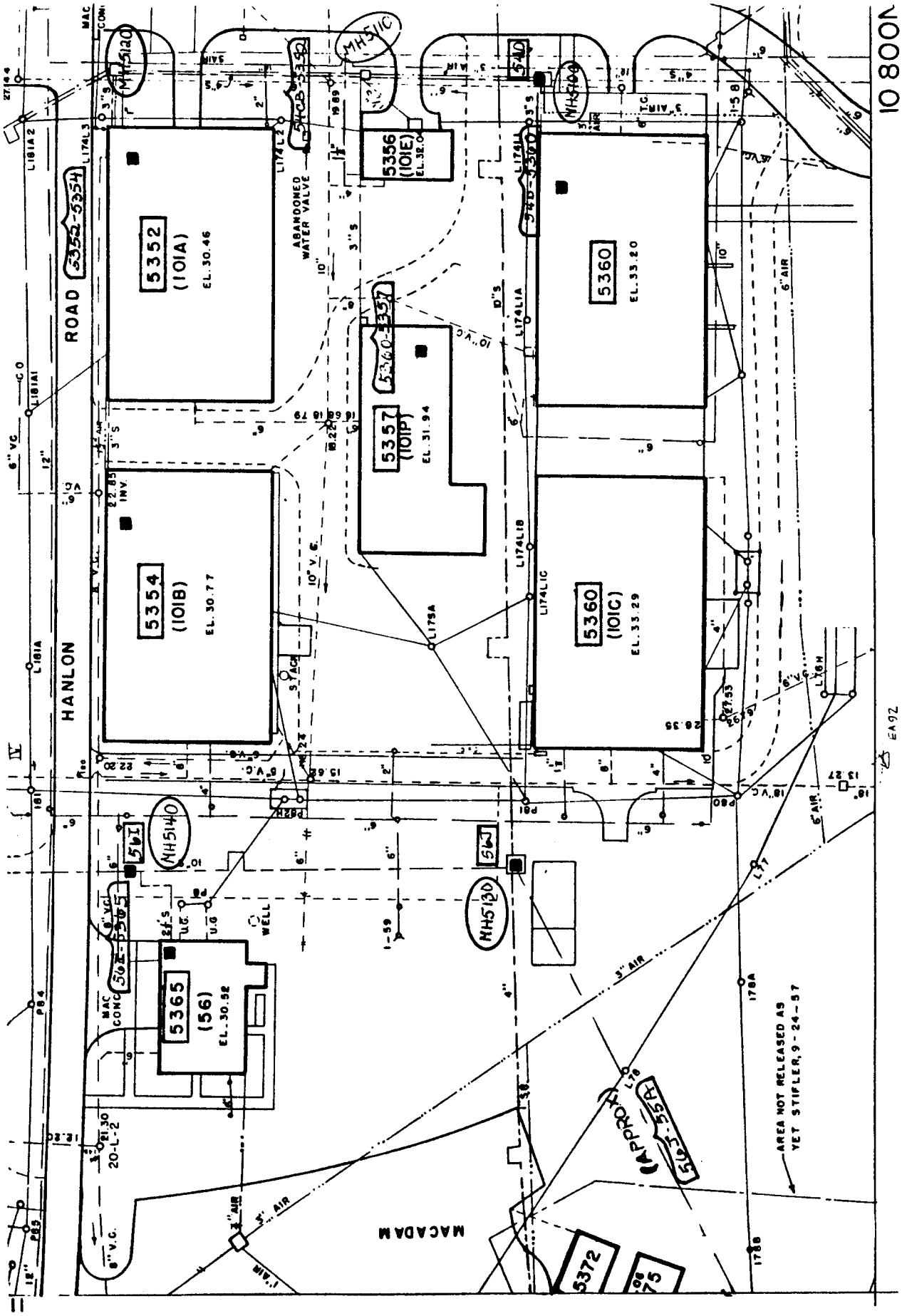

CC
SEPTIC TANK
704R8
704R7
704R6
16'W RC
1-1/2'W
1-1/4'W
1-1/2'W
2'W
1-26
255L2R6
255L2R7
255L2R5
ROAD
BOND
CONC
FLEMING
GRAVEL
704RSR1HRS1
EL 22.12
5158
509
EL 22.29
255L4S1
255L4
255L5
255L3
255L2R1
FUEL LINE
RAVEL
N 11 600

19N-4

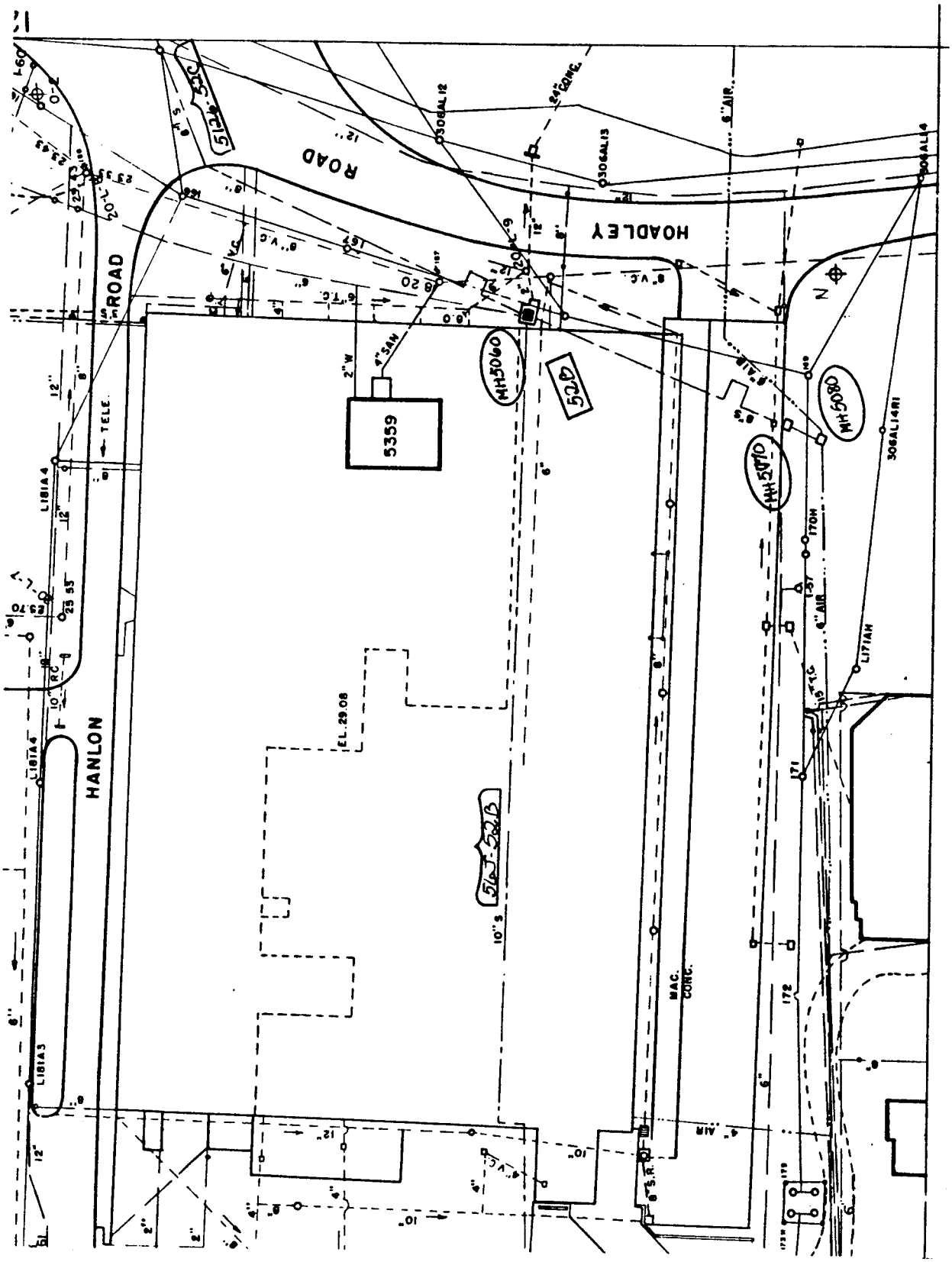

11600N
MAC
3" AIR
5329
(74D)
5330
(74)
EL. 24.02
5340
(138)
5317
(102N)
EL. 26.65
5332
(74B)
5333
(74A)
MH5150
MH5160
T-5327
56F
56G
56H
56J
56G-56J
56F-56G
12" V.C.
8" V.C.

20L-1

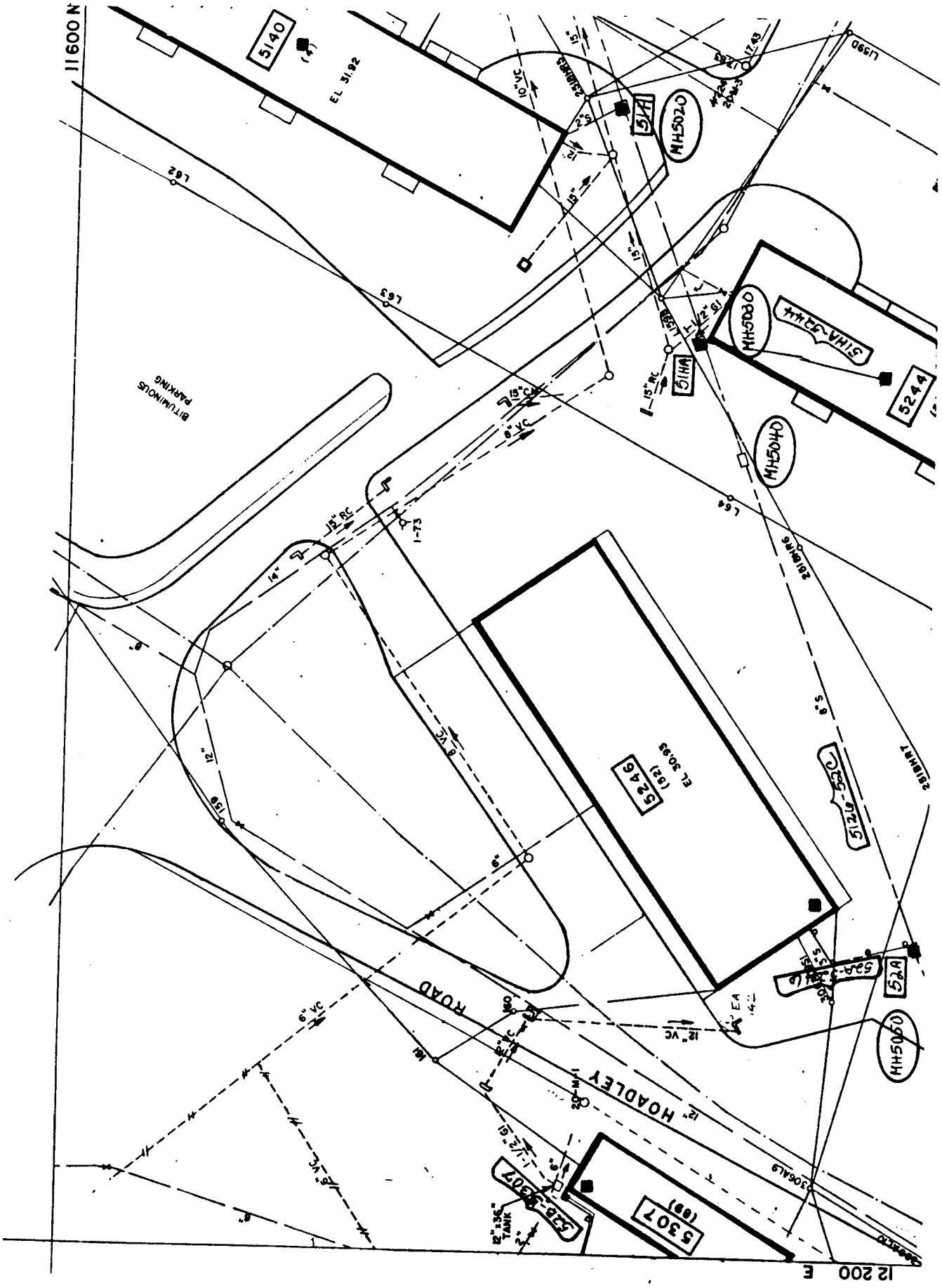

20L-2
DAM PARKING
5307
5RB-5307
SUB STA.
1" AIR
C.O.
6" V.C.
12" V.C.
20-L-5
20-L-6
23.46
#151
7L7

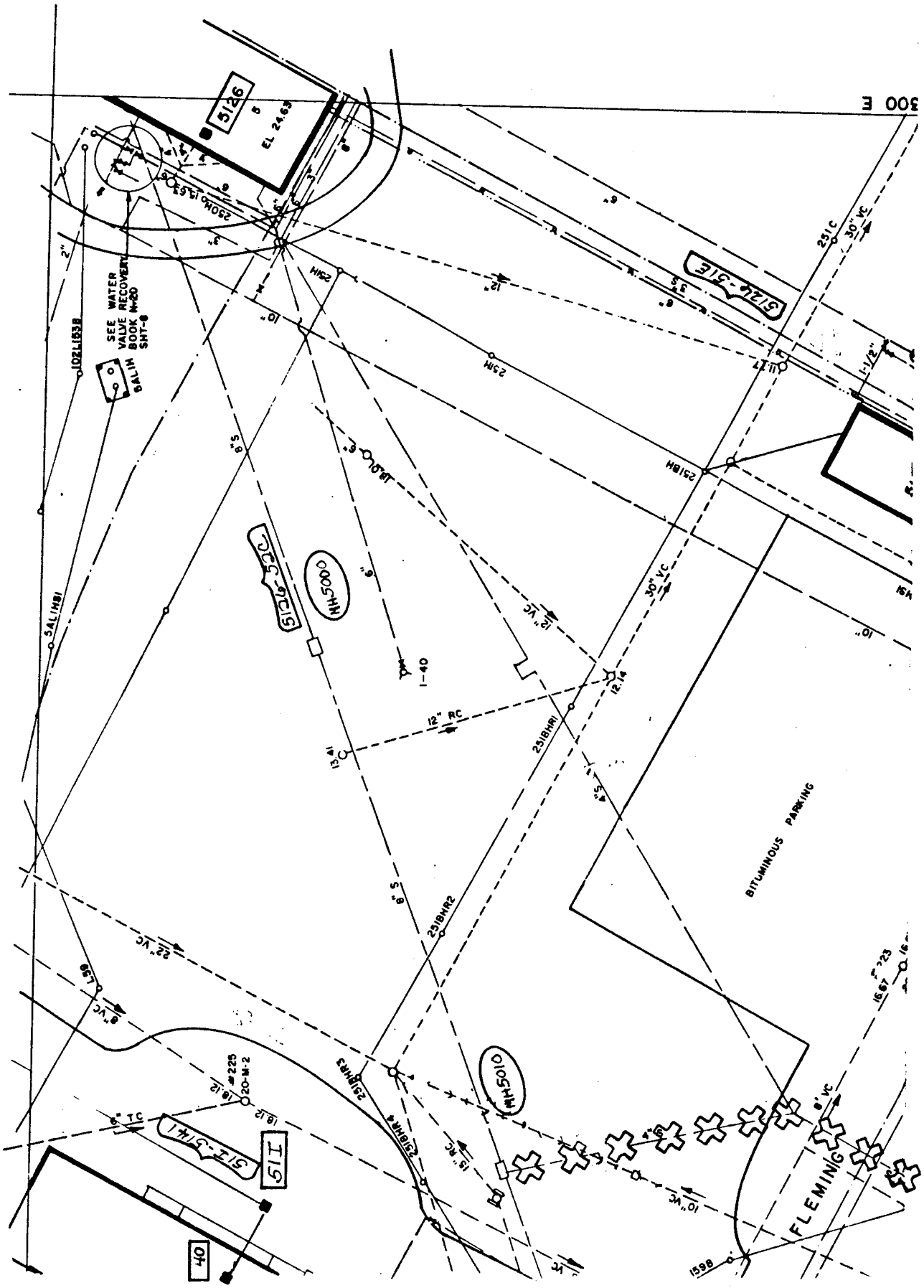

HANLON ROAD
5352 (101A) EL. 30.46
5354 (101B) EL. 30.77
5356 (101E) EL. 32.0
5357 (101P) EL. 31.94
5360 EL. 33.20
5360 (101C) EL. 33.29
5365 (56) EL. 30.52
ABANDONED WATER VALVE
MACADAM
WELL
AREA NOT RELEASED AS YET STIFLER, 9-24-97
APPROX.
10 800N

20L-3

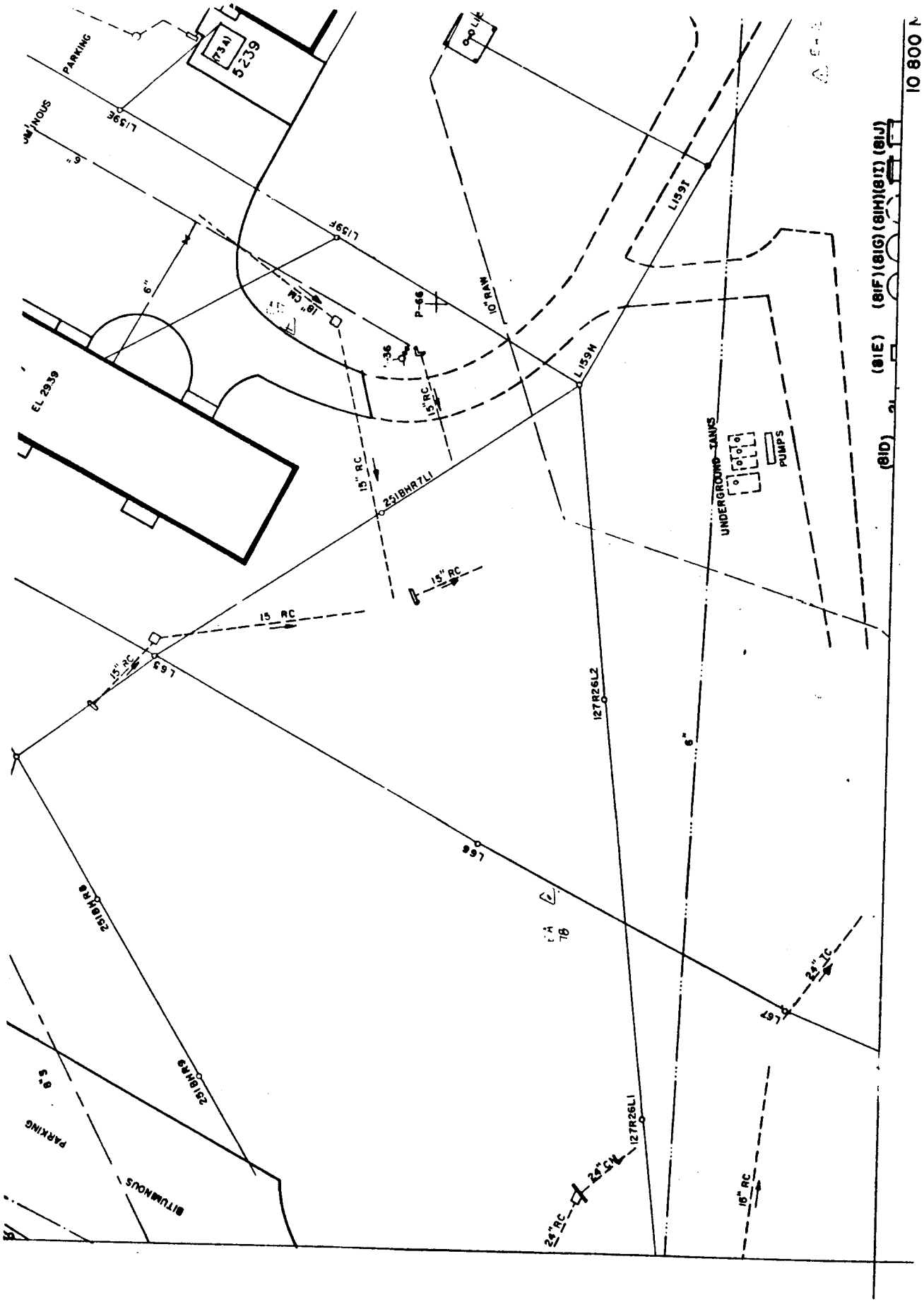

HANLON ROAD
HOADLEY ROAD
5359
MH5060
MH5080
MH5070
EL. 29.08
MAC. CONC.
24" CONC.
6" AIR
4" SAN
TELE.
N

20L-4

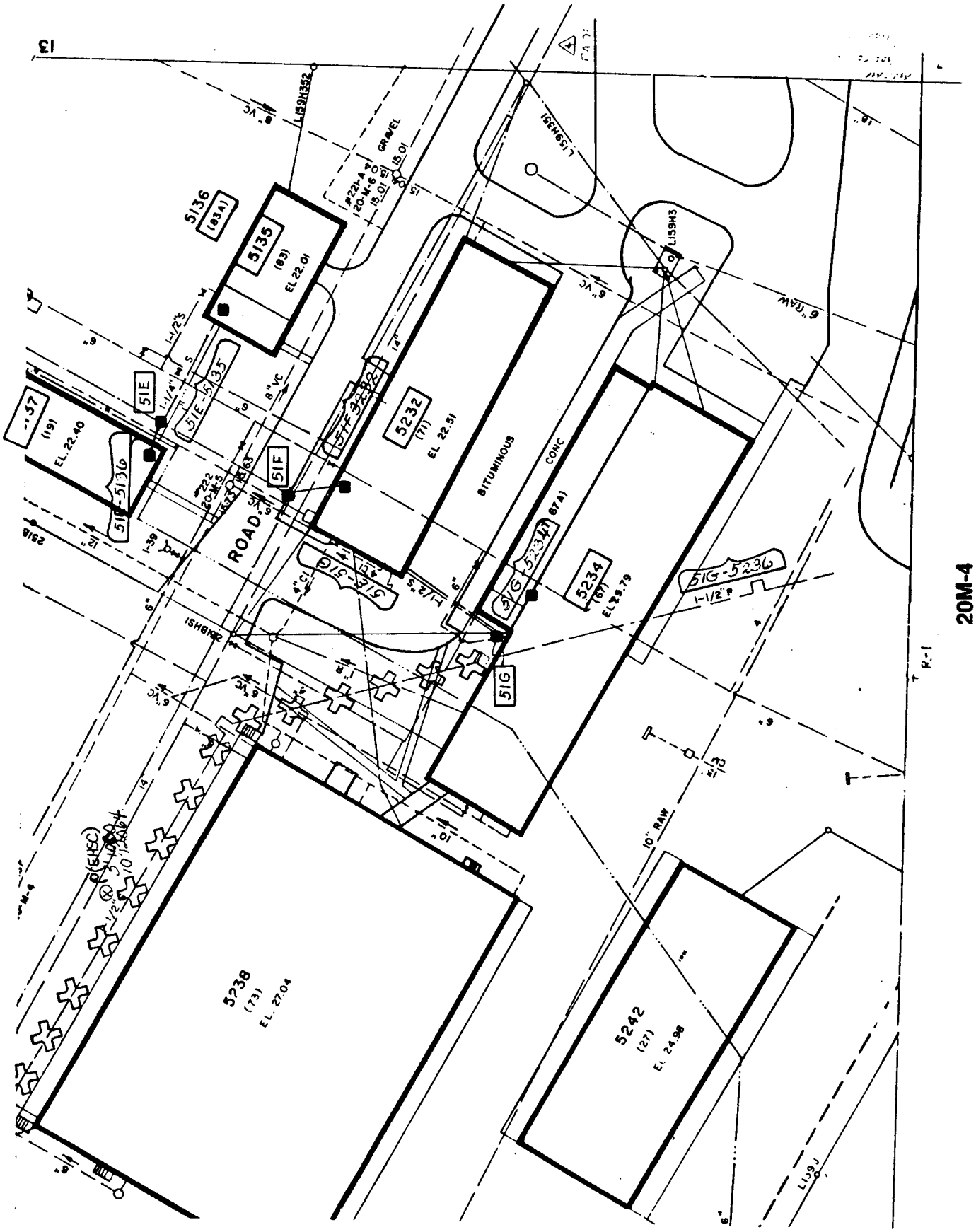

11 600 N
12 200 E
5140
EL 31.92
5244
5307
(BB)
5246
(192)
EL 30.93
BITUMINOUS PARKING
HOADLEY ROAD
MH5060
MH5070
MH5080
MH5090
MH5100
5124
5126
5128
5130
5132
5134
5136
5138
5140
5142
5144
5146
5148
5150
5152
5154
5156
5158
5160
5162
5164
5166
5168
5170
5172
5174
5176
5178
5180
5182
5184
5186
5188
5190
5192
5194
5196
5198
5200
5202

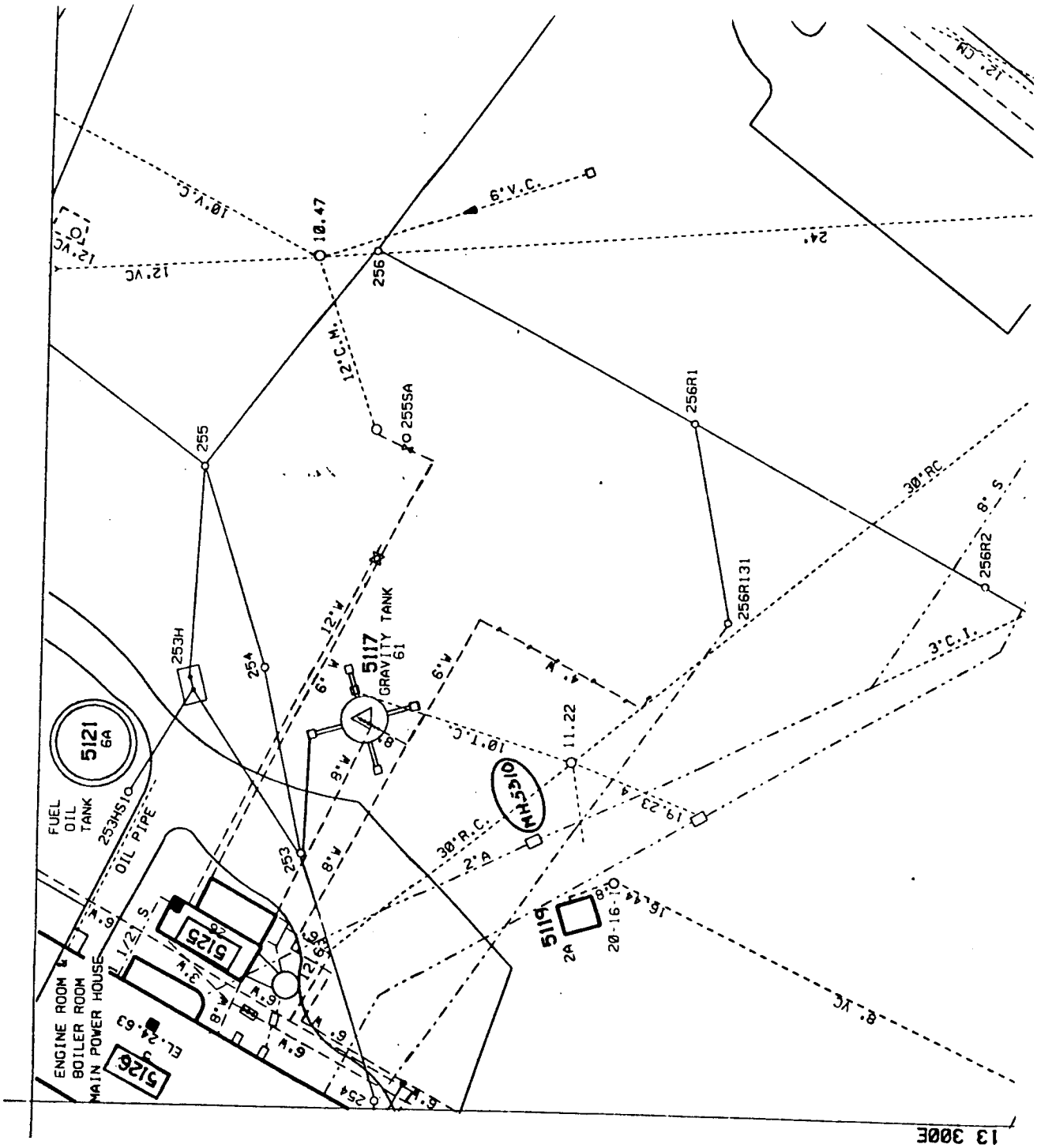

300 E
5126
EL 24.63
SEE WATER VALVE RECOVERY BOOK N-20 SHT-8
BALIH
BE5117201
5ALIHBI
5126-51E
5126-53C
MH5000
MH5010
5126-51H1
5126-51
40
BITUMINOUS PARKING
FLEMING
231BHR1
231BHR2
231BHR3
231BHR4
231C
231BH
231H
231IH
30" VC
12" RC
22" VC
8" VC
10" VC
20-M-2
#225
1598
1-40

20M-2

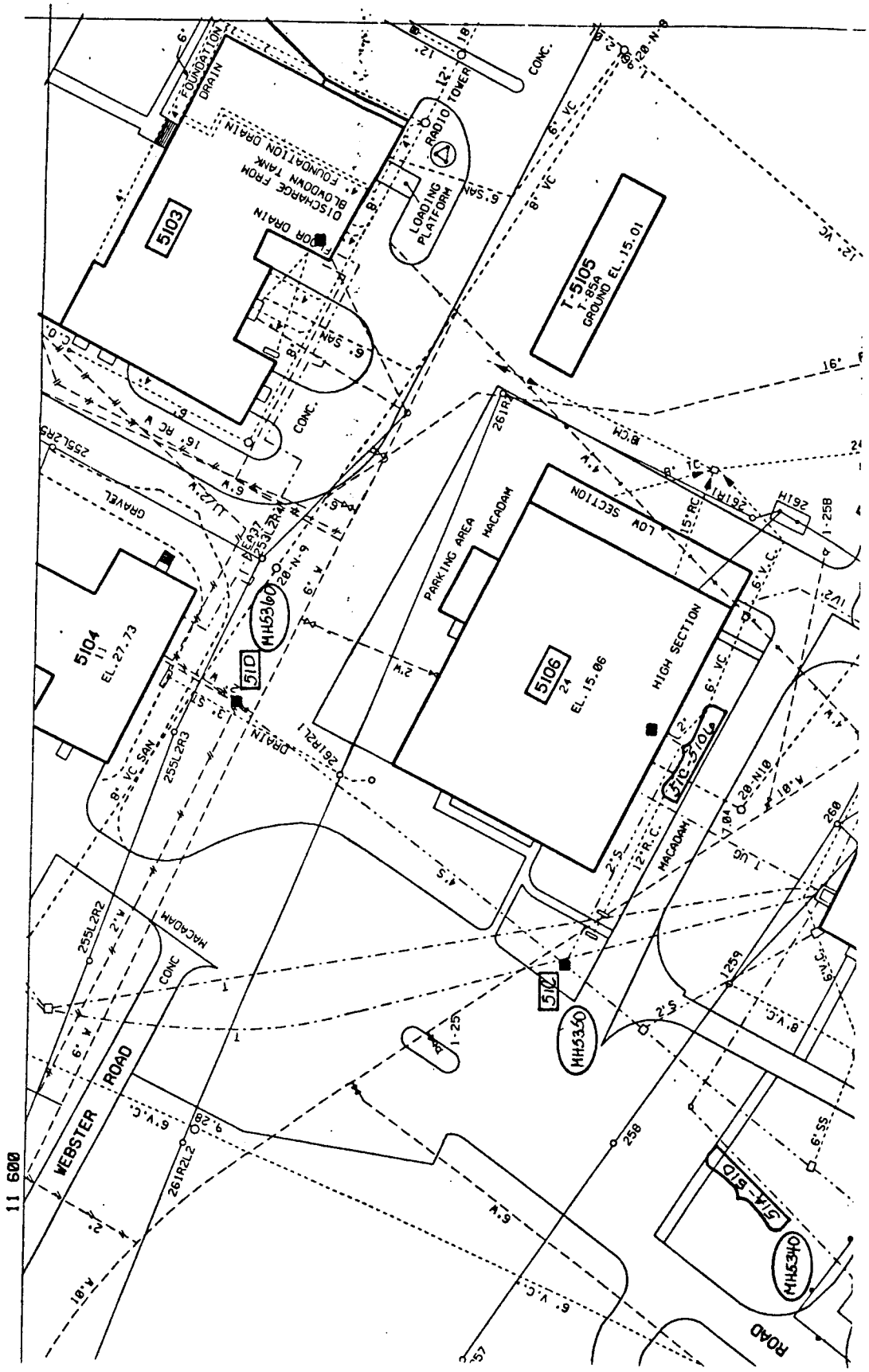

PARKING
BITUMINOUS
EL 2939
L139E
L139F
L139T
L139W
10" RAW
P-66
15" RC
18" CM
251BMR7L1
127R26L2
127R26L1
UNDERGROUND TANKS
PUMPS
(81D)
(81E)
(81F)(81G)(81H)(81I)(81J)
10 800 N

20M-3

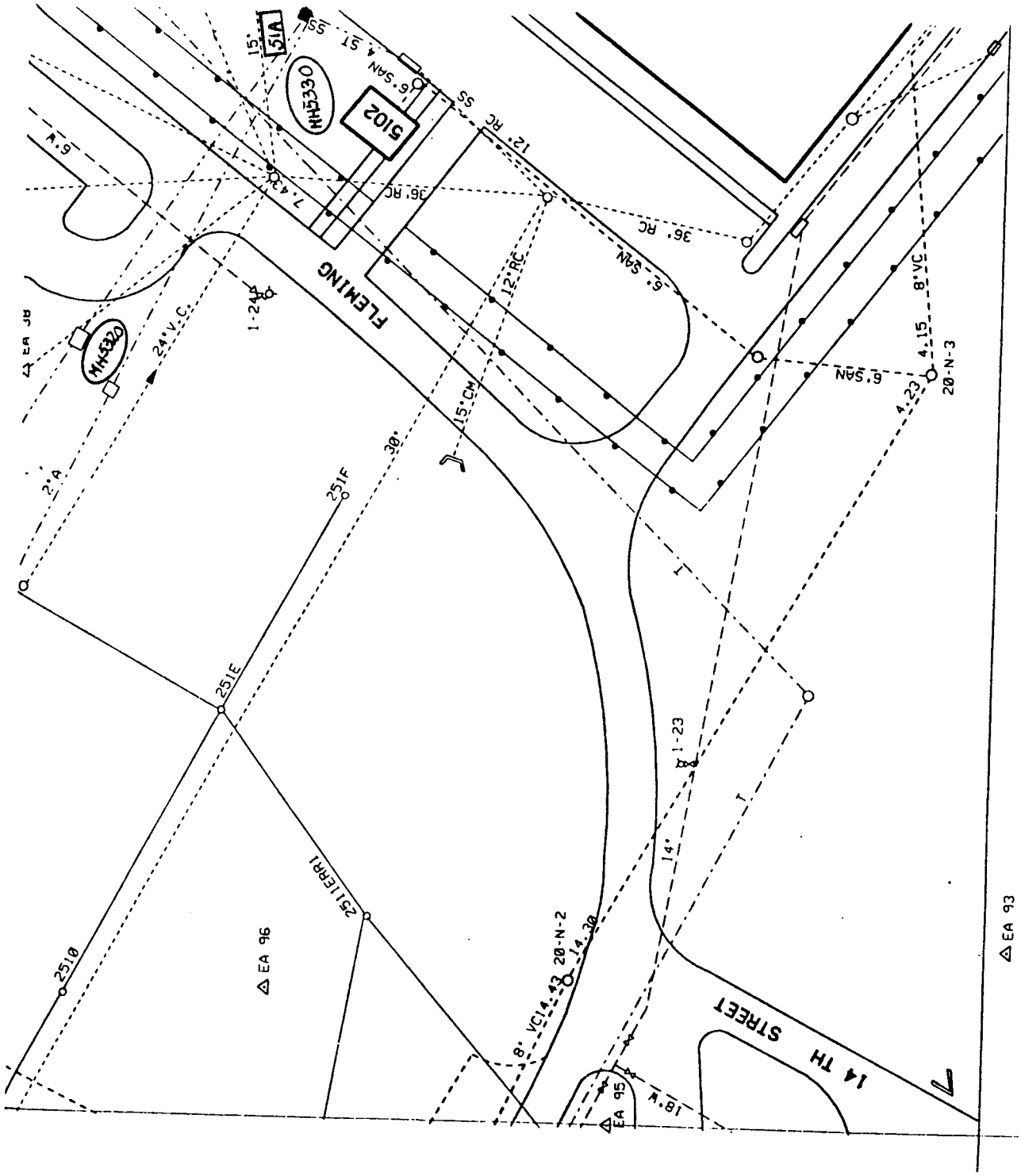

5136
(83A)
5135
(83)
EL 22.01
GRAVEL
5232
(71)
EL 22.51
BITUMINOUS
CONC
5234
(67)
5238
(73)
EL. 27.04
5242
(27)
EL. 24.98
ROAD
51E
51F
51G
51E-5135
51E-5136
51G-5234
51G-5236
10" RAW
6" RAW
20M-4


5121
6A
FUEL
OIL
TANK
253HS10
OIL PIPE
253H
254
255
256
10.47
12'C.M.
12'VC
10'V.C.
9'V.C.
24'
255A
256R1
256R131
256R2
30'RC
8'S
3'C.I.
5117
GRAVITY TANK
61
6'W
12'W
8'W
10'T.C.
11.22
19.23
4'W
MH5910
30'R.C.
2'A
253
5115
2A
20-16-10
16.44
8'VC
5125
26
1/21.S
3'W
6'W
21.69
5126
EL. 24.63
ENGINE ROOM
BOILER ROOM
MAIN POWER HOUSE
254
13 300E

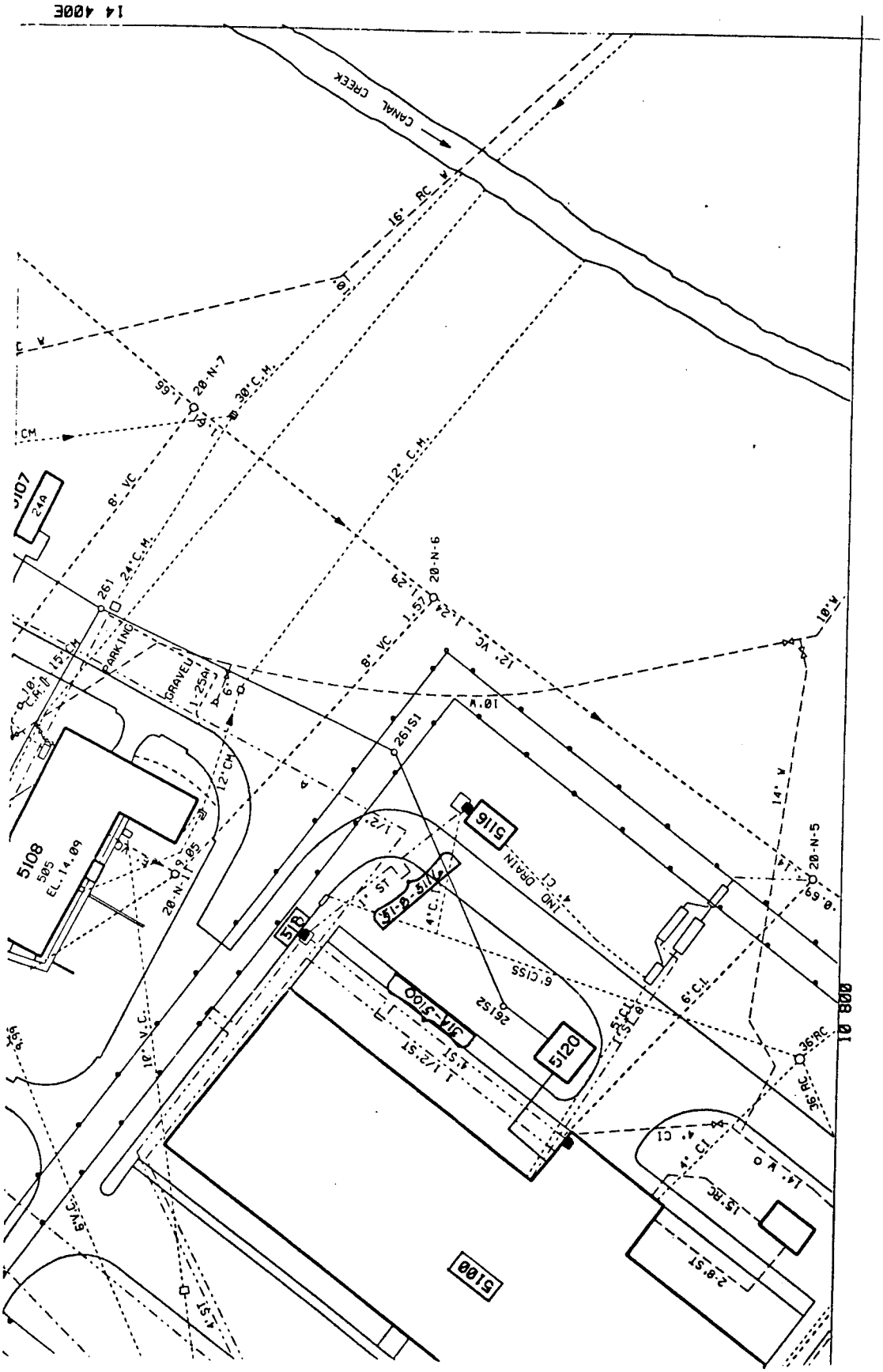
20N-1


5103
5104
EL. 27.73
5106
EL. 15.06
T-5105
GROUND EL. 15.01
RADIO TOWER
LOADING PLATFORM
DISCHARGE FROM BLOWDOWN TANK
FOUNDATION DRAIN
CONC.
GRAVEL
PARKING AREA
MACADAM
LOW SECTION
HIGH SECTION
WEBSTER ROAD
11 600

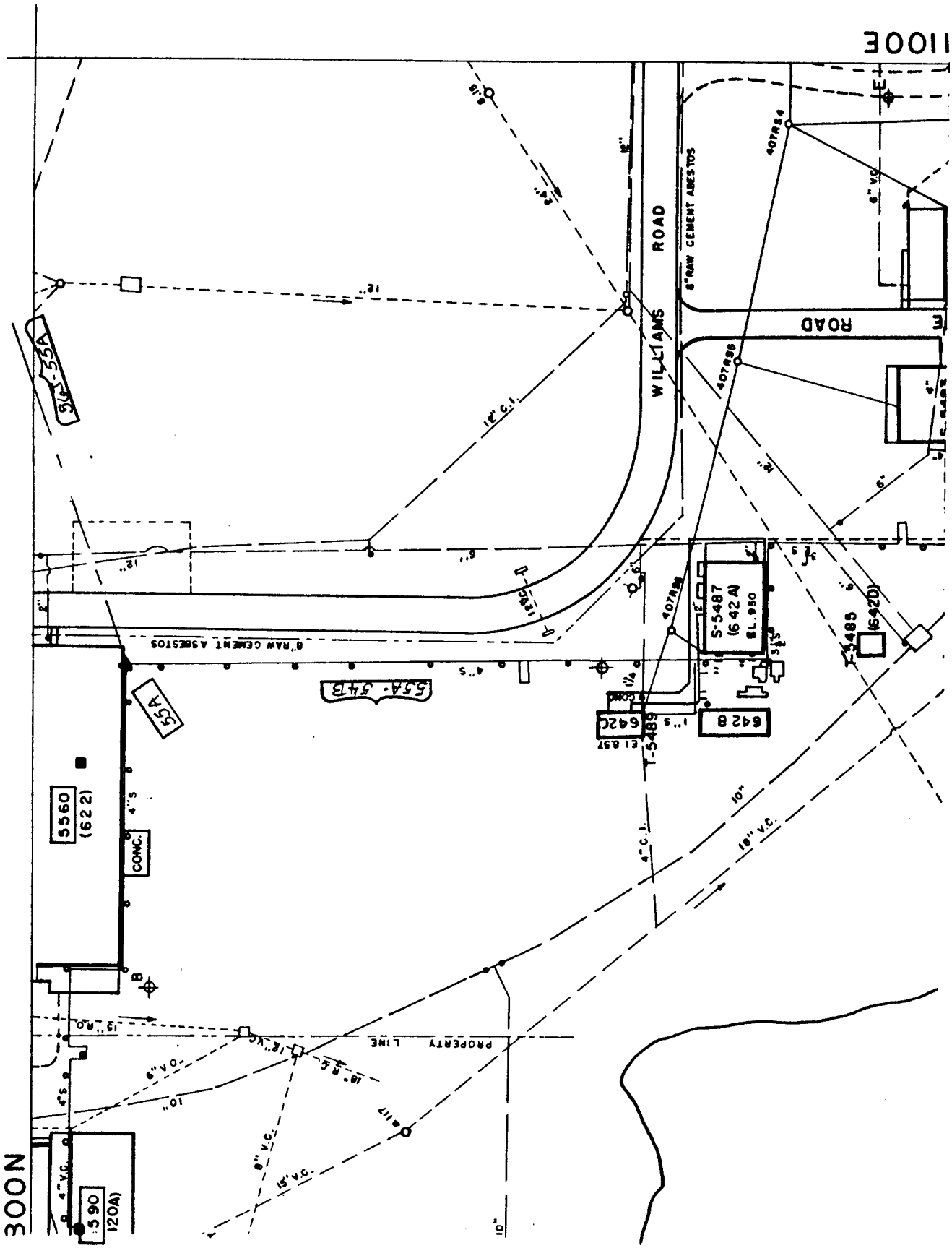
20N-2


FLEMING
14 TH STREET
5102
51A
MH5330
MH5320
EA 96
EA 95
EA 93
20-N-2
20-N-3
251E
251F
251EERI
251D
1-23
1-24
4.23
4.15
14.30
14.43
7.42
24' V.C.
8' VC
6' SAN
36' RC
12' RC
15' CM
30'
14'
18' W
2' A
6' W
4' ST
55'
15'

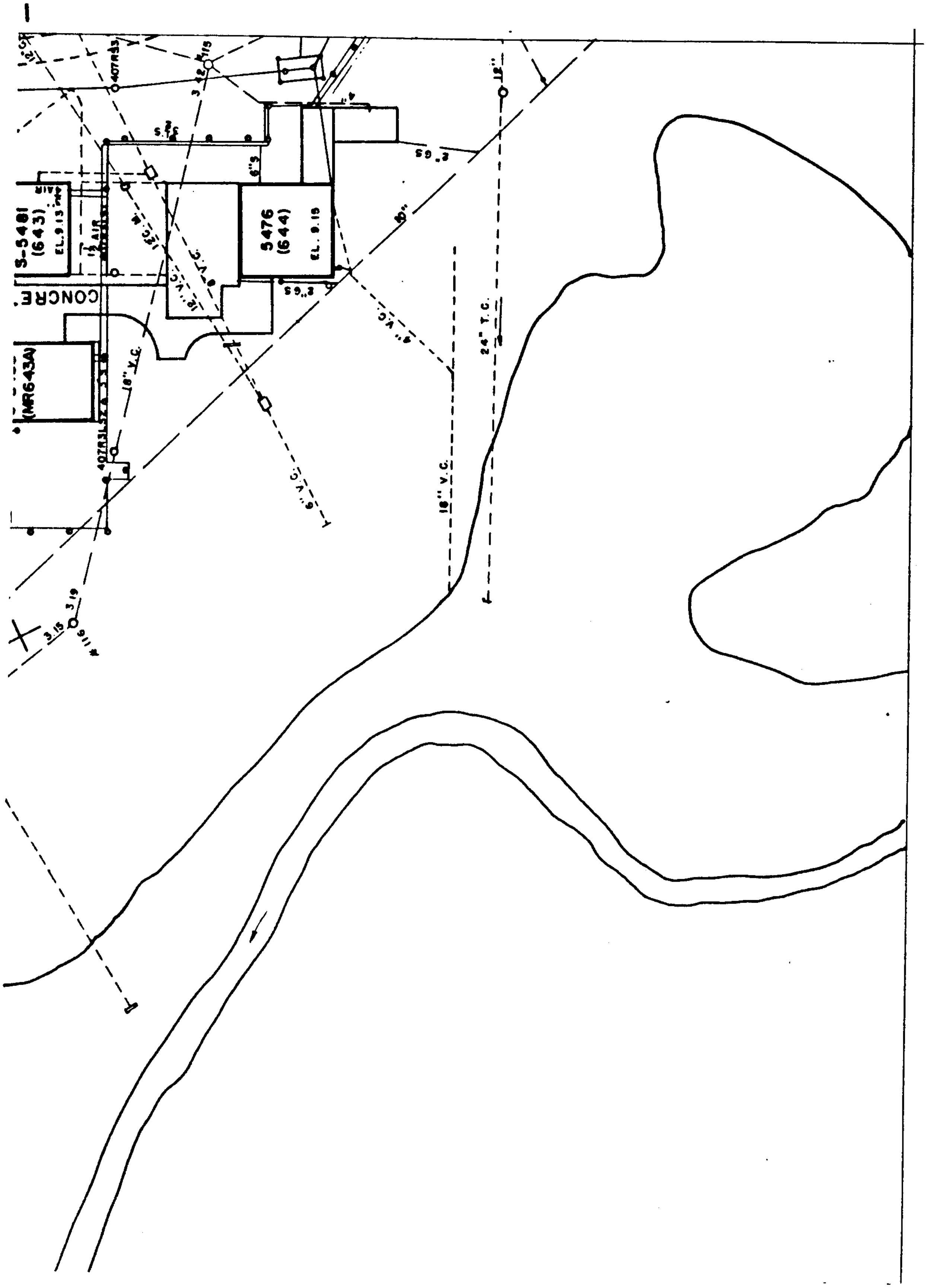
20N-3


CANAL CREEK
5100
5108
5116
5120
5107
PARKING
GRAVEL
20-N-7
20-N-6
20-N-5
20-N-1
26S1
26S2
26S1S1
24A
5A
5B
5A-5100
5A-5-5B
1 1/2-ST
4-ST
2-8-ST
IND DRAIN
6-CISS
12" C.M.
8" VC
30" C.M.
24" C.M.
15" RC
14" VC
14" V
18" V
36" RC
14" V.C.
6" V.C.
10" V.C.
4" C.I.
4" C.I.
6" C.I.
5" C.I.
4" C.I.
14 4006
10 800

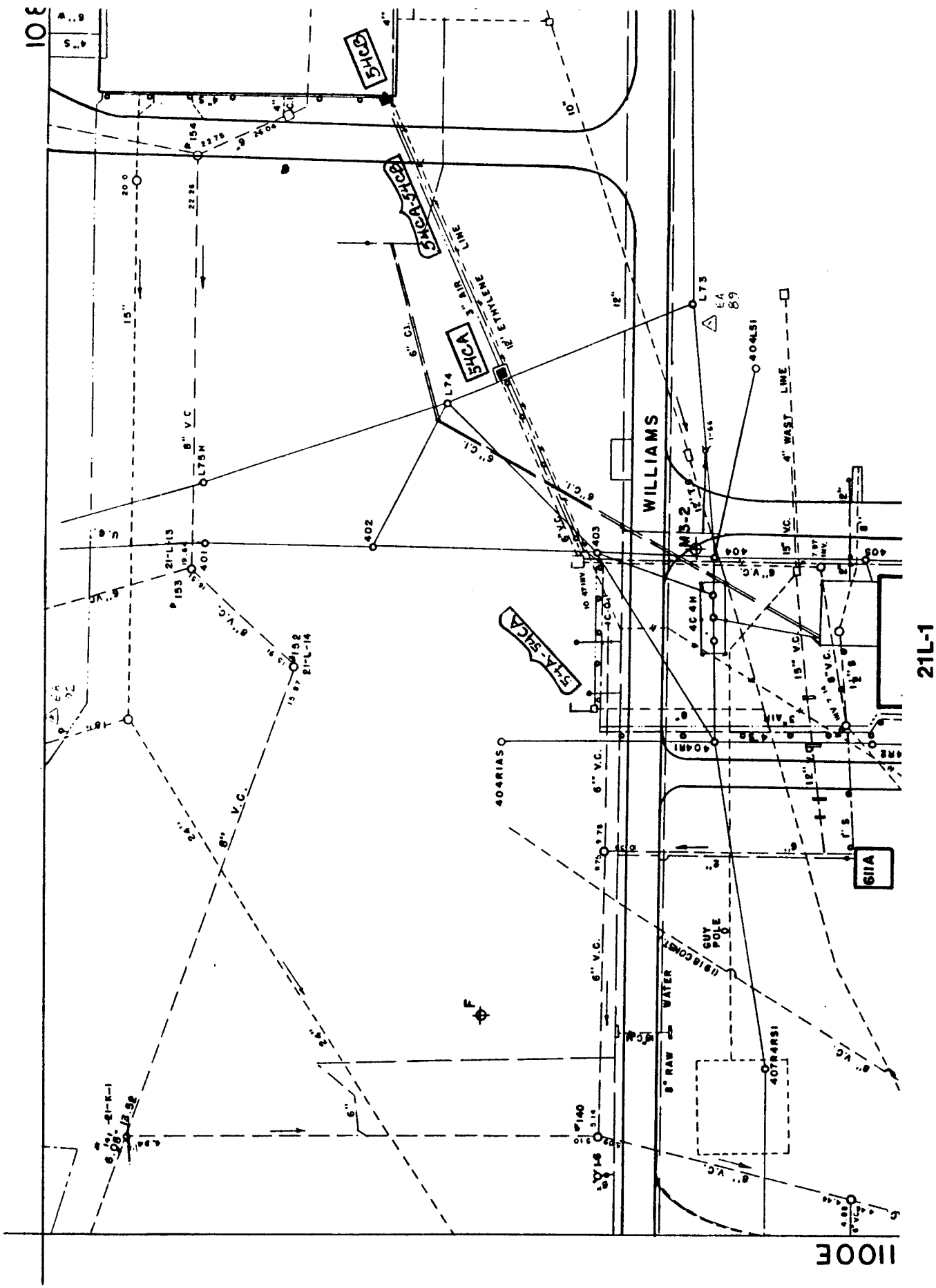
20N-4

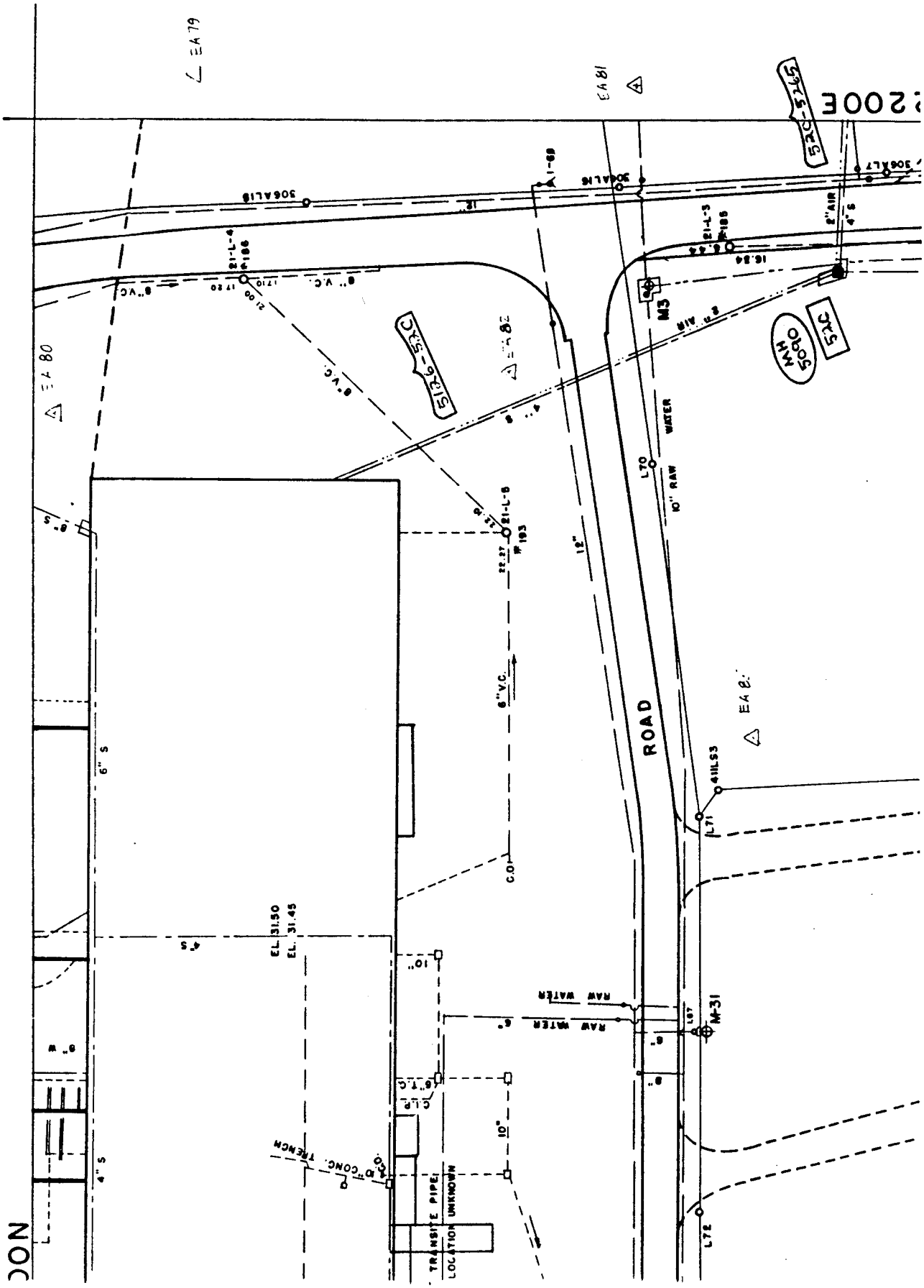

1100E
300N
WILLIAMS ROAD
ROAD
8" RAW CEMENT ASBESTOS
8" RAW CEMENT ASBESTOS
5560 (622)
CONC.
5590 (120A)
55A
55A-55B
S-5487 (642A) EL. 950
642B
642C
T-5489
T-5485
(642D)
PROPERTY LINE
18" C.I.
10" V.C.
18" V.C.
15" V.C.
8" V.C.
6" V.C.
4" V.C.
4" C.I.
10"
6"
4"S
13" R.C.
18" R.C.
18" V.C.
407R84
407R88
407R89
407R90
407R91
407R92
407R93
407R94
407R95
407R96
407R97
407R98
407R99
407R100
407R101
407R102
407R103
407R104
407R105
407R106
407R107
407R108
407R109
407R110
407R111
407R112
407R113
407R114
407R115
407R116
407R117
407R118
407R119
407R120
407R121
407R122
407R123
407R124
407R125
407R126
407R127
407R128
407R129
407R130
407R131
407R132
407R133
407R134
407R135
407R136
407R137
407R138
407R139
407R140
407R141
407R142
407R143
407R144
407R145
407R146
407R147
407R148
407R149
407R150
407R151
407R152
407R153
407R154
407R155
407R156
407R157
407R158
407R159
407R160
407R161
407R162
407R163
407R164
407R165
407R166
407R167
407R168
407R169
407R170
407R171
407R172
407R173
407R174
407R175
407R176
407R177
407R178
407R179
407R180
407R181
407R182
407R183
407R184
407R185
407R186
407R187
407R188
407R189
407R190
407R191
407R192
407R193
407R194
407R195
407R196
407R197
407R198
407R199
407R200
407R201
407R202
407R203
407R204
407R205
407R206
407R207
407R208
407R209
407R210
407R211
407R212
407R213
407R214
407R215
407R216
407R217
407R218
407R219
407R220
407R221
407R222
407R223
407R224
407R225
407R226
407R227
407R228
407R229
407R230
407R231
407R232
407R233
407R234
407R235
407R236
407R237
407R238
407R239
407R240
407R241
407R242
407R243
407R244
407R245
407R246
407R247
407R248
407R249
407R250
407R251
407R252
407R253
407R254
407R255
407R256
407R257
407R258
407R259
407R260
407R261
407R262
407R263
407R264
407R265
407R266
407R267
407R268
407R269
407R270
407R271
407R272
407R273
407R274
407R275
407R276
407R277
407R278
407R279
407R280
407R281
407R282
407R283
407R284
407R285
407R286
407R287
407R288
407R289
407R290
407R291
407R292
407R293
407R294
407R295
407R296
407R297
407R298
407R299
407R300
407R301
407R302
407R303
407R304
407R305
407R306
407R307
407R308
407R309
407R310
407R311
407R312
407R313
407R314
407R315
407R316
407R317
407R318
407R319
407R320
407R321
407R322
407R323
407R324
407R325
407R326
407R327
407R328
407R329
407R330
407R331
407R332
407R333
407R334
407R335
407R336
407R337
407R338
407R339
407R340
407R341
407R342
407R343
407R344
407R345
407R346
407R347
407R348
407R349
407R350
407R351
407R352
407R353
407R354
407R355
407R356
407R357
407R358
407R359
407R360
407R361
407R362
407R363
407R364
407R365
407R366
407R367
407R368
407R369
407R370
407R371
407R372
407R373
407R374
407R375
407R376
407R377
407R378
407R379
407R380
407R381
407R382
407R383
407R384
407R385
407R386
407R387
407R388
407R389
407R390
407R391
407R392
407R393
407R394
407R395
407R396
407R397
407R398
407R399
407R400
407R401
407R402
407R403
407R404
407R405
407R406
407R407
407R408
407R409
407R410
407R411
407R412
407R413
407R414
407R415
407R416
407R417
407R418
407R419
407R420
407R421
407R422
407R423
407R424
407R425
407R426
407R427
407R428
407R429
407R430
407R431
407R432
407R433
407R434
407R435
407R436
407R437
407R438
407R439
407R440
407R441
407R442
407R443
407R444
407R445
407R446
407R447
407R448
407R449
407R450
407R451
407R452
407R453
407R454
407R455
407R456
407R457
407R458
407R459
407R460
407R461
407R462
407R463
407R464
407R465
407R466
407R467
407R468
407R469
407R470
407R471
407R472
407R473
407R474
407R475
407R476
407R477
407R478
407R479
407R480
407R481
407R482
407R483
407R484
407R485
407R486
407R487
407R488
407R489
407R490
407R491
407R492
407R493
407R494
407R495
407R496
407R497
407R498
407R499
407R500
407R501
407R502
407R503
407R504
407R505
407R506
407R507
407R508
407R509
407R510
407R511
407R512
407R513
407R514
407R515
407R516
407R517
407R518
407R519
407R520
407R521
407R522
407R523
407R524
407R525
407R526
407R527
407R528
407R529
407R530
407R531
407R532
407R533
407R534
407R535
407R536
407R537
407R538
407R539
407R540
407R541
407R542
407R543
407R544
407R545
407R546
407R547
407R548
407R549
407R550
407R551
407R552
407R553
407R554
407R555
407R556
407R557
407R558
407R559
407R560
407R561
407R562
407R563
407R564
407R565
407R566
407R567
407R568
407R569
407R570
407R571
407R572
407R573
407R574
407R575
407R576
407R577
407R578
407R579
407R580
407R581
407R582
407R583
407R584
407R585
407R586
407R587
407R588
407R589
407R590
407R591
407R592
407R593
407R594
407R595
407R596
407R597
407R598
407R599
407R600
407R601
407R602
407R603
407R604
407R605
407R606
407R607
407R608
407R609
407R610
407R611
407R612
407R613
407R614
407R615
407R616
407R617
407R618
407R619
407R620
407R621
407R622
407R623
407R624
407R625
407R626
407R627
407R628
407R629
407R630
407R631
407R632
407R633
407R634
407R635
407R636
407R637
407R638
407R639
407R640
407R641
407R642
407R643
407R644
407R645
407R646
407R647
407R648
407R649
407R650
407R651
407R652
407R653
407R654
407R655
407R656
407R657
407R658
407R659
407R660
407R661
407R662
407R663
407R664
407R665
407R666
407R667
407R668
407R669
407R670
407R671
407R672
407R673
407R674
407R675
407R676
407R677
407R678
407R679
407R680
407R681
407R682
407R683
407R684
407R685
407R686
407R687
407R688
407R689
407R690
407R691
407R692
407R693
407R694
407R695
407R696
407R697
407R698
407R699
407R700
407R701
407R702
407R703
407R704
407R705
407R706
407R707
407R708
407R709
407R710
407R711
407R712
407R713
407R714
407R715
407R716
407R717
407R718
407R719
407R720
407R721
407R722
407R723
407R724
407R725
407R726
407R727
407R728
407R729
407R730
407R731
407R732
407R733
407R734
407R735
407R736
407R737
407R738
407R739
407R740
407R741
407R742
407R743
407R744
407R745
407R746
407R747
407R748
407R749
407R750
407R751
407R752
407R753
407R754
407R755
407R756
407R757
407R758
407R759
407R760
407R761
407R762
407R763
407R764
407R765
407R766
407R767
407R768
407R769
407R770
407R771
407R772
407R773
407R774
407R775
407R776
407R777
407R778
407R779
407R780
407R781
407R782
407R783
407R784
407R785
407R786
407R787
407R788
407R789
407R790
407R791
407R792
407R793
407R794
407R795
407R796
407R797
407R798
407R799
407R800
407R801
407R802
407R803
407R804
407R805
407R806
407R807
407R808
407R809
407R810
407R811
407R812
407R813
407R814
407R815
407R816
407R817
407R818
407R819
407R820
407R821
407R822
407R823
407R824
407R825
407R826
407R827
407R828
407R829
407R830
407R831
407R832
407R833
407R834
407R835
407R836
407R837
407R838
407R839
407R840
407R841
407R842
407R843
407R844
407R845
407R846
407R847
407R848
407R849
407R850
407R851
407R852
407R853
407R854
407R855
407R856
407R857
407R858
407R859
407R860
407R861
407R862
407R863
407R864
407R865
407R866
407R867
407R868
407R869
407R870
407R871
407R872
407R873
407R874
407R875
407R876
407R877
407R878
407R879
407R880
407R881
407R882
407R883
407R884
407R885
407R886
407R887
407R888
407R889
407R890
407R891
407R892
407R893
407R894
407R895
407R896
407R897
407R898
407R899
407R900
407R901
407R902
407R903
407R904
407R905
407R906
407R907
407R908
407R909
407R910
407R911
407R912
407R913
407R914
407R915
407R916
407R917
407R918
407R919
407R920
407R921
407R922
407R923
407R924
407R925
407R926
407R927
407R928
407R929
407R930
407R931
407R932
407R933
407R934
407R935
407R936
407R937
407R938
407R939
407R940
407R941
407R942
407R943
407R944
407R945
407R946
407R947
407R948
407R949
407R950
407R951
407R952
407R953
407R954
407R955
407R956
407R957
407R958
407R959
407R960
407R961
407R962
407R963
407R964
407R965
407R966
407R967
407R968
407R969
407R970
407R971
407R972
407R973
407R974
407R975
407R976
407R977
407R978
407R979
407R980
407R981
407R982
407R983
407R984
407R985
407R986
407R987
407R988
407R989
407R990
407R991
407R992
407R993
407R994
407R995
407R996
407R997
407R998
407R999
407R1000

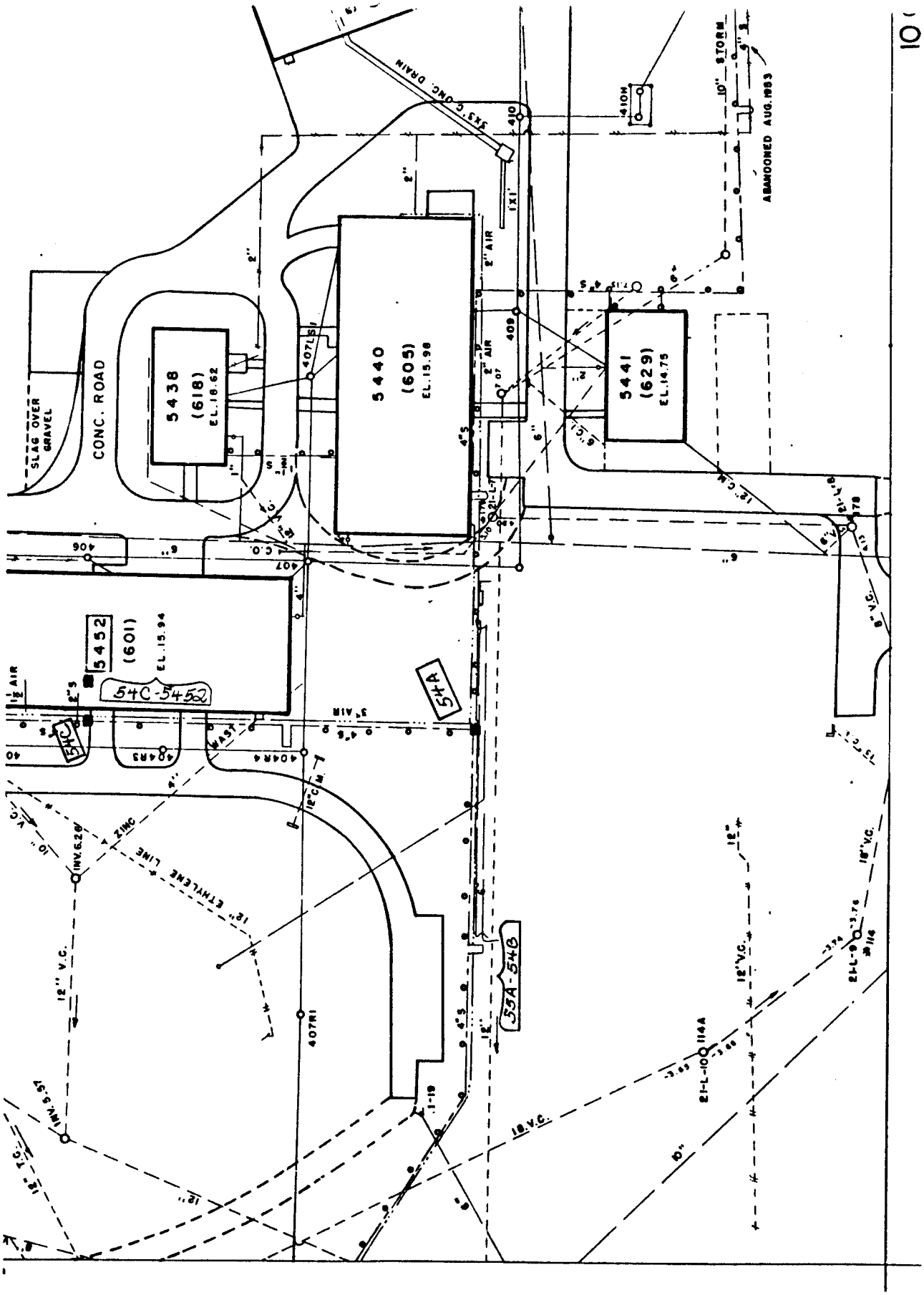
21K-2

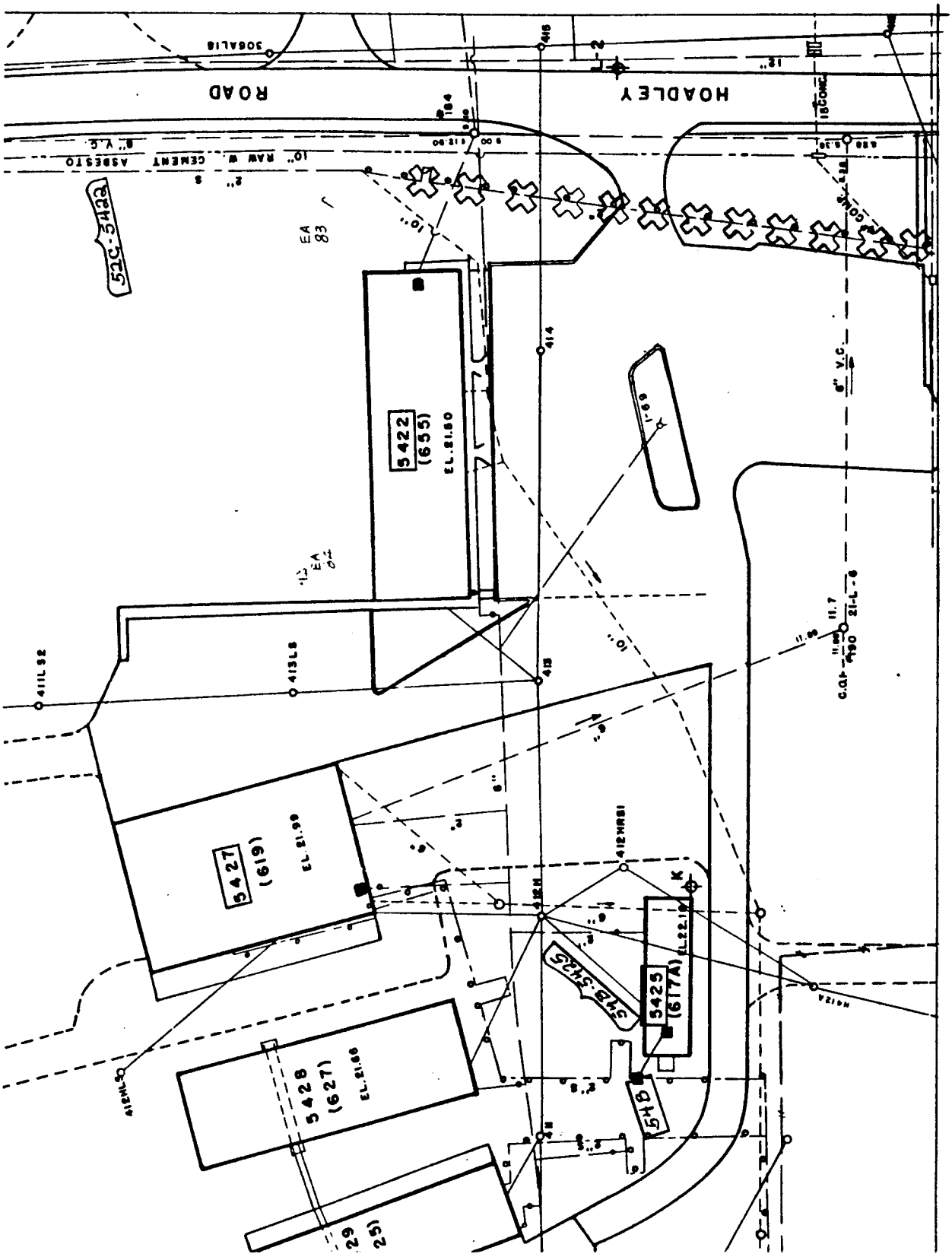


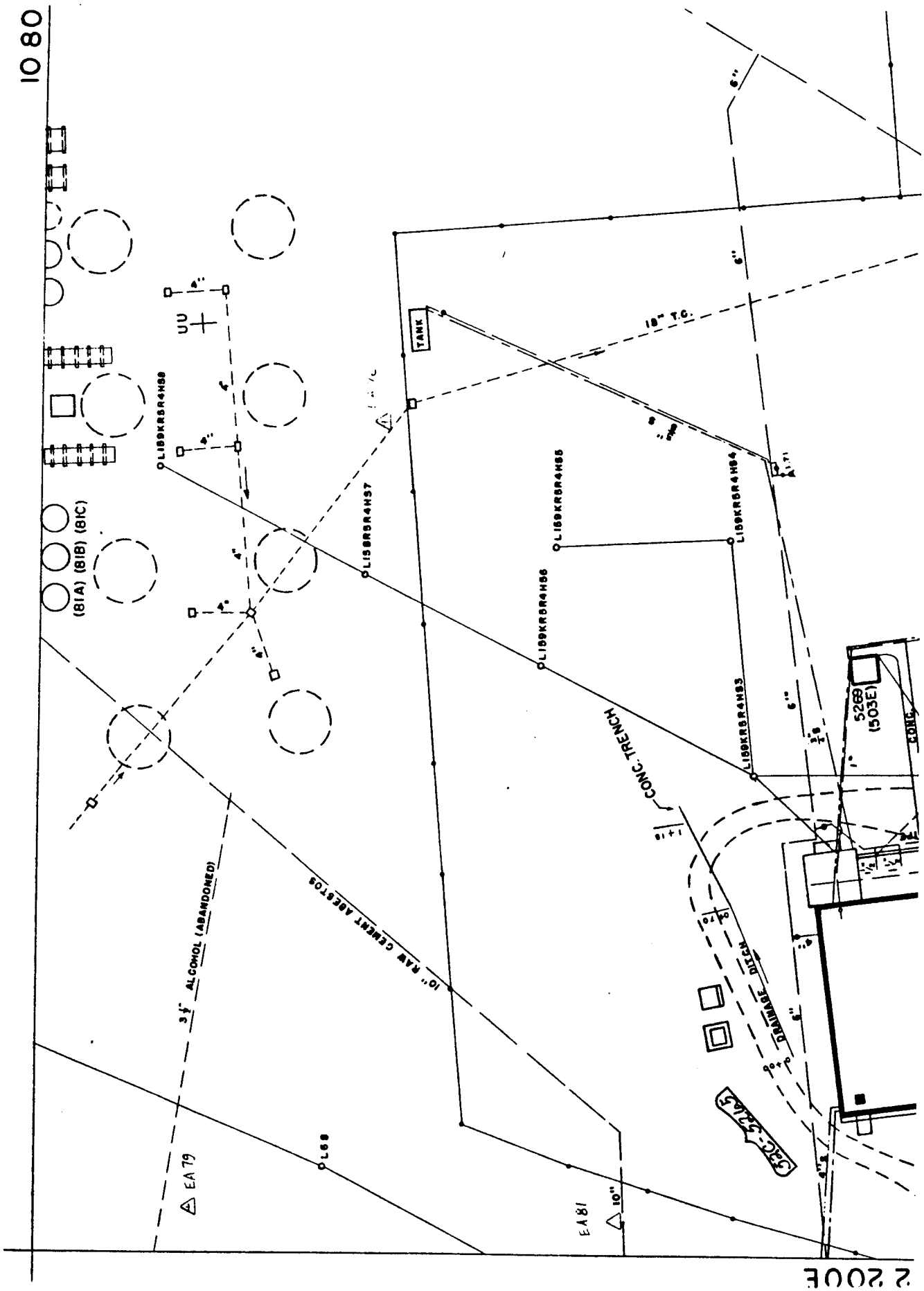
21K-4

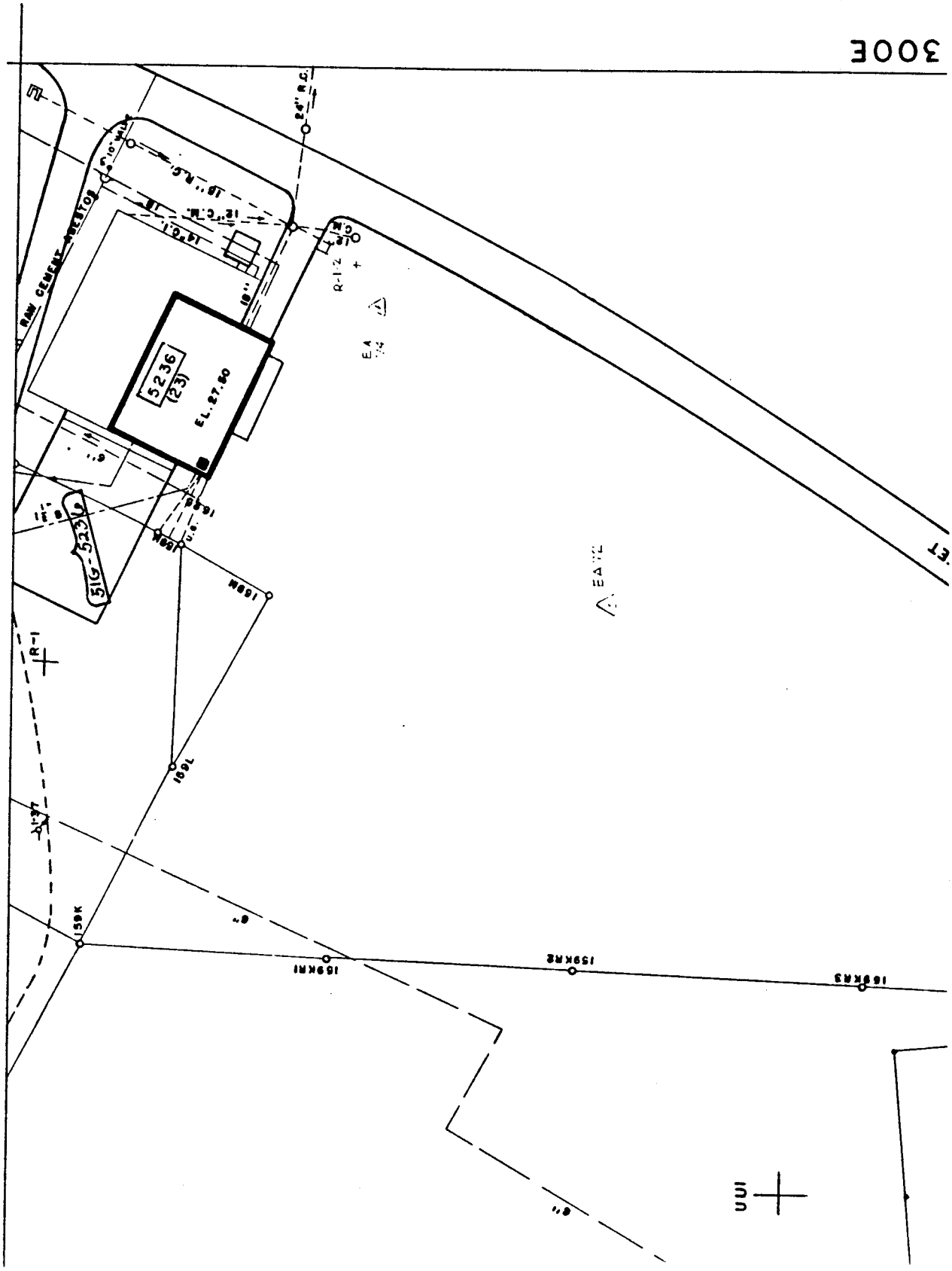

WILLIAMS
MS-2
21L-1
611A
5HCA
5HCB
5HCA-5HCB
5HA-5HCA
GUY POLE
8" RAW WATER
4" WAST LINE
404LS1
404RIAS
407R4RS1
402
403
401
L73
L74
L75W
8" V.C.
6" V.C.
15" V.C.
6" C.I.
12" E.MTLENE AIR LINE


ROAD
RAW WATER
10" RAW WATER
TRANSITE PIPE LOCATION UNKNOWN
EL. 31.50
EL. 31.45
21L-2

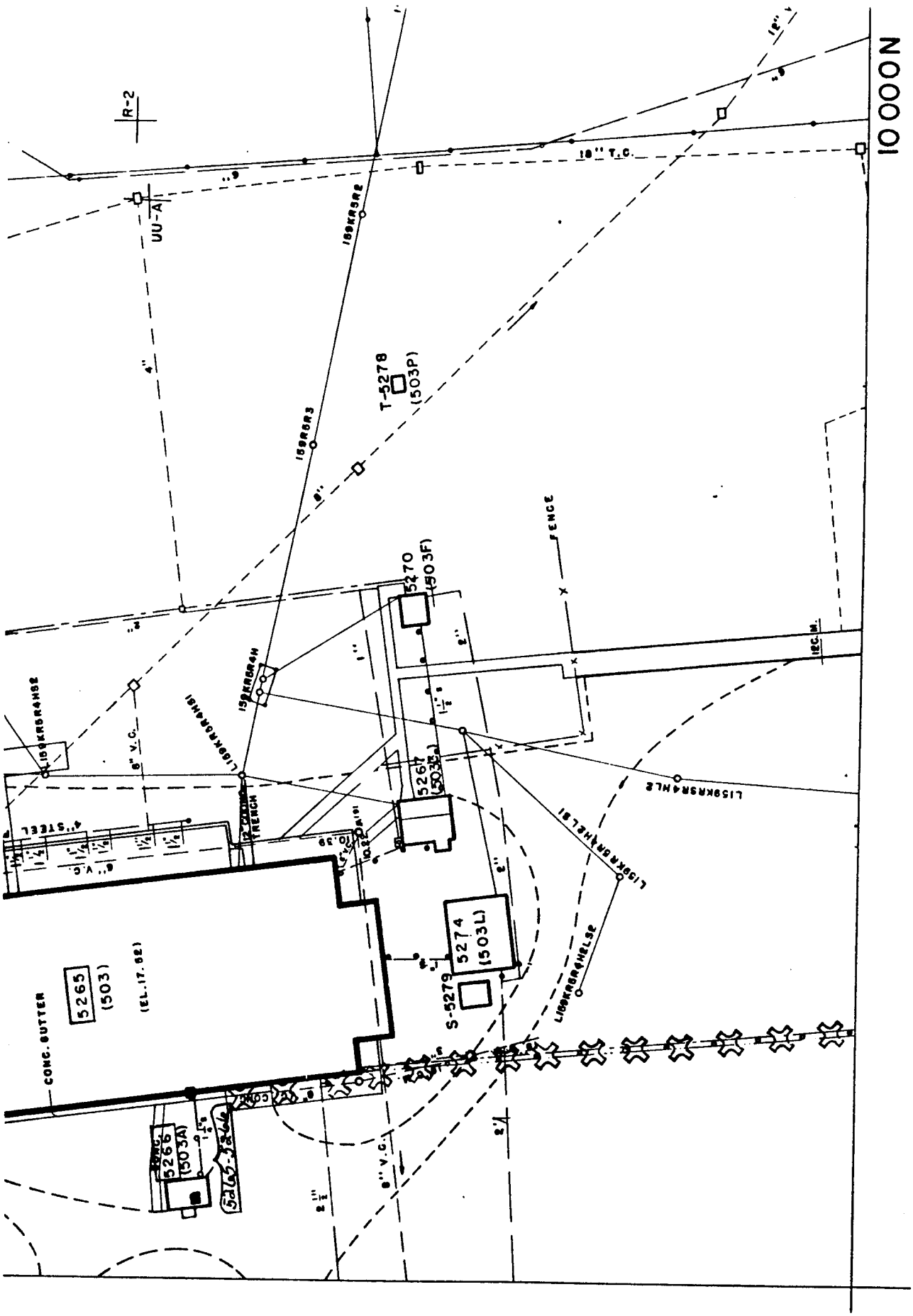

5438
(618)
EL. 18.62
5440
(605)
EL. 15.98
5441
(629)
EL. 14.75
5452
(601)
EL. 15.94
CONC. ROAD
SLAG OVER GRAVEL
ABANDONED AUG. 1983
10" STORM
54C-5452
54A
55A-54B
12" ETHYLENE LINE
12" V.C.
18" V.C.
407R1
21L-3


HOADLEY
ROAD
5422
(655)
EL. 21.50
5427
(619)
EL. 21.99
5428
(627)
EL. 21.96
5425
(617A)
EL. 22.18
5422-5425
5426-5427
5426
EA
83
6" V.C.
21L-4


10 80
2 200E
(81A) (81B) (81C)
TANK
18" T.C.
L159KR5R4H58
L159KR5R4H57
L159KR5R4H56
L159KR5R4H55
L159KR5R4H54
L159KR5R4H53
CONC. TRENCH
DRAINAGE DITCH
3½" ALCOHOL (ABANDONED)
10" RAW CEMENT ASBESTOS
EA 79
EA 81
L68
5269
(503E)
CONC.
21M-1


300E
5236
(23)
EL. 27.80
516-523
R-1
R-1-2
159K
159KM1
159KM2
159KM3
159L
159M
159N
159P
159R
159S
159T
159U
159V
159W
159X
159Y
159Z
159AA
159AB
159AC
159AD
159AE
159AF
159AG
159AH
159AI
159AJ
159AK
159AL
159AM
159AN
159AO
159AP
159AQ
159AR
159AS
159AT
159AU
159AV
159AW
159AX
159AY
159AZ
159BA
159BB
159BC
159BD
159BE
159BF
159BG
159BH
159BI
159BJ
159BK
159BL
159BM
159BN
159BO
159BP
159BQ
159BR
159BS
159BT
159BU
159BV
159BW
159BX
159BY
159BZ
159CA
159CB
159CC
159CD
159CE
159CF
159CG
159CH
159CI
159CJ
159CK
159CL
159CM
159CN
159CO
159CP
159CQ
159CR
159CS
159CT
159CU
159CV
159CW
159CX
159CY
159CZ
159DA
159DB
159DC
159DD
159DE
159DF
159DG
159DH
159DI
159DJ
159DK
159DL
159DM
159DN
159DO
159DP
159DQ
159DR
159DS
159DT
159DU
159DV
159DW
159DX
159DY
159DZ
159EA
159EB
159EC
159ED
159EE
159EF
159EG
159EH
159EI
159EJ
159EK
159EL
159EM
159EN
159EO
159EP
159EQ
159ER
159ES
159ET
159EU
159EV
159EW
159EX
159EY
159EZ
159FA
159FB
159FC
159FD
159FE
159FF
159FG
159FH
159FI
159FJ
159FK
159FL
159FM
159FN
159FO
159FP
159FQ
159FR
159FS
159FT
159FU
159FV
159FW
159FX
159FY
159FZ
159GA
159GB
159GC
159GD
159GE
159GF
159GG
159GH
159GI
159GJ
159GK
159GL
159GM
159GN
159GO
159GP
159GQ
159GR
159GS
159GT
159GU
159GV
159GW
159GX
159GY
159GZ
159HA
159HB
159HC
159HD
159HE
159HF
159HG
159HH
159HI
159HJ
159HK
159HL
159HM
159HN
159HO
159HP
159HQ
159HR
159HS
159HT
159HU
159HV
159HW
159HX
159HY
159HZ
159IA
159IB
159IC
159ID
159IE
159IF
159IG
159IH
159II
159IJ
159IK
159IL
159IM
159IN
159IO
159IP
159IQ
159IR
159IS
159IT
159IU
159IV
159IW
159IX
159IY
159IZ
159JA
159JB
159JC
159JD
159JE
159JF
159JG
159JH
159JI
159JJ
159JK
159JL
159JM
159JN
159JO
159JP
159JQ
159JR
159JS
159JT
159JU
159JV
159JW
159JX
159JY
159JZ
159KA
159KB
159KC
159KD
159KE
159KF
159KG
159KH
159KI
159KJ
159KK
159KL
159KM
159KN
159KO
159KP
159KQ
159KR
159KS
159KT
159KU
159KV
159KW
159KX
159KY
159KZ
159LA
159LB
159LC
159LD
159LE
159LF
159LG
159LH
159LI
159LJ
159LK
159LL
159LM
159LN
159LO
159LP
159LQ
159LR
159LS
159LT
159LU
159LV
159LW
159LX
159LY
159LZ
159MA
159MB
159MC
159MD
159ME
159MF
159MG
159MH
159MI
159MJ
159MK
159ML
159MM
159MN
159MO
159MP
159MQ
159MR
159MS
159MT
159MU
159MV
159MW
159MX
159MY
159MZ
159NA
159NB
159NC
159ND
159NE
159NF
159NG
159NH
159NI
159NJ
159NK
159NL
159NM
159NN
159NO
159NP
159NQ
159NR
159NS
159NT
159NU
159NV
159NW
159NX
159NY
159NZ
159OA
159OB
159OC
159OD
159OE
159OF
159OG
159OH
159OI
159OJ
159OK
159OL
159OM
159ON
159OO
159OP
159OQ
159OR
159OS
159OT
159OU
159OV
159OW
159OX
159OY
159OZ
159PA
159PB
159PC
159PD
159PE
159PF
159PG
159PH
159PI
159PJ
159PK
159PL
159PM
159PN
159PO
159PP
159PQ
159PR
159PS
159PT
159PU
159PV
159PW
159PX
159PY
159PZ
159QA
159QB
159QC
159QD
159QE
159QF
159QG
159QH
159QI
159QJ
159QK
159QL
159QM
159QN
159QO
159QP
159QQ
159QR
159QS
159QT
159QU
159QV
159QW
159QX
159QY
159QZ
159RA
159RB
159RC
159RD
159RE
159RF
159RG
159RH
159RI
159RJ
159RK
159RL
159RM
159RN
159RO
159RP
159RQ
159RR
159RS
159RT
159RU
159RV
159RW
159RX
159RY
159RZ
159SA
159SB
159SC
159SD
159SE
159SF
159SG
159SH
159SI
159SJ
159SK
159SL
159SM
159SN
159SO
159SP
159SQ
159SR
159SS
159ST
159SU
159SV
159SW
159SX
159SY
159SZ
159TA
159TB
159TC
159TD
159TE
159TF
159TG
159TH
159TI
159TJ
159TK
159TL
159TM
159TN
159TO
159TP
159TQ
159TR
159TS
159TT
159TU
159TV
159TW
159TX
159TY
159TZ
159UA
159UB
159UC
159UD
159UE
159UF
159UG
159UH
159UI
159UJ
159UK
159UL
159UM
159UN
159UO
159UP
159UQ
159UR
159US
159UT
159UU
159UV
159UW
159UX
159UY
159UZ
159VA
159VB
159VC
159VD
159VE
159VF
159VG
159VH
159VI
159VJ
159VK
159VL
159VM
159VN
159VO
159VP
159VQ
159VR
159VS
159VT
159VU
159VV
159VW
159VX
159VY
159VZ
159WA
159WB
159WC
159WD
159WE
159WF
159WG
159WH
159WI
159WJ
159WK
159WL
159WM
159WN
159WO
159WP
159WQ
159WR
159WS
159WT
159WU
159WV
159WW
159WX
159WY
159WZ
159XA
159XB
159XC
159XD
159XE
159XF
159XG
159XH
159XI
159XJ
159XK
159XL
159XM
159XN
159XO
159XP
159XQ
159XR
159XS
159XT
159XU
159XV
159XW
159XX
159XY
159XZ
159YA
159YB
159YC
159YD
159YE
159YF
159YG
159YH
159YI
159YJ
159YK
159YL
159YM
159YN
159YO
159YP
159YQ
159YR
159YS
159YT
159YU
159YV
159YW
159YX
159YY
159YZ
159ZA
159ZB
159ZC
159ZD
159ZE
159ZF
159ZG
159ZH
159ZI
159ZJ
159ZK
159ZL
159ZM
159ZN
159ZO
159ZP
159ZQ
159ZR
159ZS
159ZT
159ZU
159ZV
159ZW
159ZX
159ZY
159ZZ
UUI

21M-2


10 000N
R-2
UU-A
18" T.C.
T-5278
(503P)
5270
(503F)
FENCE
5267
(503E)
5265
(503)
(EL. 17.82)
CONC. GUTTER
5274
(503L)
S-5279
5266
(503A)
8" V.C.
4" STEEL
CONC. TRENCH
LIC. M.

21M-3

Appendix B: Pipe Section and Manhole Inventory Spreadsheets for Edgewood Area Heat Distribution Piping

Overview

An inventory of the pipe sections and manholes at EA was prepared from the information supplied by DPW personnel, information on the utility maps, and the findings of the system survey. This information has also been stored electronically in a computer spreadsheet to serve as a living reference document for DPW personnel. To facilitate the identification of distribution system sections for use during the condition survey, an identification scheme was developed based on node numbers. The node numbers are shown on the maps in Appendix A. Pipe sections are identified by the node numbers of the section endpoints. Data on the pipe sizes, materials of construction, age, and other aspects were compiled for each section to the extent possible with the information available. In addition, locations of the manholes were tabulated. It is recommended that the computer version of the spreadsheet be updated as changes are made to the system.

Explanatory Notes for Pipe Section Table

Table B1 contains pipe section inventory data. The SECTION ID column contains the Section Identification as described above. To assist with pipe section location, the MAP SHT contains the number of the 40-scale map sheet(s) upon which the pipe section appears. The FROM LOCATION and TO LOCATION columns give the location of the section's endpoints. The OH/UG column notes whether the section is overhead/aboveground (OH) or underground (UG). The STM DIAM column gives the diameter

of the steam line in inches. The R DIAM column gives the diameter of the condensate line (if any) in inches. The LENGTH column gives the length of the section in feet. The MAT CODE column gives the material of construction as follows:

MAT CODE	EXPLANATION OF MATERIALS USED
AG	Aboveground - Insulated & Aluminum-Cased Piping Mounted on Steel Poles, Concrete Piers, or Wood Trestles
RW	Prefabricated (Ricwil) Metal Casing, Heavy Coal Tar Coating
T	Buried Tile (Terra Cotta) System
S-WY	Steel Cast in Wyecor, Direct Buried, No Casing
S-PR	Steel Wrapped with Fiberglass Insulation + Vapor Barrier Surrounded by Protexulate, Direct Buried, No Casing
FGR	Fiberglass-Reinforced Plastic Condensate Return Line

The YEAR INST column gives the approximate year of pipe installation. Exact years were not available. Several locations were identified as NEW. This pipe was installed within the last 10 years, but an exact year was not available. The SUMMER column notes whether or not the section is on or off during the summer. An entry of SOME in this column denotes that the line is used intermittently in the summertime, based on demand.

Explanatory Notes for Manhole Table

Table B2 contains manhole inventory information. A manhole numbering scheme was set up to facilitate the identification of the manholes so that inspection comments could be correlated to them. In general, manhole identifications were assigned for each area beginning at the heating plant and proceeding around the loop. The manholes closest to the plant in each area (E3312, E4160, and E5126) were assigned the numbers 3000, 4000, and 5000, respectively. Identification numbers were assigned to subsequent manholes based upon increments of 10. For example, in the 3000 area, the manhole closest to E3312 was assigned the number 3000, the next manhole was assigned the number 3010, the next manhole was assigned the number 3020, and so forth. Increments of 10 were used to allow additional manholes to be inserted into the inventory system and still remain in order according to location. On the manhole inventory chart, this identification number is contained in the MANHOLE ID column. The NODE or SECTION column indicates the node number for manholes that are located at a node, and the section number for manholes that are located along a pipe section (not at a node). The LOCATION column includes more specific location information.

Table B1. Pipe section identification spreadsheet for APG/EA.

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
3160-3165	21Q	BLD E3160	BLD T3165	OH	2		210	AG	1940	ON
31A-3100	22P	NODE 31A	BLD E3100	OH	6	3	280	AG	1940	ON
31B-3148	22Q	NODE 31B	BLD T3148	OH	6		90	AG	1940	ON
3222-3242	23P	BLD E3222	BLD E3242	OH	1.5	NO	150	AG	1940	ON
32A-3265	23P	NODE 32A	BLD T3265	OH	3		50	AG	1940	ON
32B-3226	23P	NODE 32B	BLD E3226	OH	4	1.5	310	AG	1940	ON
32C-3266	23P	NODE 32C	BLD E3266	OH	1.25		40	AG	1940	ON
32D-3266	23P	NODE 32D	BLD E3266	OH	1.5		120	AG	1940	ON
32E-32L	23P	NODE 32E	NODE 32L	OH	2		20	AG	1940	ON
32F-3222	23P	NODE 32F	BLD E3222	OH	3		40	AG	1940	ON
32G-3244	23P	NODE 32G	BLD E3244	OH	3		440	AG	1940	ON
32H-3228	23P	NODE 32H	BLD E3228	OH	2		10	AG	1940	ON
32I-3230	23P	NODE 32I	BLD E3230	OH	2		10	AG	1940	ON
32J-3232	23P	NODE 32J	BLD E3232	OH	2		10	AG	1940	ON
32K-3234	23P	NODE 32K	BLD E3234	OH	2		10	AG	1940	ON
32L-3222	23P	NODE 32L	BLD E3222	OH	2		60	AG	1940	ON
32L-32K	23P	NODE 32L	NODE 32K	OH	3		450	AG	1940	ON
3312-30A	22-23P,21-24Q	BDG E3312	NODE 30A	OH	6	4	3350	AG	1940	ON
3312-3160	22-23P,21-24Q	BLD E3312	BLD E3160	OH	6	3	3945	AG	1940	ON
3312-3330	24Q	BDG E3312	BDG E3330	OH	8		100	AG	1940	ON
3312-33A	24P	BLD E3312	NODE 33A	OH	5	3	590	AG	1940	ON
3312-3516	24Q,25Q	BDG E3312	BDG E3516	OH	5	2	280	AG	1940	ON

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
3312-37A	24P-S	BDG E3312	NODE 37A	OH	8	4	1930	AG	1940	ON
3326-3325	24P	BLD E3326	BLD E3325	OH	1.5	NO	120	AG	1940	ON
3329-3326	24P	BLD E3329	BLD E3326	OH	1.25	NO	220	AG	1940	ON
33A-3320	24P	NODE 33A	BLD E3320	OH	2.5	1.5	20	AG	1940	ON
33A-3331	24P	NODE 33A	BLD E3331	OH	4	2	160	AG	1940	ON
33AA-3346	24P	NODE 33AA	BDG E3346	OH	1	NO	100	AG	1940	ON
33B-3360	24Q	NODE 33B	BDG T3360	OH	1		10	AG	1940	ON
33C-3370	24Q	NODE 33C	BDG T3370	OH	1		80	AG	1940	ON
33D-3348	24Q	NODE 33D	BDG E3348	OH	1.5		20	AG	1940	ON
33E-3334	24Q	NODE 33E	BLD E3334	OH	3		150	AG	1940	ON
33F-3329	24Q,24P	NODE 33F	BLD E3329	OH	1	NO	90	AG	1940	ON
3514-3525	25Q	BDG E3514	BDG E3525	OH	2	NO	350	AG	1940	ON
3516-35B	25Q	BDG E3516	NODE 35B	OH	2.5	1.25	140	AG	1940	ON
3516-35H	25Q	BDG E3516	NODE 35H	OH	3	NO	360	AG	1940	ON
3560-3566	25R	BLD E3560	BLD E3566	OH	1		40	AG	1940	ON
3563-3567	25R	BDG E3563	BDG E3567	OH	1		30	AG	1940	ON
35A-3510	25Q	NODE 35A	BDG E3510	OH	3	2	420	AG	1940	ON
35B-3500	25P	NODE 35B	BDG E3500	OH	2	1.25	30	AG	1940	ON
35B-3514	25Q	NODE 35B	BDG E3514	OH	2		60	AG	1940	ON
35C-3517	25Q	NODE 35C	BDG T3517	OH	1.5		10	AG	1940	ON
35D-3518	25Q	NODE 35D	BDG T3518	OH	1.5		10	AG	1940	ON
35E-3519	25Q	NODE 35E	BDG T3519	OH	1.5		10	AG	1940	ON
35F-3521	25Q	NODE 35F	BDG T3521	OH	1.5		10	AG	1940	ON
35G-3523	25Q	NODE 35G	BDG T3523	OH	1.5		10	AG	1940	ON

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
35GA-3540	25Q	NODE 35GA	BDG E3540	OH	1.5		10	AG	1940	ON
35H-3550	25Q	NODE 35H	BLD E3550	OH	3		100	AG	1940	ON
35H-35J	25Q	NODE 35H	NODE 35J	OH	2	NO	160	AG	1940	ON
35I-3552	25Q	NODE 35I	BLD E3552	OH	2		140	AG	1940	ON
35J-3542	25Q	NODE 35J	BDG E3542	OH	1.5	NO	120	AG	1940	ON
35J-3546	25Q	NODE 35J	BDG E3546	OH	1.25	NO	140	AG	1940	ON
35K-35KA	25R	NODE 35K	NODE 35KA	OH	8	4	150	AG	1990	ON
35K-35M	25R	NODE 35K	NODE 35M	OH	4	2	180	AG	1940	ON
35KA-3549	25R	NODE 35KA	BDG E3549	OH	8	4	400	AG	1989	ON
35KA-3570	25R	NODE 35KA	BDG E3570	OH	4	2	40	AG	1940	ON
35L-3563	25R	NODE 35L	BDG E3563	OH	3		30	AG	1940	ON
35M-3560	25R	NODE 35M	BDG E3560	OH	3		80	AG	1940	ON
36A-3615	24Q	NODE 36A	BDG 3615	OH	0.75		160	AG	1940	ON
36A-3622	24Q	NODE 36A	BDG E3622	OH	1		90	AG	1940	ON
36B-35K	24R	NODE 36B	NODE 35K	OH	8	4	380	AG	1989	ON
3726-3724	24S	BDG E3726	BDG E3724	OH	3		130	AG	1940	ON
3726-3728	24S	BDG E3726	BDG E3728	OH	2		140	AG	1940	ON
37A-3580	24S,25S	NODE 37A	BDG E3580	OH	3	2	620	AG	1940	ON
37A-3726	24S	NODE 37A	BDG E3726	OH	4	2	220	AG	1940	ON
30A-3081	21Q	NODE 30A	BDG 3081	UG	6	4	250	RW	1940	ON
3220-3224	23P	BLD E3220	BLD E3224	UG	3	NONE	190	T	1940	ON
3224-3226	23P	BLD E3224	BLD E3226	UG	2	1	50	T	1940	ON
32E-3220	23P	NODE 32E	BLD E3220	UG	6	4	430	T	1940	ON
37A-3835	24S	NODE 37A	BDG E3835	UG	6	4	1200	RW	1990	ON

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
4225-42M	24O	BLD 4225	NODE 42M	OH	4	2	130	AG	1992	ON
4160-4162	400	BLD E4160	BLD E4162	UG	2	1.5	50	T	1940	ON
4160-44A	24M	BLD E4160	NODE 44A	UG	8	6	350	T	1940	ON
4160-4810	24L	BLD E4160	BLD E4810	UG	2	1.5	320	S-PR	1991	ON
4225-4230	24N	BLD E4225	BLD E4230	UG	3	1.5	280	T	1962	ON
42A-4221	24N	NODE 42A	BLD E4221	UG	3?	?	700	S-PR	1987?	ON
42A-4229	24N	NODE 42A	BLD E4229	UG	3	3?	500	S-PR	1987?	ON
42B-4227	24N	NODE 42B	BLD E4227	UG	3?	?	20	S-PR	1987?	ON
42C-4228	24N	NODE 42C	BLD E4228	UG	3?	?	20	S-PR	1987?	ON
42D-4224	24N	NODE 42D	BLD E4224	UG	3?	?	40	S-PR	1987?	ON
42E-4223	24N	NODE 42E	BLD E4223	UG	3?	?	180	S-PR	1987?	ON
42F-4222	24N	NODE 42F	BLD E4222	UG	3?	?	40	S-PR	1987?	ON
42M-4210	400	NODE 42M	BLD E4210	UG	2	?	400	S-PR	1992	ON
42M-42N	24O,24N	NODE 42M	NODE 42N	UG	4	2	480	S-PR	1992	ON
42N-4215	24N	NODE 42N	BLD E4215	UG	3	1.5	160	S-PR	1992	ON
42N-4220	24N	NODE 42N	BLD E4220	UG	2	1	80	S-PR	1992	ON
44A-44B	24M	NODE 44A	NODE 44B	UG	4	2	130	T	1940	ON
44A-44C	24M	NODE 44A	NODE 44C	UG	6	6-4	480	T	1940	ON
44A-44F	24M	NODE 44A	NODE 44F	UG	8	3	160	T	1940	ON
44B-4465	24M	NODE 44B	BLD E4465	UG	2.5	2	40	T	1940	ON
44B-4470	24M	NODE 44B	BLD E4470	UG	2.5	2	80	T	1940	ON
44C-4430	24M	NODE 44C	BLD E4430	UG	2.5	NONE	80	T	1940	ON
44C-44D	24M	NODE 44C	NODE 44D	UG	4	4	100	T	1940	ON
44D-4140	24M,23M	NODE 44D	BLD E4140	UG	4	1.5	380	S-PR	1991	ON

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
44D-44E	24M	NODE 44D	NODE 44E	UG	4	3	110	T	1940	ON
44E-4405	24M	NODE 44E	BLD E4405	UG	2.5	2	40	T	1940	ON
44E-4410	24M	NODE 44E	BLD E4410	UG	2.5	2	80	T	1940	ON
44F-44G	24M	NODE 44F	NODE 44G	UG	6	3	180	T	1940	ON
44F-4620	24M	NODE 44F	BLD E4620	UG	4	2.5-1.5	500	S-PR	1991	ON
44G-44H	24M	NODE 44G	NODE 44H	UG	4	3	140	T	1940	ON
44G-44IA	24M	NODE 44G	NODE 44IA	UG	6	3	240	T	1940	ON
44H-4475	24M	NODE 44H	BLD E4475	UG	2.5	2	60	T	1940	ON
44H-4480	24M	NODE 44H	BLD E4480	UG	2.5	3	30	T	1940	ON
44I-4455	24M	NODE 44I	BLD E4455	UG	2.5	2	80	T	1940	ON
44I-4460	24M	NODE 44I	BLD E4460	UG	2.5	2	40	T	1940	ON
44IA-44J	24M	NODE 44IA	NODE 44J	UG	5	3.5	250	T	1940	ON
44J-4435	24M	NODE 44J	BLD E4435	UG	2.5	2	70	T	1940	ON
44J-4440	24M	NODE 44J	BLD E4440	UG	2.5	2	40	T	1940	ON
44J-44K	24M	NODE 44J	NODE 44K	UG	4	3	80	T	1940	ON
44K-4420	24M	NODE 44K	BLD E4420	UG	2.5	2	120	T	1940	ON
44K-44L	24M	NODE 44K	NODE 44L	UG	3.5	2	40	T	1940	ON
44L-42A	24M	NODE 42L	NODE 42A	UG	3	2	400	T	1940	ON
44L-44M	24M	NODE 44L	NODE 44M	UG	3	2	40	T	1940	ON
44M-4415	24M	NODE 44M	BLD E4415	UG	2.5	2	80	T	1940	ON
5126-5125	20N	BLD E5126	BLD E5125	OH	1.5		50	AG	1940	
5126-51E	20M	BLD 5126	NODE 51E	OH	3	NO	370	AG	1940	ON
5126-51J	19N	BLD E5126	NODE 51J	OH	6		80	AG	1940	OFF

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
51E-5135	20M	NODE 51E	BLD E5135	OH	1	NO	60	AG	1940	
51E-5137	20M	NODE 51E	BLD E5137	OH	1?	NO	20	AG	1940	
51E-51G	20M	NODE 51E	NODE 51G	OH	1.5	NO	180	AG	1940	ON
51F-5232	20M	NODE 51F	BLD E5232	OH	1	NO	20	AG	1940	
51G-5234	20M	NODE 51G	BLD E5234	OH	1	NO	20	AG	1940	
51J-51K	19N	NODE 51J	NODE 51K	OH	3		130	AG	1940	OFF
51K-5175	19N	NODE 51K	BLD E5175	OH	1.5		20	AG	1940	OFF
51K-5179	19M,19N	NODE 51K	BLD E5179	OH	3		260	AG	1940	OFF
51KA-5173	19N	NODE 51KA	BLD E5173	OH	1.5		10	AG	1940	OFF
51L-5101	19M	NODE 51L	BLD E5101	OH	3	YES	480	AG	1940	ON
51L-51LA	19M	NODE 51L	NODE 51LA	OH	3	YES	340	AG	1940	ON
51L-51R	18L-M,19M	NODE 51L	NODE 51R	OH	10	YES	960	T	1940	SOME
51M-5146	19M	NODE 51M	BLD E5146	OH	2	YES	60	AG	1940	ON
51O-5180	18M	NODE 51O	BLD E5180	OH	1	YES	120	AG	1940	ON
51R-5188	18L	NODE 51R	BLD E5188	OH	4	YES	260	AG	1940	SOME
52B-5307	20L	NODE 52B	BLD E5307	OH	2		560	AG	1940	OFF
54A-54CA	21L	NODE 54A	NODE 54CA	OH	4		585	AG	1940	OFF
54B-5425	21L	NODE 54B	BLD E5425	OH	1.5		20	AG	1940	OFF
54B-5427	21L	NODE 54B	BLD E5427	OH	2		180	AG	1940	OFF
54C-5452	21L	NODE 54C	BLD E5452	OH	2		20	AG	1940	OFF
54CB-5352	20L	NODE 54CB	BLD E5352	OH	4		625	AG	1940	OFF
55A-54B	21K,21L	NODE 55A	NODE 54B	OH	4		1530	AG	1940	OFF
55A-5590	21K	NODE 55A	BLD E5590	OH	4		160	AG	1940	OFF
5695-5697	17J	BLD E5695	BLD E5697	OH	2		560	AG	1940	OFF

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
56C-56D	19L,18L	NODE 56C	NODE 56D	OH	8	YES	780	AG,FGR	1940	OFF
56D-56E	18L,18K	NODE 56D	NODE 56E	OH	4	NO	400	AG	1940	OFF
56D-57A	18L,17L	NODE 56D	NODE 57A	OH	6	YES	440	AG,FGR	1940	OFF
56E-5648	17J-K,18K	NODE 56E	BLD E5648	OH	2	NO	360	AG	1992	OFF
56FA-56K	18J-K,19K	NODE 56FA	NODE 56K	OH	8		1445	AG	1940	OFF
56FB-56FA	20L	NODE 56FB	NODE 56FA	OH	8		600	AG	1940	OFF
56K-5685	17J	NODE 56K	BLD E5685	OH	4		40	AG	1940	OFF
56K-5695	17J	NODE 56K	BLD E5695	OH	6		290	AG	1940	
57A-5703	17L	NODE 57A	BLD E5703	OH	3	YES	320	AG,FGR	1940	OFF
57A-5707	17L	NODE 57A	BLD E5707	OH	3	YES	10	AG	1940	OFF
55A-5560	21K	NODE 55A	BLD E5560	OH?	1.5		20	?	1940	OFF
5126-51A	20N	BLD E5126	NODE 51A	UG	8	NO	620	S-PR	NEW	ON
5126-51L	19M	BLD E5126	NODE 51L	UG	10	YES	620	T	1940	SOME
5126-52C	20M	BLD E5126	NODE 52C	UG	8	YES	1960	T	1940	OFF
51A-5100	20N	NODE 51A	BLD E5100	UG	4	NO	410	S-PR	NEW	ON
51A-51D	20N	NODE 51A	NODE 51D	UG	4	NO	570	S-PR	NEW	ON
51B-5116	20N	NODE 51B	BLD E5116	UG	1	NO	100	S-PR	NEW	ON
51C-5106	20N	NODE 51C	BLD 5106	UG	2	NO	130	S-PR	NEW	ON
51D-5103	20N	NODE 51D	BLD E5103	UG	2	NO	260	S-PR	NEW	ON
51G-5236	20M,21M	NODE 51G	BLD E5236	UG	1.5	NO	240	T	1940	ON
51H-51I	20M	NODE 51H	NODE 51I	UG	2		160	T	1940	
51HA-5244	20M	NODE 51HA	BLD E5244	UG	1.5		20	T	1940	
51I-5140	20M	NODE 51I	BLD 5140	UG	1.5?		10	T	1940	
51I-5141	20M,19M	NODE 51I	BLD E5141	UG	1.5		160	T	1940	

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
51J-5165	19N	NODE 51J	BLD E5165	UG	4		610	T	1940	OFF
51LA-51P	18M,19M	NODE 51LA	NODE 51P	UG	3	YES	540	S-WY	1980	ON
51N-5181	18M	NODE 51N	BLD E5181	UG	1?	?	10	?		ON
51O-5183	18M	NODE 51O	BLD E5183	UG	3	YES	60	?		ON
51P-5026	18M	NODE 51P	BLD E5026	UG	1.5	YES	130	S-WY	1980	ON
51P-5027	18M	NODE 51P	BLD E5027	UG	1.5?	YES	20	S-WY	1980	ON
51R-56A	18L,19L,20L	NODE 51R	NODE 56A	UG	14	NO	560	T	1940	OFF
5265-5266	21M	BLD E5265	BLD E5266	UG	1.25		40	T	1940	
52A-5246	20M	NODE 52A	BLD E5246	UG	3		60	T	1940	
52C-5265	21L,21M	NODE 52C	BLD 5265	UG	4	NO	280	T	1940	OFF
52C-5422	21L	NODE 52C	BLD E5422	UG	2	NO	240	T	1940	OFF
5352-5354	20L	BLD E5352	BLD E5354	UG	3	YES	100	T,FGR	1940	OFF
5360-5357	20L	BLD E5360	BLD E5357	UG	2		80	T	1940	
54CA-54CB	21L	NODE 54CA	NODE 54CB	UG	4		100	T	1940	OFF
54D-5360	20L	NODE 54D	BLD E5360	UG	3		100	T	1940	OFF
56A-5604	19L	NODE 56A	BLD E5604	UG	4	YES	40	T,FGR	1940	SOME
56A-56B	19L	NODE 56A	NODE 56B	UG	3	YES	290	T,FGR	1940	SOME
56A-56F	19L	NODE 56A	NODE 56F	UG	16	6	870	T	1940	OFF
56B-5609	19L	NODE 56B	BLD E5609	UG	2	YES	50	T,FGR	1940	?
56F-56FC	19K,20L	NODE 56F	NODE 56FC	UG	8		290	S-PR	1992	OFF
56F-56G	20L	NODE 56F	NODE 56G	UG	10	NO	220	?	NEW	OFF
56FC-56FB	19K	NODE 56FC	NODE 56FB	UG	8		325	S-WY	1980	OFF
56G-56J	20L	NODE 56G	NODE 56J	UG	10	NO	500	T	1940	OFF
56I-5365	20L	NODE 56I	BLD E5365	UG	2.5	NO	50	T	1940	OFF

Table B1. (Cont'd).

Section ID	Map Sheet	From Location	To Location	OH/ UG	STM DIAM	R DIAM	Length	MAT Code	Year Inst	Summer
56J-52B	20L	NODE 56J	NODE 52B	UG	10		900	T	1940	OFF
56J-55A	21K,21L	NODE 56J	NODE 55A	AG	4	NO	720	AG	NEW	OFF

Table B2. Manhole identification spreadsheet for APG/EA.

Manhole ID	Node or Section	Location
3000	32E-E3220	NEAR NODE 32E
3010	32E-E3220	NEAR E3222
3020	32E-E3220	NEAR E3220
4000	E4160-E4810	CLOSEST TO E4160
4010	E4160-E4810	BETWEEN E4160 & E4810
4020	E4160-E4810	CLOSEST TO E4810
4030	E4160-44A	BETWEEN E4160 & NODE 44A
4040	NODE 44A	AT NODE 44A
4050	NODE 44B	AT NODE 44B
4060	44A-44C	NEAR BLD E4445
4070	44A-44C	NEAR LEACH RD.
4080	44A-44C	NEAR BLD 4430
4090	NODE 44C	AT NODE 44C
4100	NODE 44D	AT NODE 44D
4110	44D-E4140	NEAR E4140
4120	NODE 44E	AT NODE 44E
4130	NODE 44F	AT NODE 44F
4140	44A-E4620	BETWEEN BLD E4470 & E4475
4150	44A-E4620	NEAR BLD E4620
4160	44F-44G	NEAR BLD E4455
4170	NODE 44G	AT NODE 44G
4180	NODE 44H	AT NODE 44H
4190	NODE 44I	AT NODE 44I
4200	NODE 44IA	AT NODE 44IA
4210	44IA-44J	NEAR BLD E4435
4220	NODE 44J	AT NODE 44J
4230	NODE 44K	AT NODE 44K
4240	NODE 44M	AT NODE 44M
4250	44L-42A	BETWEEN E4415 & E4420
4260	NODE 42A	AT NODE 42A
4270	NODE 42D	AT NODE 42D
4280	NODE 42E	AT NODE 42E
4290	42E-4223	NEAR BLD 4223

Table B2. (Cont'd).

Manhole ID	Node or Section	Location
4300	NODE 42F	AT NODE 42F
4310	42A-E4221	NEAR BLD E4221
5000	E5126-52C	1ST MH AFTER BLD E5126
5010	E5126-52C	NEAR BLD 5238
5020	NODE 51H	AT NODE 51H
5030	NODE 51HA	AT NODE 51HA
5040	E5126-52C	NEAR BLD 5244
5050	NODE 52A	AT NODE 52A
5060	NODE 52B	AT NODE 52B
5070	E5126-52C	ABOUT 200 FT FROM MH 5060
5080	E5126-52C	ABOUT 50 FT FROM MH 5070
5090	NODE 52C	AT NODE 52C
5100	NODE 54D	AT NODE 54D
5110	54A-E5352	BETW BLD E5352 & E5360
5120	E5352	AT BLD E5352
5135	E5380	AT BLD E5380
5130	NODE 56J	AT NODE 56J
5140	NODE 56I	AT NODE 56I
5150	NODE 56H	AT NODE 56H
5160	NODE 56G	AT NODE 56G
5170	REMOVED	
5180	56F-56FA	NEAR BLD 5654
5190	NODE 56FA	AT NODE 56FA
5200	56A-56F	FLEMING & ALLEY
5210	56A-56F	NEAR BLD E5616
5220	NODE 56C	AT NODE 56C
5230	NODE 56A	AT NODE 56A
5240	56A-56B	NEAR BLD E5604
5250	NODE 56B	AT NODE 56B
5260	NODE 51R	AT NODE 51R
5270	NODE 51L	AT NODE 51L
5275	NODE 51M	AT NODE 51M, NEAR BLD E5101
5280	51L-51P	NEAR W.E.P. LINE
5290	NODE 51O	AT NODE 51O

Table B2. (Cont'd).

Manhole ID	Node or Section	Location
5300	51L-51P	NEAR BLACKHAWK RD
5310	E5126-51A	NEAR BLD E5126
5320	E5126-51A	BETWEEN MH 5310 & MH 5330
5330	NODE 51A	AT NODE 51A
5340	NODE 51C	AT NODE 51C
5350	51A-51D	NEAR BLD E5106
5360	51D-E5103	NEAR BLD E5103

Appendix C: 1993 Condition Survey Results for Edgewood Area

Aboveground System: Pipe Section Condition Ratings

Tables C1 and C2 contain pipe section condition ratings for the portions of the aboveground system that were surveyed. In the 3000 area, approximately 16,900 linear feet, or 83 percent of the aboveground system was surveyed. In the 5000 area, approximately 7,600 linear feet, or 58 percent of the aboveground system was surveyed. The 4000 area contains a negligible amount of aboveground piping. The pipe sections are listed in alphanumeric order. Each section that was inspected is given a rating according to the following scale:

G = Good condition: no deficiencies noted; no repairs needed

F = Fair condition: minor deficiencies (such as missing insulation) noted; minor repairs needed

P = Poor condition: major deficiencies (such as leaks or severe steaming) were noted. Replacement should be considered.

Pipe Section Inspection Comments

The pipe sections that were inspected are listed below in alphanumeric order. Most of these sections are aboveground. The comments and deficiencies noted during the walk-through inspection appear under each pipe section identification. Inspections were conducted according to the procedures described in Chapter 3 of the main text. In addition, sections that have been proposed for replacement by APG have been noted.

SECTION 31B-3148: There is a small leak near T3148 next to the building.

SECTION 3222-3242: There is a flange leak near Bldg E3222. There is a small amount of missing insulation. The rest of the line looks good.

SECTION 32A-3265: There is a slight valve leak. The steam and condensate lines are totally uninsulated.

SECTION 32B-3226: The metal poles need recoating. There is missing insulation at elbows and on some lengths of pipe, especially near the expansion loop and on the takeoff to Bldg E3226.

SECTION 32C-3266: There is missing insulation at elbow.

SECTION 32F-3222: There is no insulation. There is an exposed valve that is steaming slightly.

SECTION 3312-30A: There are some sections of missing insulation along this line. An uninsulated section about 15' long was noted near T3151. At the transfer station where lines are tied together, there is missing insulation, and valves are exposed and uninsulated. Eventually, a galvanized steel ladder should be installed to replace the existing wooden one at the transfer station.

SECTION 3312-3160: This section is proposed for replacement with 10 in. steam, 6 in. return. New R line has already been installed from node 32E to Bldg E3148. The new line is in good condition. However, the old line is in poor condition and is undersized. There is missing insulation on several sections of the steam & return lines. The tree growing between the lines near fence adjacent to transfer station should be removed. There is a leaning support pole also near this fence. The expansion loop near E3234 is tilted such that it would be impossible to completely drain it. There is a leaky valve at node 32G and condensate is dripping onto the other pipes. There is another leaky valve near T3151 where the two lines come back together. Just past node 31B, there is a support that appears to be missing pipe hangers and the pipes are resting directly on the cross members of the support.

SECTION 3312-33A: Steel poles need to be recoated. Some elbows have missing insulation.

SECTION 3312-3516: Both steam and condensate lines are missing insulation on some elbows.

SECTION 3312-37A: Proposed for replacement in Year 1 with 10" steam, 6" return. Condensate line is in EXTREMELY poor condition. There were severe condensate leaks and steaming near Bldg E3370. Most leaks were on the top area of pipe. Insulation was badly deteriorated and wet in some areas. Insulation was removed from lines in several locations. Visual inspection revealed that lines were corroding from the outside, most likely due to wet insulation. Steam line was in fair condition, although there was missing insulation in some places, especially at the elbows. There was also missing insulation on return line. Corrosion problems on metal poles. Also,

some cable supports are badly corroded and others are slack. Trees around and between lines should be removed. There is a leaky valve on the return line near node 37A. This valve is not protected from the weather. There is a leaky flange near the junction with steam line 36B-35K. Some of the support poles were leaning. The abandoned, leaning structure near the lines at 3615 should be removed or relocated. Missing insulation was noted near Bldg T3370.

SECTION 33A-3331: Check insulation on section that crosses the road. Steel poles need recoating.

SECTION 33C-3370: There is missing insulation near the junction with the 8 in. main.

SECTION 33E-3334: There is insulation missing at the elbows.

SECTION 3516-35B: Top cross-members of support poles are corroded. A steam trap was blowing in front of Bldg E3516.

SECTION 35A-3510: Steam line is missing insulation on some elbows. The return line is about 2 years old and is in good condition.

SECTION 35B-3500: There is insulation missing from the elbow and insulation missing from about 5' of pipe.

SECTION 35B-3514: There is missing insulation at the elbows.

SECTION 35H-3550: There is no condensate return line. Insulation is missing from elbow near E3550. Support poles need recoating.

SECTION 35H-35J: There is a small amount of insulation missing from elbow. Support poles need recoating.

SECTION 35I-3552: There is a small amount of insulation missing from elbow. Also insulation is missing near E3552. Support poles need recoating.

SECTION 35K-35M: There is a small amount of missing insulation.

SECTION 35KA-3570: There is missing insulation on a section of the line.

SECTION 36B-35K: At one location, the pipes do not rest on the support rollers. Rollers should be adjusted upward so the pipes are supported.

SECTION 3726-3724: This line has been proposed for replacement with same size line overhead.

SECTION 3726-3728: This line has been proposed for replacement with same size line overhead.

SECTION 37A-3580: Metal poles are corroded and should be sandblasted and recoated.

SECTION 37A-3726: This line has been proposed for replacement with same size line overhead. Remove the tree growing between the steam and return lines. There is a small amount of missing insulation.

SECTION 30A-3081: If these are watershed caps where pipes enter the ground, the conduit of the underground line is not pressure-testable.

SECTION 37A-3835: This is an underground line. There was about 2 in. water and steaming in manhole near Bldg 3724. There was also water in the CP test station. Problems reported by O&M personnel with drainage of condensate. Suspect some wet insulation. O&M had to drain condensate line. An excavation was done here, but couldn't locate line. Ground was steaming at soil sample location. No external corrosion problems reported.

SECTION 51L-51R: There was severe steaming at 51R. There is a bent support pole near 5185. There is steaming water in the stream downhill from the manhole.

SECTION 52B-5307: Insulation is missing at the elbows.

SECTION 54A-54CA: O&M says that this line has no function, is in terrible condition, and should be removed. Asbestos is present.

SECTION 54CB-5362: O&M says that this line has no function, is in terrible condition, and should be removed. Asbestos is present.

SECTION 5695-5697: There is an area of steaming near Bldg E5697.

SECTION 56C-56D: The steam line is in fair to poor condition. It is covered with asbestos insulation.

SECTION 56D-56E: There is a small amount of insulation missing on the elbows on the section that goes across the road.

SECTION 56E-5648: There was steaming at the Bldg near node 56E.

SECTION 56FA-56K: Insulation is missing from the elbows on the steam line. The condensate line is out of service and is in failed condition. The pipe supports are somewhat deteriorated and have experienced surface corrosion over 50 to 100% of the surface. In some areas, the lines are overgrown with vegetation (trees, weeds, and grass).

SECTION 56K-5685: Insulation is missing on sections of the line going across the street.

SECTION 5126-51A: This line is underground and has been proposed for replacement with the same size during Year 1. A condensate line is planned. There was dead grass above the line and evidence of poor pipe condition in the manholes inspected.

SECTION 51A-5100: This section is proposed for replacement of steam line and addition of new condensate line.

SECTION 51A-51D: This section is proposed for replacement of steam line and addition of new condensate line.

SECTION 51B-5116: This section is proposed for replacement of steam line and addition of new condensate line.

SECTION 51C-5106: This section is proposed for replacement of steam line and addition of new condensate line.

SECTION 51D-5103: This section is proposed for replacement of steam line and addition of new condensate line.

SECTION 5360-5357: There was steaming near Bldg E5357.

SECTION 56A-5604: The manhole near 5604 was steaming. This indicates the presence of water in the manhole and high heat loss.

SECTION 56A-56F: O & M says this line needs to be rerouted because Bldg E5626 is being torn down; needs to hook into line next to 5604. Steam was coming from the vaults. There was a blowing steam trap near Bldg E5625.

SECTION 56F-56G: The vent between 56F and 56G was steaming.

Underground System: Manhole Inspection Comments

The manholes that were inspected are listed below in numeric order. The comments and deficiencies that were noted during the field inspection appear next to the manhole identification. Note that where severe manhole deficiencies are indicated (particularly steaming or water intrusion), it is likely that the corresponding piping is also deteriorated.

MANHOLE 4040: Dimensions are 12' x 12' x 9' deep. This is a raised-top manhole with steel plate covers.
PROBLEMS: There is no sump pump. Water marks on the walls indicate previous flooding at the 3 foot level. There is considerable debris in the manhole. The hole in the wall from old system penetration should be sealed and waterproofed. Cracks in manhole walls need to be repaired. Repair the valve packing leak. Install new screens at the manhole vent openings. There was no steaming of the conduit vents.

MANHOLE 4130: Manhole was dry at the time of the survey.
PROBLEMS: Valve packing leak should be repaired. Install manhole access ladder. Pipe supports and structural beams are badly corroded. Seal manhole wall cracks and openings. Fifteen feet of piping requires insulation. One of the conduit casings has completely corroded through. There was slight vapor from steam line conduit casing. There is no sump pump.

MANHOLE 4170: Dimensions are 9' x 9' x 9' deep. Manhole was dry at the time of the survey.
PROBLEMS: Valve packing leak should be repaired. Install manhole access ladder. Pipe supports and structural beams are badly corroded. Seal manhole cracks and wall openings. Insulation is missing from piping. There is no sump pump.

MANHOLE 4190: PROBLEMS: Repair valve packing leak. All internal piping requires insulation. Slight vapor was observed at one of the conduit vents. Slight leak was observed in condensate return piping. There were some wall cracks and general deterioration. There is no sump pump.

MANHOLE 4220: Dimensions are 7' x 6' x 7' deep.
PROBLEMS: There was a slight leak in the condensate line. There were two valve packing leaks. Slight vapor was coming from steam conduit vent. There were several large cracks in the manhole walls. There is no sump pump.

MANHOLE 4230: Dimensions are 6' x 8' x 7' deep.
PROBLEMS: Steam and water were coming out of the tile conduit run to the building. Internal support steel channels are severely corroded. Valve packing leak should be repaired. The vent on one of the conduit casings is disconnected. The manhole floor is wet but not flooded. There is no sump pump.

MANHOLE 5000: Distribution conduit is full round tile.
PROBLEMS: Manhole walls are cracked and spalling. There is no access ladder. Roller guides on each side of the manhole are broken. Prefabricated top for manhole is not set properly on manhole walls. New hinges should be provided for access hatch. There is no sump pump.

MANHOLE 5010: Dimensions are 4' x 7' x 5' deep. Conduit is full round tile.
PROBLEMS: There is no access ladder. The manhole is outlined by dead grass indicating high heat loss. There is considerable corrosion on internal piping. There is no sump pump.

MANHOLE 5020: Dimensions are 4' x 5' x 8' deep.
PROBLEMS: Dead grass outlines the conduit run from Manhole 5010, indicating high heat loss. There is no insulation on the 8 in. steam line or the 2 in. take-off. There is no sump pump.

MANHOLE 5030:
PROBLEMS: Dead grass outlines conduit path between manholes, indicating high heat loss. The 8" steam line and 2" take-off are not insulated. Two inch line extends to outside of building and is exposed and uninsulated for a distance of 25 ft. Exposed pipe surface temperature is 260 °F. There is no sump pump. There is a heavy mud deposit on the manhole floor.

MANHOLE 5055: Dimensions are 5' x 5' x 6' deep.
PROBLEMS: Seven feet of 8" steam line are not insulated. There is no sump pump. Condensate is being wasted through a 1" line; the failed steam trap should be replaced.

MANHOLE 5060: Dimensions are 6' x 6' x 9' deep. Manhole has solid concrete top with steel plate access hatch. This is a transition manhole from the underground to the aboveground system.
PROBLEMS: Anchor in manhole is broken. There is no sump pump.

MANHOLE 5070: Dimensions are 5' x 4' x 9' deep.
PROBLEMS: Five feet of 8" steam line are uninsulated. There is no sump pump. The 4 in. take-off and the underside of steel plate tops are badly corroded.

MANHOLE 5080: Transition manhole from aboveground to underground system.
PROBLEMS: Manhole is filled with mud covering the heat-carrying pipe. There is no sump pump.

MANHOLE 5090: PROBLEMS: Dry grass outlines the route of the conduit to manhole, indicating high heat loss. Insulation in the tile conduit has fallen off for a distance of about 5 ft from manhole wall. Most of the internal piping is uninsulated. Surface temperature of the steam line is 330 °F and of the condensate line is 170 °F. The 8" steel channel holding the heavy slip-type expansion joint is badly corroded and weakened. Crack in the manhole wall may allow groundwater infiltration. There is no sump pump.

MANHOLE 5095: Dimensions are 4' x 6' x 5' deep. Extends from underground to aboveground at building.
PROBLEMS: There is no insulation on the steam line. The steam line is corroded. The anchor support beam is corroded. There is no sump pump.

MANHOLE 5100: PROBLEMS: Insulation is missing from pipes in manhole. Manhole internals are very deteriorated and are in poor condition. There is no sump pump.

MANHOLE 5130: Dimensions are 8' x 10' x 9' deep. This is a transition manhole from underground to aboveground system. This is a raised-top manhole.
PROBLEMS: Failed steam trap in manhole should be replaced. There is no sump pump.

MANHOLE 5135: This manhole was steaming during the drive-by inspection, indicating high heat loss and the presence of standing water in manhole.

MANHOLE 5160: This manhole was steaming during the drive-by inspection, indicating high heat loss and the presence of standing water in the manhole.

MANHOLE 5220: Contains 16" steam line (steel in terra cotta), and a fiberglass condensate return line.
PROBLEMS: There were 3 to 4 in. of water in the bottom of the manhole. The manhole was steaming. There is no sump pump.

MANHOLE 5230: This manhole was steaming during the drive-by inspection, indicating high heat loss and the presence of standing water in the manhole.

MANHOLE 5240: This manhole was steaming during the drive-by inspection, indicating high heat loss and the presence of standing water in the manhole.

MANHOLE 5310: This is a raised-top manhole with solid steel plate top. Contains 8 in. steam line but no condensate return. The steam line is encased in a 16 in. diameter full round tile. Manhole contains a bellows-type expansion joint. Steam line is in good condition.
PROBLEMS: Access ladder rungs are severely corroded and should be replaced. Insulation is needed for about 10 ft of piping. Screening on manhole wall vents should be replaced. Insulation in the tile conduit is missing for a distance of about 3 ft from the manhole wall. Temperature reading on the steam pipe surface is 330 °F. There is no sump pump.

MANHOLE 5320: Dimensions are 11' x 6' x 8' deep. Raised-top manhole with solid steel plate top. Manhole contains a bellows-type expansion joint.
PROBLEMS: Access ladder rungs are very corroded (up to 50 percent material loss on some) and should be replaced. Insulation is needed for about 10 feet of piping. Screening on manhole wall vents should be replaced. Insulation in the tile conduit is missing for a distance of about 3 feet from the manhole wall. Manhole braces need to be replaced. Pipe supports are in good condition. There is no sump pump.

MANHOLE 5330: This manhole is located in a restricted area and could not be inspected. Heavy steaming was noted from the manhole ventilation pipes, indicating serious problems.

MANHOLE 5340: Dimensions are 4' x 6' x 7' deep.
PROBLEMS: Manhole floor is covered with mud almost completely enveloping the piping. Piping has no insulation. There is no sump pump.

MANHOLE 5350: This is a solid top manhole with access hatch.
PROBLEMS: There is no insulation on the internal piping. There is no sump pump.

MANHOLE 5360: Dimensions are 5' x 8' x 6' deep. This is a solid top manhole with access hatch. PROBLEMS: There is no insulation on 6' of piping. There is no sump pump.

Table C1. Aboveground pipe section condition ratings for the 3000 Area.

Section ID	Length (ft)	Steam	Condensate
31A-3100	280	G	G
31B-3148	90	F	NONE
3222-3242	150	F	NONE
32A-3265	50	P	P
32B-3226	310	F	F
32C-3266	40	F	NONE
32F-3222	40	P	NONE
32G-3244	440	G	NONE
32L-3222	60	G	NONE
32L-32K	450	G	NONE
3312-30A	3350	F/G	F
3312-3160	3945	G/P	P*
3312-33A	590	F	F
3312-3516	280	F	F
3312-37A	1930	F	P
33A-3320	20	F	F
33A-3331	160	F	F
33AA-3346	100	G	NONE
33C-3370	80	F	NONE
33D-3348	20	G	G
33E-3334	150	G	NONE
33F-3329	90	G	G
3514-3525	350	G	G
3516-35B	140	G	G
3516-35H	360	G	NONE
35A-3510	420	F	G
35B-3500	30	G	F
35B-3514	60	F	F
35H-3550	100	G	NONE
35H-35J	160	F	NONE
35I-3552	140	F	NONE
35K-35KA	150	G	G
35K-35M	180	G	G

Table C1. (Cont'd).

Section ID	Length (ft)	Steam	Condensate
35KA-3549	400	G	G
35KA-3570	40	F	F
36A-3615	160	G	G
36A-3622	90	ABANDONED	
36B-35K	380	G	G
3726-3724	130	F	P
3726-3728	140	F	P
37A-3580	620	G	G
37A-3726	220	F	P
TOTAL RATED (LF)	16895		
*Good in replaced areas around 3100			

Table C2. Aboveground pipe section condition ratings for the 5000 area.

Section ID	Length (ft)	Steam	Condensate
5126-51J	80	G	NONE
51J-5165	610	G	NONE
51J-51K	130	G	NONE
51K-5179	260	G	NONE
51L-5101	480	G	NOT RATED
51L-51R	960	F	NOT RATED
51R-5188	260	G	NONE
52B-5307	560	F	NOT RATED
5695-5697	560	F	NOT RATED
56C-56D	780	F-P	G
56D-56E	400	G	NONE
56D-57A	440	G	G
56E-5648	360	F	NONE
56FA-56K	1445	F-P	SHUTOFF
56K-5695	290	F	NOT RATED
TOTAL RATED (LF)	7615		

Appendix D: Worksheet for Determining Potential Savings Associated With Returning Condensate

Figure D1 contains a worksheet for calculating the potential cost savings that could be realized from returning condensate instead of dumping it. The dumping of condensate requires the addition of makeup water at the boiler to replace what has been lost. The calculation takes into account the cost of the makeup water, the cost of energy to heat the water, and the cost of treatment chemicals.

PROCEDURE: (1) Enter data to right of heavy bar "%"
(2) Complete form referring to designated charts.

Hot Water Temperature (condensate return)	$\%T_H$=	°F
Cold Water Temperature (make up)	$\%T_C$=	°F
Difference in Temperature (T_H-T_C)	ΔT=	°F
Chart *Find T_H on the x-axis 1 *read C_T on the y-axis	C_T=	Btu/°F*gal ≈8.34
Energy Content of 1 Gallon $I_1=\Delta T*C_T$	I_1=	Btu/gal
Velocity of Condensate Return	%V=	ft/sec
μ = V(12in/ft)	μ=	in/sec
Inner Diameter of Condensate Pipe	%d=	in
Radius of Condensate Pipe (r=d/2)	r=	in
Chart *Find T_H on the x-axis 2 *Read V_g on the y-axis	V_g=	in^3/gal ≈231
Condensate Flow rate $I_2=\mu\pi r^2/V_g$	I_2=	gal/sec
Fraction of Year System is Operational (full year=1.0; 4 months=0.33)	$\%f_1$=	[0.0-1.0]
Fraction of Condensate Returned	$\%f_2$=	[0.0-1.0]
Energy Make-up Per Year $I_3=f_1*(1-f_2)*I_1*I_2*(31.54)$	I_3=	MBtu/yr
Price of Energy	$\%P_E$=	$/MBtu
Cost to Heat Condensate Make-up Water Per Year ($C_1=I_3*P_E$)	C_1=	$/yr
Total Cost of Water + Chemical Treatment per Gallon (make-up water)	$\%P_C$=	$/gal
Yearly Cost of Water + Chemicals $C_2=I_2*P_C(3.154x10^7$ sec/yr)	C_2=	$/yr
Total Cost (potential savings of condensate return line repair/replacement) $C_T=C_1+C_2$	C_T=	$/yr

Figure D1. Worksheet for calculating cost savings related to recycling condensate instead of dumping it.

Chart 1: cp vs T (see line 4 of worksheet).

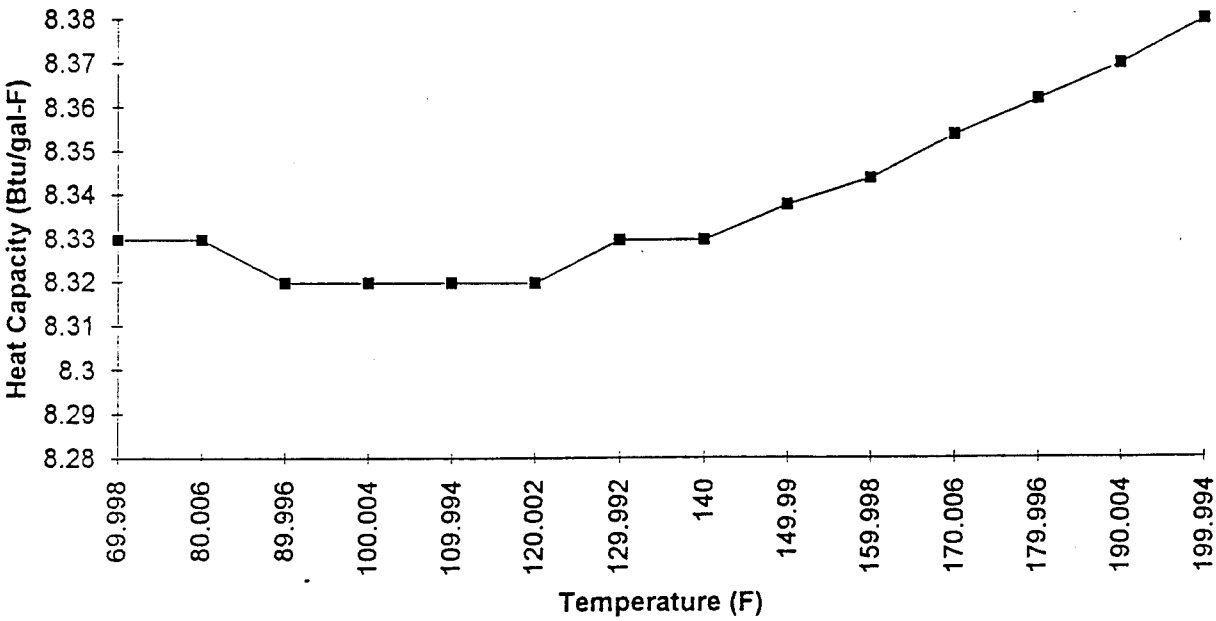


Chart 2: in^3/gal vs T (see line 10 of worksheet).

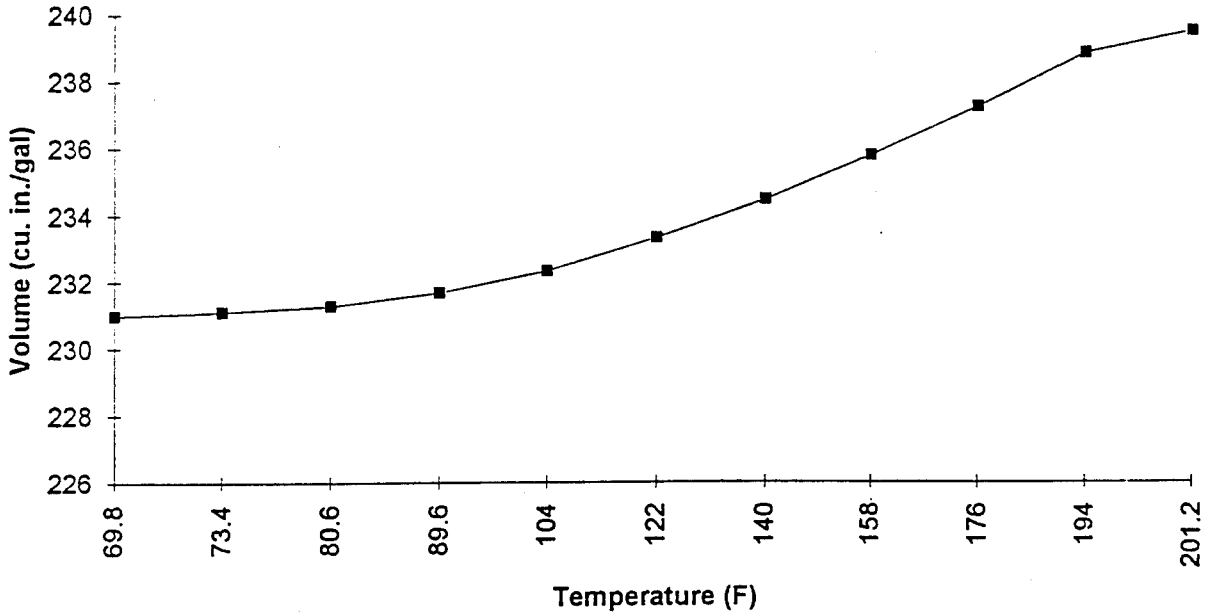


Figure D1. (Cont'd.)

Appendix E: Excerpt From CEGS 02695: Site Classification Procedure

The following text is a direct excerpt from CEGS 02695 detailing the site classification procedure for heat distribution systems.

```
*************************************************************************
DEPARTMENT OF THE ARMY                                CEGS-02695 (May 1991)
U.S. ARMY CORPS OF ENGINEERS                        -----------------------
                                                      Superseding
                                                      CEGS-02695 (March 1989)

                GUIDE SPECIFICATION FOR MILITARY CONSTRUCTION

*************************************************************************

                              SECTION 02695

            PREAPPROVED UNDERGROUND HEAT DISTRIBUTION SYSTEM

                                  05/91
*************************************************************************
             NOTE:  This guide specification covers the
             requirements for an insulated underground heat
             distribution system and/or condensate return system
             of the preapproved and pre-engineered type.  This
             guide specification is to be used in the preparation
             of project specifications in accordance with ER
             1110-345-720.
*************************************************************************

PART 1   GENERAL

*************************************************************************
            NOTE F:  Classification of the site conditions for
             the underground heat distribution system will be
             based on the following criteria:

             a.  Underground Water Condition Classification

             If at all practicable, a soils engineer familiar
             with the underground water conditions at the site
```

should be employed to establish the site classification. Site classifications are defined in Table A. If underground water conditions at the site are not available, a detailed site classification survey should be made. This survey should be conducted within the framework of the following guidelines:

(1) The survey should be made after the general layout of the system has been determined and should cover the entire length of the proposed system.

(2) If at all possible, the survey should be conducted during the time of the year when the water table is at its highest point. If this is not possible, water table measurements should be corrected to indicate conditions likely to exist at the time of year when the water table is at its highest point.

(3) As a minimum, information on groundwater conditions, soil types, terrain, and precipitation rates/irrigation practices in the area of the system should be collected.

(4) Information on terrain and precipitation rates/irrigation practices may be obtained from available records at the installation.

(5) Information on water table conditions and soil types will be obtained through borings, test pits, or other suitable exploratory means. Generally, a boring or test pit should be made at least every 100 feet along the line of the proposed system, and each exploratory hole should extend to a level at least 5 feet below the anticipated elevation of the bottom of the system. If a significant difference in underground conditions is found at adjacent exploratory points, additional explorations should be made between those points in order to determine more precisely where the change occurs.

Upon completion of the site classification survey, each exploration point should be classified as A, B, C, or D on the basis of the criteria presented in Table B. Soil types given in Table B are based on the soil classification system presented in ASTM D 2487. When doubt exists as to the proper classification of a point, the next higher classification should be assigned; e.g., if a

certain point could be considered either B or C, it should be assigned a B classification. Those decisions, like many engineering decisions, frequently will require the exercise of judgment on the part of the responsible engineer. The worst underground water condition encountered between any two valve manholes shall determine the class of system to be installed in that section of the system.

b. Soil Corrosiveness Classification

The soil at the site should be classified as corrosive or noncorrosive on the basis of the following criteria:

(1) Corrosive -- The soil resistivity is less than 30,000 ohms-centimeter (ohm-cm) or stray direct currents can be detected underground.

(2) Noncorrosive -- The soil resistivity is 30,000 ohm-cm or greater and no stray direct currents can be detected underground.

The classification should be made by an experienced corrosion engineer based on a field survey of the site carried out in accordance with recognized guidelines for conducting such surveys. When the survey indicates that the soil at the site is corrosive, the system shall be cathodically protected.

c. Soil pH

If there is any reason to suspect that the soil pH will be less than 5.0 anywhere along the proposed path of the system, pH measurements should be made at pipeline depth at close intervals along the proposed route, and all locations at which the pH is less than 5.0 should be indicated in the contract documents. Soil pH should be determined by an experienced soils engineer, preferably the same engineer responsible for other soil engineering work.

d. Soil Stability

The load-bearing qualities of the soil in which the system will be installed should be investigated by an experienced soils engineer, again preferably the same engineer responsible for other soils engineering work, and the location and nature of potential soil problems should be identified.

Table A. SITE CLASSIFICATION DEFINITIONS

Site Classification	General Conditions for Classification
A - Severe	1. The water table is expected to be frequently above the bottom of the system and surface water is expected to accumulate and remain for long periods in the soil surrounding the system. 2. The water table is expected to be occasionally above the bottom of the system and surface water is expected to accumulate and remain for long periods in the soil surrounding the system.
B - Bad	1. The water table is expected to be occasionally above the bottom of the system and surface water is expected to accumulate and remain for short periods (or not at all) in the soil surrounding the system. 2. The water table is expected never to be above the bottom of the system but surface water is expected to accumulate and remain for short periods in the soil surrounding the system.
C - Moderate	The water table is expected never to be above the bottom of the system but surface water is expected to accumulate and remain for short periods in the soil surrounding the system.
D - Mild	The water table is expected never to be above the bottom of the system and surface water is not expected to accumulate or remain in the soil surrounding the system.

Table B. SITE CLASSIFICATION CRITERIA

Site Classification (Note 1)	Water Table Level	Soil Types (Note 2)	Terrain	Precipitation Rates or Irrigation Practices in Area
A	Water table within 1 foot of bottom of system	Any	Any	Any
	Water table within 5 feet of bottom of system	GC, SC, CL, CH,	Any	Any
B	Water table within 5 feet of bottom of system	GW, GP, SW, SP	Any	Any
	No groundwater encountered	GC, SC, CL, CH, OH	Any	Equivalent to 3 in. or more in any one month or 20 in. or more in one year
C	No groundwater encountered	GM, SM, ML, OL,	Any	Equivalent to 3 in. or more in any one month or 20 in. or more in one year
	No groundwater encountered	GC, SC, CL, CH, OH	Any except low areas	Equivalent to less than 3 in. in any one month or less than 20 in. in one year.
D	No groundwater encountered	GW, GP, SW, SP	Any	Any
	No groundwater encountered	GM, SM, ML, OL, MH	Any	Equivalent to less than 3 in. in any one month or less than 20 in. in one year.

Note 1: See Table A. SITE CLASSIFICATION DEFINITIONS.

Note 2: See ASTM D 2487 for Soil Classifications.

Appendix F: Material Safety Data Sheets (MSDS) for Boiler Water Treatment Chemicals Used at Edgewood Area

01-20-1993 13:51 14106712617 DIRECTORATE PUBLIC WORK/EA HEAT/ P.02

MATERIAL SAFETY DATA SHEET

VESTAL LABORATORIES

I - PRODUCT IDENTIFICATION

COMPANY NAME: Calgon Vestal Laboratories

ADDRESS: 5035 Manchester Avenue
St. Louis, MO 63110

Tel No: (314)535-1810
Nights: (314)862-2000
CHEMTREC:(800)424-9300

PRODUCT NAME: CB-260

Product No.: 1724

Synonyms: Reducing Agent

II - HAZARDOUS INGREDIENTS OF MIXTURES

MATERIAL:	(CAS#)	% By Wt.	TLV	PEL
Sodium Sulfite	(7757-83-7)	<15	N/A	N/A

III- PHYSICAL DATA

Vapor Pressure, mm Hg: Like Water
Evaporation Rate(ether=1): N/AV
Solubility in H2O: Complete
Freezing Point F: N/AV
Boiling Point F: >212
Specific Gravity H2O=1 @25C: 1.14 - 1.16

Vapor Density (Air=1)60-90F: Like H2O
% Volatile by wt @80%
pH @ Solution 7.2-7.8
pH as Distributed: N/A
Appearance: Dark amber liquid
Odor: Slight chemical odor

IV - FIRE AND EXPLOSION

Flash Point F: Not flammable

Flammable Limits: N/A

Extinguishing Media: Product is not flammable.

Special Fire Fighting Procedures: None

Unusual Fire and Explosion Hazards: None

V - REACTIVITY DATA

Stability - Conditions to avoid: None known

Incompatibility: Strong oxidizers

Hazardous Decomposition Products: Oxides of sulfur when heated to decomposition.

Conditions Contributing to Hazardous Polymerization: None known

(Cont'd on Page 2)

CB-260

VI - HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE (Medical Conditions Aggravated/Target Organ Effects,
A. ACUTE (Primary Route of Exposure) EYES and SKIN:On the basis of animal testing,we would not expect this product to produce any skin or eye irritation.INGESTION:Results from acute toxicity testing show that the material would not be considered toxic as defined by the CPSC protocols.
B.SUBCHRONIC,CHRONIC,OTHER: No available information was found.

VII - EMERGENCY AND FIRST AID PROCEDURES

Good First Aid should be followed in all cases of exposure.
EYES:In case of eye contact,flush with plenty of water for at least 15 minutes.If irritation develops,call a physician.

VIII - SPILL OR LEAK PROCEDURES

Spill Management: Dike area to contain as much spilled material as possible.Remove any remaining material by absorbing on vermiculite or other suitable material and place in sealed container for disposal.

Waste Disposal Methods: Flush with plenty of water.Dispose of in accordance with local,state and federal regulations.

IX - PROTECTION INFORMATION/CONTROL MEASURES

Respiratory: Not required	Eye: Not required	Glove: Not required

Other Clothing and Equipment: Not required

Ventilation: Normal

X - SPECIAL PRECAUTIONS

Precautions to be taken in Handling and Storing: Wash thoroughly after handling.Keep container closed.Exercise caution in the storage and handling of all chemical substances.

Additional Information: Read and observe all label precautions.

Prepared by:R.C.Jente Revision Date:08/12/87

Seller makes no warranty, expressed or implied, concerning the use of this product other than indicated on the label. Buyer assumes all risk of use and/or handling of this material when such use and/or handling is contrary to label instructions.

While Seller believes that the information contained herein is accurate, such information is offered solely for its customers' consideration and verification under their specific use conditions. This information is not to be deemed a warranty or representation of any kind for which Seller assumes legal responsibility.

01-20-1993 13:52 14106712617 DIRECTORATE PUBLIC WORK/EA HEAT/ P.04

MATERIAL SAFETY DATA SHEET

VESTAL LABORATORIES

I - PRODUCT IDENTIFICATION

COMPANY NAME: Calgon Vestal Laboratories

ADDRESS: 5035 Manchester Avenue
St. Louis, MO 63110

Tel No: (314)535-1810
Nights: (314)862-2000
CHEMTREC:(800)424-9300

PRODUCT NAME: CB-409

Product No.: 1198

Synonyms: Caustic pH Adjuster

II - HAZARDOUS INGREDIENTS OF MIXTURES

MATERIAL:	(CAS#)	(ORAL LD50)	% By Wt.	TLV	PEL
Sodium Hydroxide	(1310-73-2)	(140mg/kg)	50	2mg/m3	2mg/m3

III- PHYSICAL DATA

Vapor Pressure, mm Hg: Like Water
Evaporation Rate(ether=1): N/A
Solubility in H2O: Complete
Freezing Point F: N/A
Boiling Point F: 288
Specific Gravity H2O=1 @25C: 1.53

Vapor Density (Air=1)60-90F: Like H2O
% Volatile by wt <5
pH @ Solution N/A
pH as Distributed: (undiluted) >13
Appearance: Water-white to turbid liq.
Odor: Characteristic

IV - FIRE AND EXPLOSION

Flash Point F: N/A

Flammable Limits: N/A

Extinguishing Media: Product is not flammable or combustible.Use media appropriate for the primary source of fire.

Special Fire Fighting Procedures: Use caution when fighting any fire involving chemicals.A self-contained breathing apparatus is essential.

Unusual Fire and Explosion Hazards: Contact with some metals can generate hydrogen gas.

V - REACTIVITY DATA

Stability - Conditions to avoid: None known

Incompatibility: Acids,Contact with some metals such as magnesium, aluminum,zinc(galvanized),tin,chromium,brass and bronze may generate hydrogen.

Hazardous Decomposition Products: Unknown

Conditions Contributing to Hazardous Polymerization: Product will not polymerize.

(Cont'd on Page 2)

01-20-1993 13:53 14106712617 DIRECTORATE PUBLIC WORK/EA HEAT/ P.05

CB-409

VI - HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE (Medical Conditions Aggravated/Target Organ Effects,
A. ACUTE (Primary Route of Exposure) EYES:Contact with eyes will result in severe burns,permanent tissue damage and possible blindness.SKIN: (Primary Route of Exposure)Contact with skin will result in severe irritation or burns with possible scarring.INGESTION:Will result in severe burns of the mouth,throat,esophagus and stomach with severe damage of contacted tissue.Can result in internal bleeding and death. INHALATION:Inhalation of mists can result in severe respiratory irritation and possible pneumonitis.
B.SUBCHRONIC,CHRONIC,OTHER: No available information was found.

VII - EMERGENCY AND FIRST AID PROCEDURES

EYES:Immediately flush eyes with plenty of water for at least 15 minutes.See a physician.SKIN:Immediately wash with soap and plenty of water for at least 15 minutes while removing contaminated clothing. Seek medical aid.INGESTION:If swallowed,DO NOT induce vomiting.Give milk if available or water to dilute.Call physician or Poison Control Center.Never give anything by mouth to an unconscious person. INHALATION:If inhaled,remove to fresh air.If not breathing,give artificial respiration.If breathing is difficult,give oxygen.Seek medical aid.

VIII - SPILL OR LEAK PROCEDURES

Spill Management: Contain spill.Absorb on absorbent material and place in a D.O.T.-approved container for disposal.Flush spill residue to the sanitary sewer with large dilutions of water where local restrictions permit.

Waste Disposal Methods: Dispose of in accordance with all federal, state and local regulations.

IX - PROTECTION INFORMATION/CONTROL MEASURES

Respiratory: Where engineering controls are impractical,use NIOSH-approved respirator appropriate for conditions.	Eye: Chemical goggles and face shield	Glove: Rubber

Other Clothing and Equipment: Rubber apron and rubber boots

Ventilation: Local exhaust ventilation recommended to control air concentrations below established limits.

X - SPECIAL PRECAUTIONS

Precautions to be taken in Handling and Storing: Do not get in eyes,on skin or clothing.Keep container closed.Wash thoroughly after handling.
Additional Information: Always add slowly to water.Read and observe all labeled precautions.

Prepared by:R.C.Jente Revision Date:08/03/87

Seller makes no warranty, expressed or implied, concerning the use of this product other than indicated on the label. Buyer assumes all risk of use and/or handling of this material when such use and/or handling is contrary to label instructions.

While Seller believes that the information contained herein is accurate, such information is offered solely for its customers' consideration and verification under their specific use conditions. This information is not to be deemed a warranty or representation of any kind for which Seller assumes legal responsi-

01-20-1993 13:54 14106712617 DIRECTORATE PUBLIC WORK/EA HEAT/ P.06

MATERIAL SAFETY DATA SHEET

VESTAL LABORATORIES

I - PRODUCT IDENTIFICATION

COMPANY NAME: Calgon Vestal Laboratories

ADDRESS: 5035 Manchester Avenue
St. Louis, MO 63110

Tel No: (314)535-1810
Nights: (314)862-2000
CHEMTREC:(800)424-9390

PRODUCT NAME: CB-150

Product No.: 1722

Synonyms: Phosphate

II - HAZARDOUS INGREDIENTS OF MIXTURES

MATERIAL: (CAS#)	% By Wt.	TLV	PEL
According to the OSHA Hazard Communications Standard,29CFR 1910.1200,this product contains no hazardous ingredients.	N/A	N/A	N/A

III- PHYSICAL DATA

Vapor Pressure, mm Hg: Like Water	Vapor Density (Air=1)80-90F: Like H2O
Evaporation Rate(ether=1): N/AV	% Volatile by wt 80
Solubility in H2O: Complete	pH @ Solution N/A
Freezing Point F: N/AV	pH as Distributed: 6.0
Boiling Point F: >212	Appearance: White liquid
Specific Gravity H2O=1 @25C: 1.17	Odor: N/AV

IV - FIRE AND EXPLOSION

Flash Point F: Not flammable	Flammable Limits: N/A

Extinguishing Media: Product is not flammable.

Special Fire Fighting Procedures: None

Unusual Fire and Explosion Hazards: None

V - REACTIVITY DATA

Stability - Conditions to avoid: N/AV

Incompatibility: Strong oxidizers

Hazardous Decomposition Products: Unknown

Conditions Contributing to Hazardous Polymerization: N/A

(Cont'd on Page 2)

CB-150

VI - HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE (Medical Conditions Aggravated/Target Organ Effects.
A. ACUTE (Primary Route of Exposure) EYES and SKIN:Not expected to produce any skin or eye irritation.INGESTION:Product is not considered to be toxic.
B.SUBCHRONIC,CHRONIC,OTHER: No available information was found.

VII - EMERGENCY AND FIRST AID PROCEDURES

EYES:In case of eye contact,flush with cool water for at least 15 minutes.If irritation develops,call a physician.SKIN:If irritation develops,flush area and contact a physician.Good first aid should be followed in all cases of exposure.

VIII - SPILL OR LEAK PROCEDURES

Spill Management: Dispose of in accordance with local,state and federal regulations.Dike area to contain as much spilled material as possible Remove any remaining material by absorbing on vermiculite or other suitable material and place in a sealed container for disposal.

Waste Disposal Methods: Flush with plenty of water.Dispose of in accordance with local,state and federal regulations.

IX - PROTECTION INFORMATION/CONTROL MEASURES

Respiratory: Not required	Eye: Not required	Glove: Gloves recommended

Other Clothing and Equipment: Not required

Ventilation: Normal

X - SPECIAL PRECAUTIONS

Precautions to be taken in Handling and Storing: Wash thoroughly after handling.Keep container closed.Exercise caution in the storage and handling of all chemical substances.

Additional Information: Read and observe label precautions.

Prepared by:R.C.Jente Revision Date:08/08/87

Seller makes no warranty, expressed or implied, concerning the use of this product other than indicated on the label. Buyer assumes all risk of use and/or handling of this material when such use and/or handling is contrary to label instructions.

While Seller believes that the information contained herein is accurate, such information is offered solely for its customers' consideration and verification under their specific use conditions. This information is not to be deemed a warranty or representation of any kind for which Seller assumes legal responsibility.

01-20-1993 13:55 14106712617 DIRECTORATE PUBLIC WORK/EA HEAT/ P.08

CALGON VESTAL LABORATORIES

MATERIAL SAFETY DATA SHEET

I - PRODUCT IDENTIFICATION

COMPANY NAME: Calgon Vestal Laboratories

ADDRESS: 5035 Manchester Avenue
St. Louis, MO 63110

Tel No: (314)535-1810
Nights: (314)535-1395
CHEMTREC:(800)424-9300

PRODUCT NAME: MagnAMINE-327

Product No.: 1740

Synonyms: Condensate corrosion inhibitor

II - HAZARDOUS INGREDIENTS OF MIXTURES

MATERIAL:	(CAS #)	% By Wt.	TLV	PEL
morpholine	(110-91-8)	< 30	20ppm	20ppm (skin)
diethylaminoethanol	(100-37-8)	< 25	10ppm	10ppm (skin)

III- PHYSICAL DATA

Vapor Pressure, mm Hg: unknown
Evaporation Rate(ether=1): unknown
Solubility in H2O: complete
Freezing Point F: NA
Boiling Point F: NA
Specific Gravity H2O=1 @25C: 1.00-1.04

Vapor Density (Air=1)80-90F: unknown
% Volatile by wt 100
pH @ Solution NA
pH as Distributed: 11.6-12.0
Appearance: clear yellow liquid
Odor: "fishy" amine odor

IV - FIRE AND EXPLOSION

Flash Point F: 168 (TOC)

Flammable Limits: Unknown

Extinguishing Media: CO2, dry chemical, alcohol foam, water spray.

Special Fire Fighting Procedures: Firefighters should wear protective clothing and use NIOSH-approved breathing apparatus.

Unusual Fire and Explosion Hazards: Emits toxic vapors under fire conditions. Vapors are heavier than air and may travel along ground to distant source of ignition.

V - REACTIVITY DATA

Stability - Conditions to avoid: Keep away from heat and open flame.

Incompatibility: Oxidizing agents, reactive metals, strong acids.

Hazardous Decomposition Products: Carbon monoxide, carbon dioxide, ammonia, disodium oxide, oxides of nitrogen.

Conditions Contributing to Hazardous Polymerization: Will not occur.

(Cont'd on Page 2)

MagnAMINE-327

VI - HEALTH HAZARD DATA

EFFECTS OF OVEREXPOSURE (Medical Conditions Aggravated/Target Organ Effects,
A. ACUTE (Primary Route of Exposure) INHALATION:May cause respiratory irritation, shortness of breath, dizziness if inhaled. (Primary Route of Exposure) EYES:Fumes irritating to mucous membranes. Will cause severe burns on contact. (Primary Route of Exposure) SKIN:Causes severe irritation or burns. Penetration may be slow and extent of damage depends on duration of exposure. INGESTION:Causes burns to mouth, throat and stomach.
B. SUBCHRONIC,CHRONIC,OTHER: None known.

VII - EMERGENCY AND FIRST AID PROCEDURES

EYES:Flush with water for 15 minutes and get medical attention. SKIN: Remove contaminated clothing and shoes. Wash exposed areas with soap and plenty of water. If irritation develops, get medical attention. INHALATION:Remove to fresh air. If symptoms persist, get medical attention. INGESTION:Give water or milk to dilute. Do NOT induce vomiting. Get immediate medical attention.

VIII - SPILL OR LEAK PROCEDURES

Spill Management: Contain spill. Extinguish ignition sources. Ventilate area. Absorb onto inert material. Flush residue with water.

Waste Disposal Methods: Incinerate in accordance with all local, state and federal regulations.

IX - PROTECTION INFORMATION/CONTROL MEASURES

Respiratory: NIOSH-recommended for organic vapors if air limits are exceeded.	Eye: Safety goggles	Glove: Vinyl or neoprene

Other Clothing and Equipment: Protective clothing.

Ventilation: Local exhaust ventilation recommended.

X - SPECIAL PRECAUTIONS

Precautions to be taken in Handling and Storing: Keep away from heat, sparks and flame. Use only with adequate ventilation. Avoid breathing vapors.

Additional Information: Avoid contact with eyes, skin and clothing. Wash thoroughly after handling.

Prepared by: D. Godward Revision Date:08/08/91

Seller makes no warranty, expressed or implied, concerning the use of this product other than indicated on the label. Buyer assumes all risk of use and/or handling of this material when such use and/or handling is contrary to label instructions.

While Seller believes that the information contained herein is accurate, such information is offered solely for its customers' consideration and verification under their specific use conditions. This information is not to be deemed a warranty or representation of any kind for which Seller assumes legal responsibility.

Appendix G: Information on Lead-Based Paint Testing

Lead-based primers, especially red lead primers, were commonly used on industrial structures until recently. There are no laws that prohibit their use on industrial facilities, but removing the paints during maintenance poses health and disposal problems. Structures as old as the Edgewood aboveground heat distribution system are likely to be primed with lead-based paint.

Before any maintenance or demolition of structures, the coatings should be tested for lead. There are three methods for testing lead in paint. The most reliable is laboratory analysis of paint chips. Another method is x-ray fluorescence (XRF) analysis. This method has the advantage of providing a direct on-the-spot readout of lead content, but it is not as accurate as laboratory analysis. There is potential for false negative and false positive readings when lead levels are low. It is, however, a good screening tool when high lead concentrations are expected. The third method is chemical spot test kits. This a qualitative test only; it gives no estimation of the amount of lead present.

When planning maintenance or demolition involving lead-painted structures, several regulations must be considered. The Occupational Safety and Health Administration (OSHA) has enacted an Interim Final Lead in Construction Standard (1926.62), which applies to all construction workers who may be exposed to lead on the job. Workers exposed to 30 micrograms of lead per cubic meter or more must be given medical surveillance and training in lead hazards. The maximum allowable exposure for workers is 50 micrograms of lead per cubic meter averaged over an 8-hour working day.

Demolition or maintenance of lead-painted structures may generate a hazardous waste. The *Resource Conservation and Recovery Act* (RCRA) prescribes how waste is to be contained, stored, transported, and disposed of. The test for determining whether a waste is to be classified as hazardous is the Toxicity Characteristic Leaching Procedure (TCLP) test. Wastes that leach more lead than 5 ppm are to be classified as hazardous.

Additional information is available from the USACERL Paint Technology Center, 217-352-6511, ext. 427.

Appendix H: The Army Boiler Water Quality Assurance Program

The following information paper was provided by the U.S. Army Center for Public Works (CECPW-ES). CECPW-ES is in charge of the Army's Boiler Water Quality Assurance program.

INFORMATION PAPER

CECPW-ES
14 Feb 94

SUBJECT: Boiler Water Quality Assurance Analysis Services

1. PURPOSE: To provide information on the availability of Boiler Water Quality Assurance services for improvement of boiler plant operations.

2. FACTS:

a. The control of water chemistry in boiler water and condensate return systems is very important for maintaining proper boiler operation. Boiler plants with poor control over their water chemistry will experience higher energy and operating costs, more plant shutdowns, higher maintenance, higher equipment replacement costs and decreased safety. It is important to have Quality Assurance (QA) performed by an independent consultant to sustain good water chemistry control. A good QA evaluation will verify the effectiveness of the DEH program and provide recommendations for making improvements in the control of a particular boiler plant's water chemistry program.

b. The QA check analyses are now available through a contract with Puckorius & Associates, Inc (P&A). Their address is attached.

c. Individual installations can fund these services themselves by preparing a delivery order directly to the contractor. The QA services must be requested through an executed delivery order before sending samples to the contractor. The procedure is fairly simple.

- Prepare a delivery order to request QA services for six months of boiler system water samples.
- Describe the contract services required and cite the contract number in the delivery order. A sample description is attached.
- After Puckorius has received the executed delivery order, send samples and in-plant test results to them.

d. Puckorius & Associates will perform the analysis, prepare a report with recommendations and send it to the installation within two weeks of receiving a sample. Sample shipping containers and new sample bottles will also be sent to the installation. If you need additional sample bottles and containers, please contact Puckorius & Associates. Questions or comments regarding these services should be directed to the names below.

Nelson Labbe /DSN 656-5202
Andrew Jackson /DSN 656-5204

Address of Puckorius & Associates, Inc. for sample analysis

Puckorius & Associates, Inc.
P.O. Box 2440
1202 Hwy. 74, Suite 210
Evergreen, CO 80439

phone: (303) 674-9897
fax: (303) 674-1453

Sample description of services

Item	Description of Supply or Services	Quantity	Unit	Unit Price	Total Cost
1.	CLIN 2AA, Boiler Water Analysis	24	ea	$113.00	$2712.00
2.	CLIN 2AB, Condensate Analysis	4	ea	126.00	504.00
3.	CLIN 2AC, Condensed Steam Analysis	1	ea	45.00	45.00
4.	CLIN 2AD, Hot Water Boiler Analysis	8	ea	63.00	504.00
5.	CLIN 2AE, Feedwater Analysis	4	ea	110.00	440.00
6.	CLIN 2AF, Deposit Analysis	1	ea	150.00	150.00
7.	CLIN 2AG, Corrosion Tester	2	ea	200.00	400.00
				TOTAL:	4,755.00

Send Analysis Reports to : *Show the address that you want the analysis reports sent to.*

Contract: DACA31-92-D-0063
Contractor: Puckorius & Associates, Inc.
P.O. Box 2440
1202 Hwy. 74, Suite 210
Evergreen, CO 80439
(303) 674-9897

Notes:

Adjust the quantities to whatever number you need. Try to order enough for six months worth of samples at a time. Once an order is prepared with a description similar to the one above, the rest of the ordering procedure is the same as any other purchase request placed for your boiler plants.

A copy of the delivery order must be sent to U.S. Army Center for Public Works , ATTN: CECPW-ES (Andrew Jackson), 7701 Telegraph Road, Alexandria, VA 22310-3862, *so that U.S. Army Center for Public Works (USACPW) can monitor contract work for your installation. The above prices are good until Oct 94. Prices and contract CLIN numbers change each option year in October. Copies of the contract are available upon request.*

If you have any boiler water treatment problems or questions regarding the contractor's work, contact USACPW.

Appendix I: Cathodic Protection Testing and Criteria and CP Diagnostic Program

How Cathodic Protection Works

When cathodic protection (CP) is applied to a structure, the structure's electrical potential changes. Understanding these changes in potential will help the user understand whether CP systems are functioning through the application of CP criteria.

The electrical potential of a structure is always measured relative to a stable "reference electrode" or "half cell." Thus, the potential that is reported is actually the potential difference between the structure of interest and the reference electrode. For underground structures, the most commonly used reference electrode is the copper-copper sulfate ($Cu/CuSO_4$) electrode. Other types of reference electrodes are sometimes used in other environments; for example silver- silver chloride is commonly used in seawater applications. To assure that potential readings are properly interpreted, the reference electrode used should always be noted. For example, readings taken with a copper-copper sulfate reference cell should be reported as ##.### volts vs $Cu/CuSO_4$.

When cathodic protection is properly applied, it produces a change in the potential of a structure with respect to a reference electrode placed in the soil in proximity to that structure. The cathodic protection current makes the measured potential more negative than the potential was before the current was applied. The amount of change produced is a measure of the effectiveness of the cathodic protection at that location.

The changes in electrical potential of the structure (with respect to a $Cu/CuSO_4$ reference electrode) that occur when the cathodic protection current is applied are depicted graphically in Figure I1. Before current is applied, the structure is at its original, or "native" potential. When the current is applied, there is a change in potential in the negative direction at the instant the current is turned on. As the current is continuously applied over an extended period of time, the potential tends to increase negatively because of polarization. Polarization of a structure occurs over a long period and a structure may not be entirely polarized even after the cathodic protection system has been in continuous operation for many months. If the current is interrupted after the structure has polarized, the potential becomes less negative

at the instant of turn-off. The potential then begins to decay, or depolarize, back to the original or native potential. Well coated structures tend to polarize and depolarize more quickly than uncoated or poorly coated structures.

Cathodic Protection Criteria

Structure-to-electrolyte potential measurements are analyzed to determine whether a structure is cathodically protected. (For a discussion of structure-to-electrolyte potential measurements, see "Structure-to-Electrolyte Potential Measurements" later in this appendix. Determination of whether or not protection is being achieved is made through the use of cathodic protection criteria. Unfortunately, there is not one simple criterion that has been accepted by all cathodic protection engineers and that can be practicably measured in the field under all circumstances.

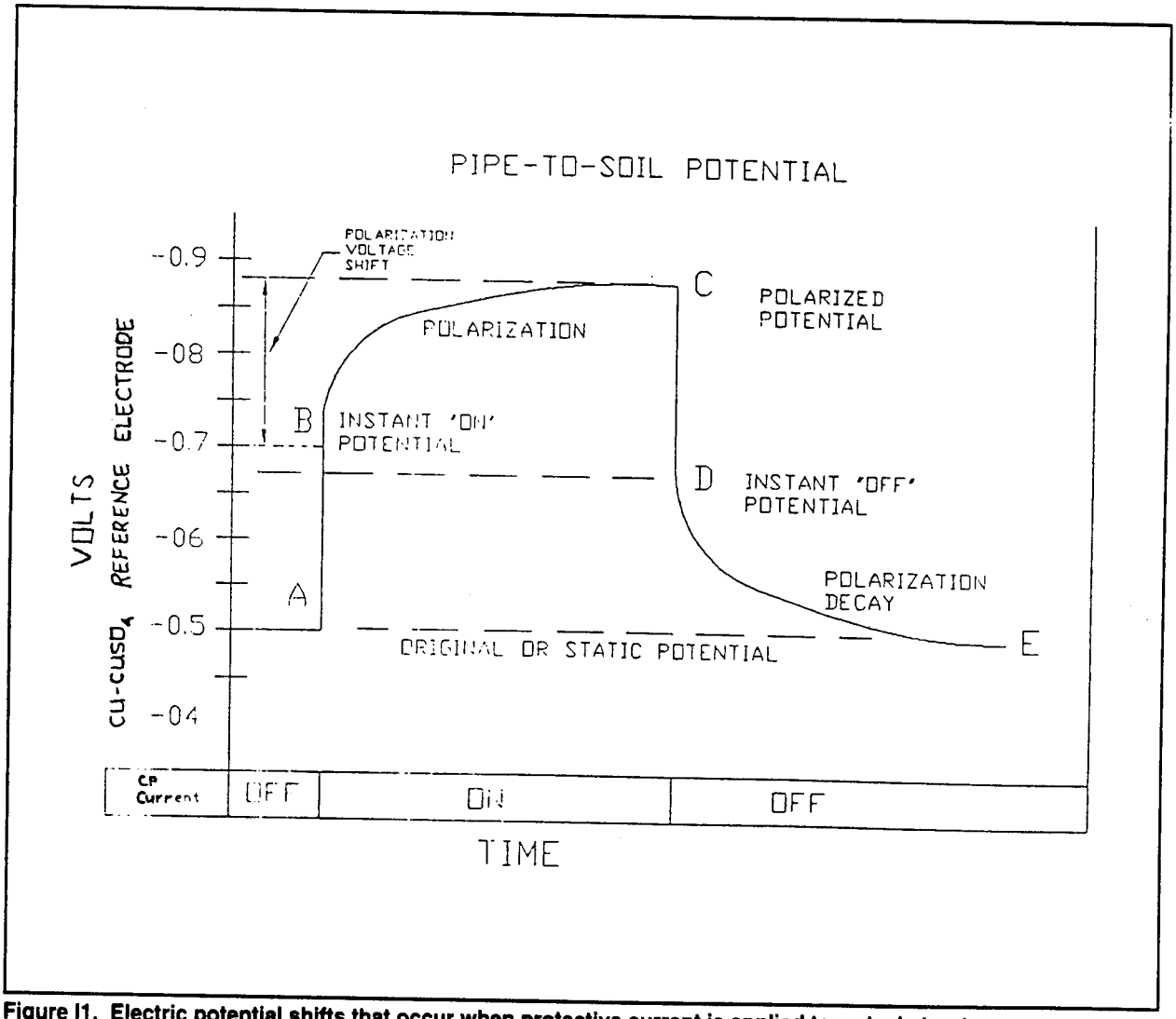


Figure I1. Electric potential shifts that occur when protective current is applied to a steel structure.

Guidance on the criteria of cathodic protection for external corrosion control on underground structures is found in two recommended practices (RPs) published by the National Association of Corrosion Engineers (NACE). These are RP0169-92, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*, and RP-02-85, *Control of External Corrosion on Metallic Buried, Partially Buried, or Submerged Liquid Storage Systems*. The criteria for cathodic protection of steel given in these two RPs were previously identical, but RP0169-92 was recently revised (April 1992) and the criteria contained therein were updated. RP-02-85 is currently undergoing revision, and it is believed that the criteria contained therein will be updated the same as RP0169-92. The revisions are mostly concerned with the handling of the IR drop present in structure-to-soil potential readings and the elimination of criteria that are impractical for field use. Thus, because the most recent guidance on criteria for protection of underground steel is given in RP0169-92, this is the guidance that will be quoted and explained here.

1. A negative (cathodic) potential of at least 850 mV with the cathodic protection applied. This potential is measured with respect to a saturated $Cu/CuSO_4$ reference electrode contacting the electrolyte. Voltage drops other than those across the structure-to-electrolyte boundary must be considered for valid interpretation of this voltage measurement.
2. A negative polarized potential of at least 850 mV relative to a saturated $Cu/CuSO_4$ reference electrode. (Polarized potential is defined as the potential across the structure/electrolyte interface that is the sum of the corrosion potential and the cathodic polarization.)
3. A minimum of 100 mV of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte. The formation or decay of polarization can be measured to satisfy this criterion.

Understanding the IR Drop

The -0.85 V on-potential criterion states that voltage drops other than those across the structure-to-electrolyte boundary must be considered when interpreting the measurements. The other two criteria refer to polarization and polarized potential. This is of utmost concern when evaluating potential measurements because only polarization provides cathodic protection. No protection is provided by the voltage drops other than those across the structure-to-electrolyte (i.e., structure-to-soil) boundary.

Unfortunately, when structure-to-soil potentials are measured in the field, the measurement includes not only the voltage drop across the structure-to-soil boundary, but also includes other voltage drops in the circuit. Corrosion engineers refer to these

other, extraneous voltage drops as IR drop or IR error. This IR drop must be minimized when taking measurements so the voltage drop measured is as close as possible to the actual voltage drop across the structure-to-soil boundary. Figure I2 shows the region of the potential-vs-time curve which is considered to be the IR drop.

Two IR drops are referred to: the *soil IR drop* and the *metal IR drop*. Husock (1979, pp 37-47) defines and explains these IR drops and offers suggestions for considering them in the interpretation of structure-to-soil potentials. (Note: "E" in the following description refers to the absolute value of the measured structure-to-soil potential.)

> It is the IR drops in the soil $(IR)_S$ and metal of the pipeline $(IR)_M$ that must be considered as shown in Figure I2 and the following equation:
>
> $$E = E_P + (IR)_M + (IR)_S$$
>
> where:
>
> E_P = the pipe-to-soil potential which exists between a hypothetical reference electrode immediately adjacent to the pipe surface and a metallic contact to the pipe close to the reference electrode.
>
> $(IR)_S$ = Voltage (IR) drop in soil between the hypothetical reference electrode placed immediately adjacent to the pipe surface and the actual position of the reference electrode placed at grade (or other location).
>
> $(IR)_M$ = Voltage (IR) drop in pipe (often referred to as metal IR drop) between a point of metallic contact close to the reference electrode and the actual point of contact to the structure. . . .
>
> Both of these IR drops are an inherent part of the potential which is measured. On coated pipe, soil IR drop is not usually significant, but it can be considerable on bare pipes especially in higher resistivity soils. Metal IR drops, particularly where there is substantial line current, must be considered on all lines, both coated and bare, particularly where there is some distance between the contact point and the reference electrode location.

In the application of the NACE potential criterion (i.e., -0.85 V. for steel), regardless of structure material, the potential must be interpreted as a polarized value. Structure-to-electrolyte measurements for comparison to the chosen criterion must be free of IR drop error. Sometimes this can be achieved by placing the reference electrode immediately adjacent to the structure or, alternatively, by measuring the potential instantaneously after the cathodic protection current is interrupted (sometimes called *instant-off* potentials).

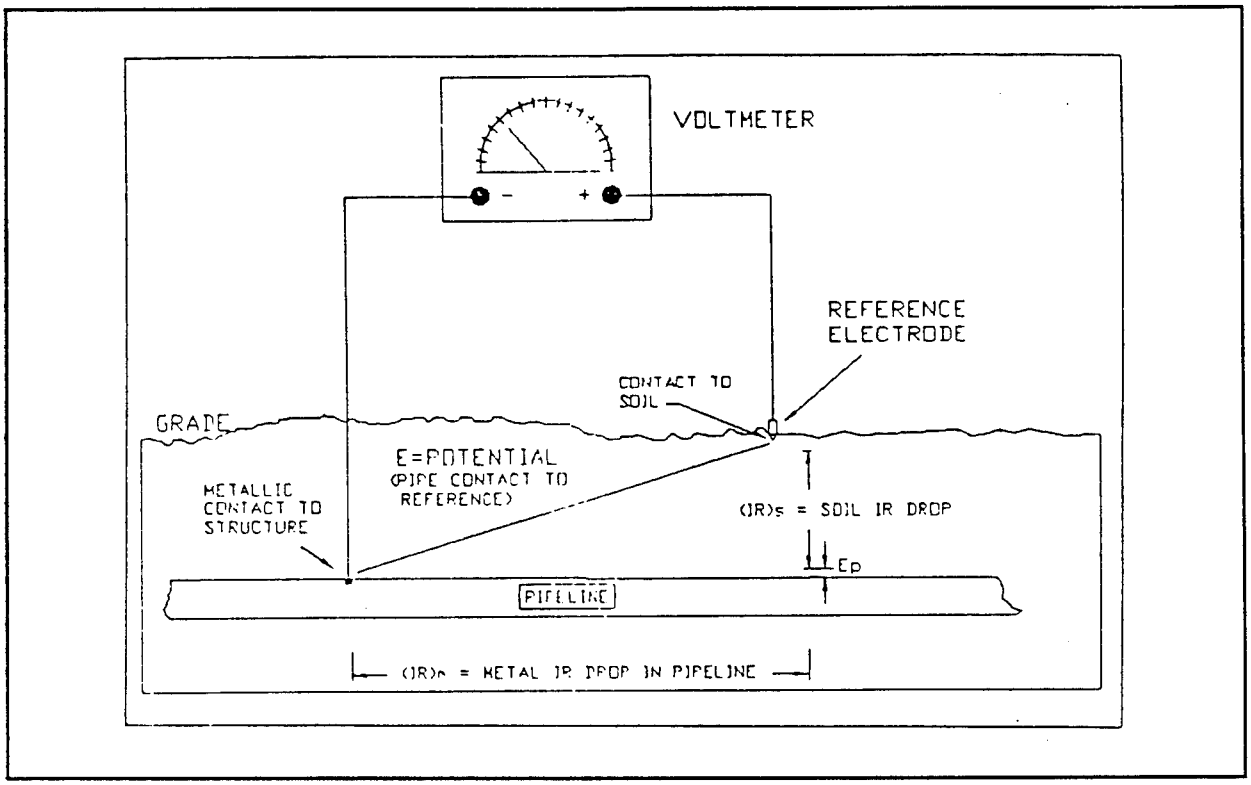


Figure I2. IR drops in structure-to-soil potential.

The IR drop also affects the 100 mV polarization voltage shift criterion. According to the 100 mV criterion, if the corrosion potential is polarized electronegatively by at least 100 mV, protection is considered to be achieved. To apply this criterion it is necessary to record structure corrosion potentials before the energization of the cathodic protection system, and then to measure polarized potentials at the same locations after the cathodic protection system has been placed in operation. Since polarization is a function of time, it is sometimes advantageous—especially on bare structures—to allow the cathodic protection system to operate for a period of time before conducting the potential survey. It is imperative that all potentials measured after energization be free of IR drop so a valid comparison to the native potentials can be made. If baseline corrosion potential data were not recorded before energization, the cathodic protection system can be turned off to allow the structure to depolarize so that the baseline data can be obtained. The disadvantage of this is that the structure could remain unprotected for an extended period of time.

Selection of a Criterion

As stated in NACE RP-01-69, no one criterion for evaluating the effectiveness of cathodic protection has proven satisfactory for all conditions. The selection of the

criterion to be used should be made carefully, preferably with the assistance of a corrosion engineer who has expertise in cathodic protection. To select the proper criterion for a particular situation, it is important to understand each criterion and its limitations. If the results obtained with the particular criterion selected indicate that the level of cathodic protection on the structure does not meet that criterion, one does not have the freedom to simply select another criterion which may be more easily met. The criterion *must* be appropriate for the application.

Each criterion described above has advantages and disadvantages that affect its applicability to a given situation. Table I1 presents the appropriate uses for each criterion. For further details, the reader should consult ESL TR-79-14.

Structure-To-Electrolyte Potential Measurements

Overview

As explained above, the structure-to-electrolyte potential is one of the most important measurements made for cathodic protection because it is used to determine whether a structure is receiving the intended corrosion protection. These are the measurements that are compared with the criteria described above. USACPW typically recommends that the measurements be taken annually.

The electrical potential of a structure is always measured relative to a stable *reference electrode* or *half cell*. Thus, the potential that is reported is actually the potential

Table I3. Summary of cathodic protection criteria.

CRITERIA: CHARACTERISTICS	-0.85 Volt	100 Millivolt Polarization Shift	-0.85 Volt Instant Off
Frequency of Use	Most Often Used	Seldom Used	Rarely Used
Readings Taken with CP Current:	ON	OFF and ON then OFF	OFF
Ease of Field Use	Easiest	Not Easy	Suitable
Suitable for Use in Stray Current Areas	Yes	No	No
Must Consider IR Drop	Yes	No	No
Primarily Used On	Well Coated Structures	Bare Structures	Well Coated Structures
Can Also Be Used When Interconnected With	Copper	Aluminum or Galvanized Steel	Copper

difference between the structure of interest and the reference electrode. If the potential of the structure is lower than that of the reference cell, it is reported as negative (-). If the potential of the structure is higher than that of the reference cell, it is reported as positive (+). An analogy for this is the use of "sea level" as a reference point for elevation measurements. For underground structures, the most commonly used reference electrode is the copper-copper sulfate ($Cu/CuSO_4$) electrode. Measurements are reported as "##.### volts referenced to $Cu/CuSO_4$."

Measurement Procedure: Sacrificial Systems

Structure-to-electrolyte potential measurements in sacrificial systems are conducted using the arrangement shown in Figure I3. One terminal of a high-resistance voltmeter is connected to the structure or component to be tested and the other terminal is connected to the $Cu/CuSO_4$ reference cell. The electrode is placed on the soil as close as possible to the structure. The potential is then read off of the voltmeter. Possible points of connection to the buried structure are at:

- cathodic protection test stations (best)
- risers
- hydrants
- exposed service entrances or manways

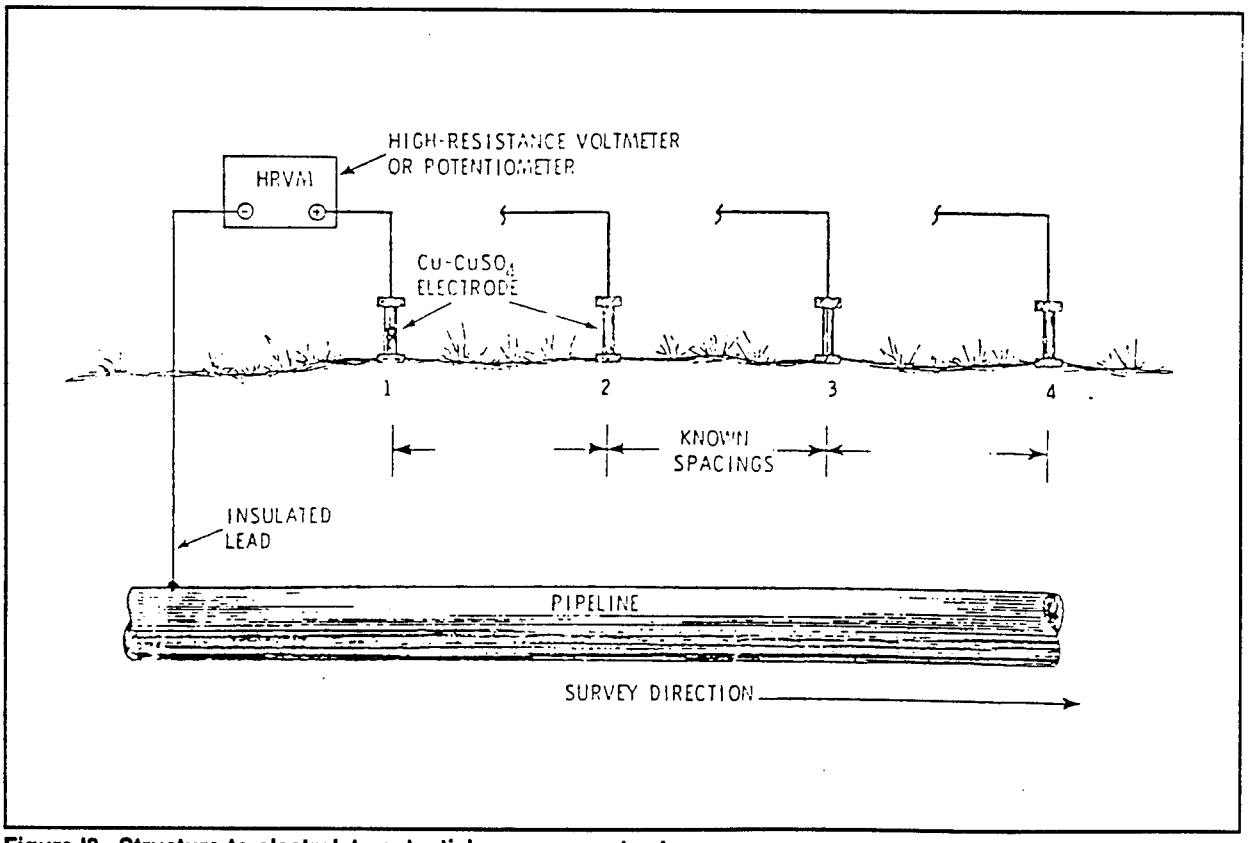


Figure I3. Structure-to-electrolyte potential measurement setup.

- meter installations
- valve installations.

Determine the polarity (+ or -) of the reading by examining the voltmeter connections. By convention, most corrosion engineers connect the negative terminal to the structure and the positive terminal to the reference cell. This requires the polarity of the measurement to be reversed when it is recorded since the electrode is the point of reference. For example, if the reading on the meter is 0.88 V, the reading would be recorded as -0.88 referenced to $Cu/CuSO_4$. Always examine the meter connections to be sure of the polarity.

The reference cell should be placed as close as possible to the structure to minimize the soil IR drop (IR_s). Usually, soil resistivities and magnitude of current flow in sacrificial systems are not large enough to cause a significant IR drop.
To ensure meaningful results:

1. Take readings with the reference cell directly over the structure to be tested.
2. Make sure there is good electrical contact between the plug of the reference electrode and the soil; it may be necessary to scrape down to moist earth or to dampen the soil with water.
3. If a test station is not available, it is important to make sure there is good electrical contact with the structure; test prods or clamps should be scraped on the metal surface or a metal file to penetrate any dirt or oxide coatings.
4. Verify that the correct polarity (+ or -) of the measurement has been reported by examining the voltmeter connections.

Knowledge of the electrical continuity within the structure being tested is *extremely important* when taking potential readings. In situations where the structures are electrically continuous, electric contact may be made at an easily accessible point and the reference cell may simply be moved from one component to the other. If components of the system are electrically isolated, electrical contact with each system component must be made separately. If in doubt about the electrical continuity of components, *play it safe* by connecting to each component separately.

Measurement Procedure: Impressed Current Systems

As discussed previously, the IR drop is a significant source of error in obtaining potential measurements. This is particularly true in an impressed current system because of the larger magnitudes of current (and usually higher soil resistivities) involved. It is important to correct for the IR drop because in an active cathodic protection environment IR drop always causes potentials to indicate more protection

than actually exists. In other words, a reading that includes IR drop may show that a structure is cathodically protected when in reality it is not.

Two basic methods can be used for the measurement of IR-free potentials: (1) current interruption or instant-off readings and (2) use of a device that samples the potential waveform and determines the IR-free potential.

The most widely accepted method for correcting the IR drop is by conducting instant-off potential measurements. This is done by interrupting the cathodic protection current (i.e., turning off the rectifier or disconnecting sacrificial anodes) and reading the potential at the moment the current is interrupted. A high-resistance voltmeter may be used for this measurement, and the same connections are made as for sacrificial systems. If multiple current sources affect the structure being tested, current interruption must be synchronized (i.e., all sources must be interrupted at the same time). To do this automatically in an impressed current system, current interruptors can be installed at each rectifier and synchronized. Synchonized current interruption can also be achieved manually by posting one technician at each rectifier and communicating via two-way radio (walkie-talkie) to synchronize the shutting off of the rectifiers.

Several devices may be used to sample the potential waveform and determine the IR-free potential. Recently developed devices such as the waveform analyzer and the cathodic protection datalogger make this procedure relatively simple. These computerized devices actually analyze the potential waveform and automatically determine the point at which the current (and, consequently, the IR drop) is zero. An oscilloscope may also be used to analyze the waveform.

Facilities Under Pavement

It has been found that measuring structure-to-electrolyte potentials of structures under pavement by using a reference electrode in contact with the pavement will result in appreciable error. The most efficient way of getting accurate measurements is to install a permanent pavement insert with a removable plug that will allow insertion of a reference electrode. The hole beneath the insert should be filled with sand to within 4 in. of the top of the insert to allow the reference electrode to make contact with the sand.

If pavement inserts cannot be used or installed, structure-to-electrolyte measurements can be taken by positioning the reference electrode at a joint or crack in the pavement where contact can be made with the soil. This method may not be as accurate as the pavement insert method.

Interpretation of Measurements

Structure-to-soil potential measurements should be interpreted according to the cathodic protection criteria set forth in an earlier section of this chapter. If cathodic protection criteria are not met on any part of the structure, corrective action must be taken.

Testing for Electrical Isolation

Overview

If dielectric or isolating flanges or unions have been installed in a system, it is important to test them periodically to verify that isolation is still being maintained. The reason for this is that the cathodic protection system has been designed to protect a certain amount of pipe/tank surface area. If the dielectric joints fail and the protected structure becomes electrically continuous with another structure, the cathodic protection system suddenly must supply current for both structures. The anodes will be consumed more rapidly than the designer intended, and the life of the cathodic protection system will be shortened—sometimes dramatically if the additional structure has a much larger surface area than the originally protected structure.

Measurement Procedure and Interpretation

For buried structures, direct measurement of the insulation resistance of a joint is difficult because the conductivity of the soil effectively bypasses the joint. Some joints are located in valve pits or other locations where they are not in direct contact with the soil and are accessible for testing using the aboveground methods given in the next paragraph. Buried insulating flanges that are in direct contact with the soil should always be equipped with test stations for testing of the joint. At a two-wire test station, a test current of several amperes is applied. If the measured potential on the supposedly isolated section does not change, or if it changes to a more positive value, the insulation is effective. As explained above, an audio frequency pipe locator can also be used to test for isolation.

For aboveground isolation joints, more direct methods can be used to test the joint. Electric insulation testers are commercially available and are the preferred method for testing isolation joints. The two contact points protruding from the instrument are placed on either side of the joint, and the meter display will indicate whether current is passing from one side to the other. Or, structure-to-soil potentials can be measured

on each side of the joint. If there is an appreciable difference, the insulation is effective.

Faulty isolation joints should be replaced to ensure that the anodes are not consumed sooner than the design engineer intended.

Anode-to-Electrolyte Potentials

This measurement simply provides an indication of which lead wire is attached to the anode and is used mostly in sacrificial CP systems. The location of a buried anode may be pinpointed by moving the reference electrode and noting the location of highest (most negative) potential. An abnormally low potential may indicate a severed lead wire or a depleted anode. This measurement is conducted in the same way as the structure-to-electrolyte potential measurement described above, except that a connection is made to the anode instead of to the structure. This measurement should be performed when structure-to-soil potentials measurements are made.

Anode-to-Structure Current

The rate of anode metal loss directly depends on the rate of current flow between the structure and the anode. This current flow is measured to indicate whether the anode is operating properly and to allow approximation of the anode life.

Measurement Procedure

Anode-to-structure current is usually measured at the test station in a sacrificial system, or at the anode junction box in an impressed current system. The anode-to-structure current is measured by inserting an ammeter into the circuit between the anode and protected structure. This may involve physically disconnecting the lead wire to insert the meter (Figure I4). Beginning at the highest range of the instrument will avoid overloading and damaging the meter. Some test stations are equipped with a shunt of known resistance so current can be measured without breaking the circuit. If a shunt is available, measure the voltage drop across the shunt and use the conversion factor printed on the shunt to calculate the current (Figure I5).

Interpretation of Measurements

An anode-to-structure current of zero may indicate that a lead wire has been broken or that the anode has been consumed. The anode should be replaced. A marked

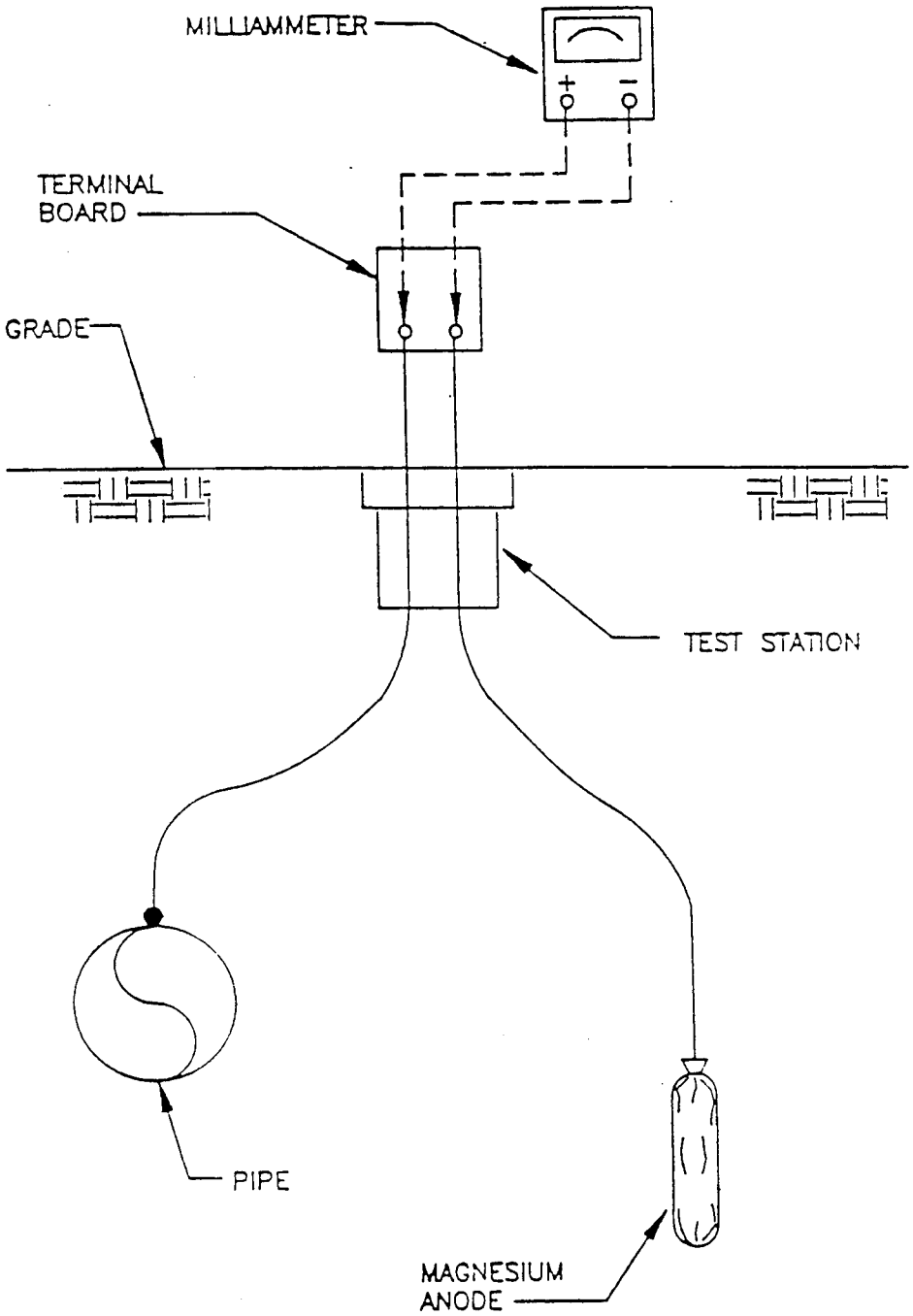


Figure I4. Measurement of anode-to-structure current using ammeter in series.

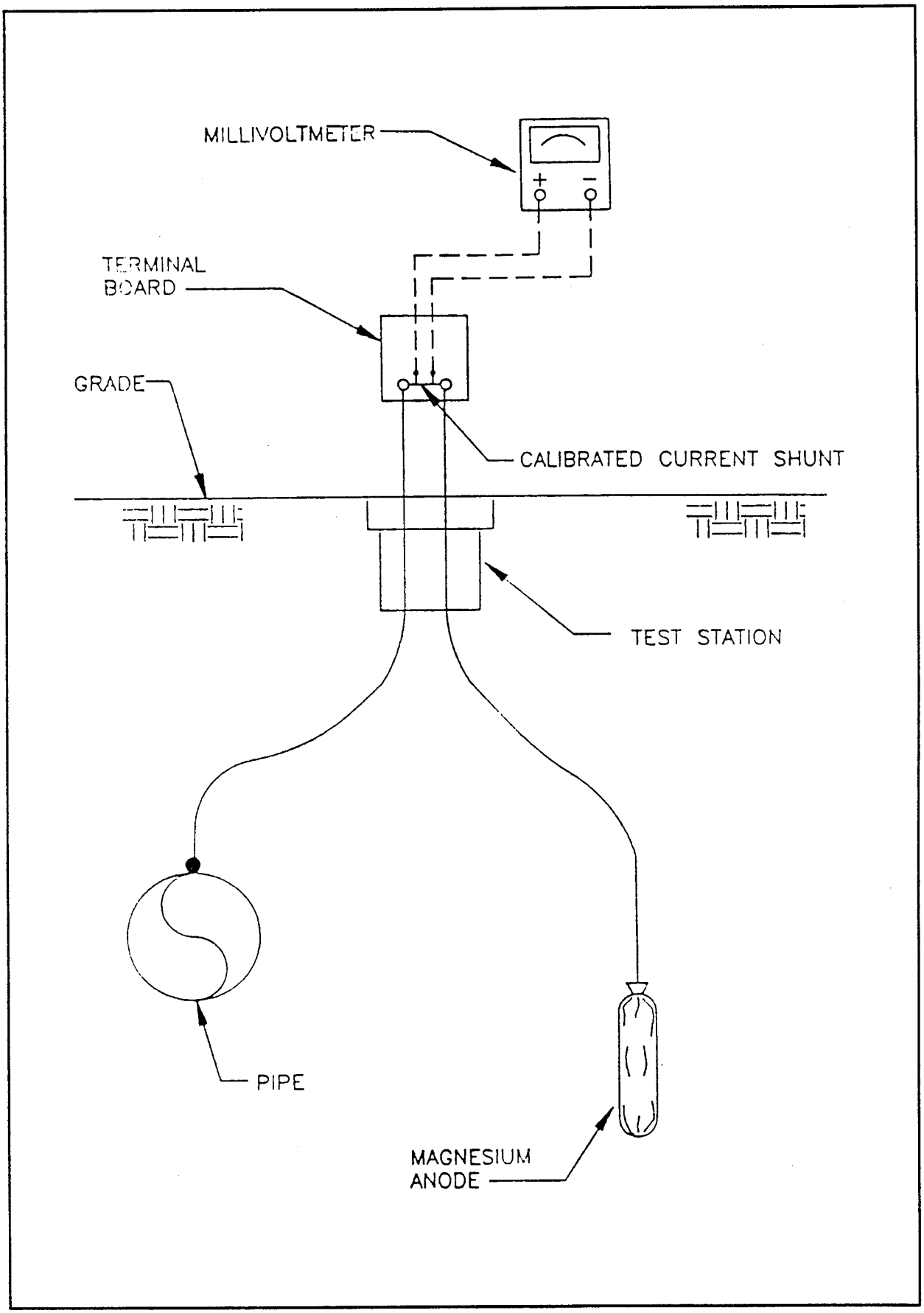


Figure I5. Measurement of anode-to-structure current using shunt and voltmeter.

decrease in the anode-to-structure current between tests may indicate that the anode is nearing the end of its life and will require replacement soon.

The USACERL CP Diagnostic Program

USACERL offers a software program that helps installation personnel more effectively manage and evaluate CP system data. Information about the CP Diagnostic program is presented in Figure I6. CP Diagnostic is available to installation DPWs at no charge.

Fact Sheet

US Army Corps
of Engineers
Construction Engineering
Research Laboratories

P.O. Box 9005
Champaign, IL 61826-9005

Public Affairs and Marketing
Communications Office
Phone (217) 352-6511

February 1994 (FM 36)

CATHODIC PROTECTION (CP) DIAGNOSTIC

The Problem

The Army owns and maintains approximately 20,000 underground fuel storage tanks (USTs); 4,000 miles of buried gas pipes; and 300 elevated water storage tanks. Millions of dollars are spent annually to repair corrosion damage to these structures. Many installations use cathodic protection (CP) systems to protect these structures against corrosion. If CP systems fail or malfunction, the structure is no longer protected. Proper maintenance of CP systems involves troubleshooting and the evaluation of large amounts of data. This is a difficult task for many installations because they do not have personnel trained in CP and corrosion control. In addition, U.S. Environmental Protection Agency (EPA) regulations have made it mandatory to monitor the CP systems protecting USTs and their piping so that corrosion protection is ensured. Assistance is needed in the evaluation, troubleshooting, and storage of CP system data.

The Technology

The U.S. Army Construction Engineering Research Laboratories (USACERL) has developed the CP Diagnostic computer program which operates on an IBM-AT or compatible microcomputer with hard drive and 640 kilobyte of random access memory. This program assists installations in evaluating, troubleshooting, and maintaining data on CP systems for underground piping, USTs, elevated water storage tanks, and civil works structures, such as miter and sector gates. Background information (e.g., structure data, anode and test point data, and rectifier specifications) and data from field measurements (e.g., structure-to-soil potential, anode currents, rectifier currents, and voltages) are loaded into the program. Based on the data, CP Diagnostic pinpoints malfunctioning systems which are not providing proper corrosion protection, as well as deteriorating systems whose performance has shown a marked decline over time. The CP Diagnostic program also generates data collection forms for the system inspector. USACERL has developed an expert system module which leads the user through a complete diagnostic procedure to determine causes and remedies for CP system failures and malfunctions. The system is written in the PROLOG computer language which is often used for expert systems.

An interface has been developed with a portable pen-based computer system to make the data collection process more efficient. Inspection forms are brought up on the screen, and

Figure I6. CP Diagnostic fact sheet.

the inspector uses the stylus attached to the computer to "write" information in the appropriate places on the screen. At the end of the day, information can be uploaded into the CP Diagnostic data base in the office. A module is currently under development which helps schedule CP system testing and repairs such that regulatory compliance is maintained.

Benefits/Savings

CP Diagnostic improves the reliability of CP systems and the structures that they protect. Malfunctioning CP systems are diagnosed so that they can be promptly repaired. Properly maintained CP systems reduce the chance of costly and potentially dangerous corrosion-induced failures of structures, including USTs, underground piping systems, elevated water storage tanks, and civil works structures, such as miter and sector gates. In addition, CP Diagnostic keeps easily accessible records which can be used to ensure compliance with the EPA corrosion protection regulations for USTs.

Status

The CP Diagnostic software and user manuals are currently available. The user manual is ADP Report M-91/24, *Cathodic Protection Diagnostic Computer Program for Sacrificial and Impressed Current Systems: Overview and Users Manual.* CP Diagnostic has been implemented at Fort Hood, TX, on the underground gas distribution system and on USTs. The program has also been implemented at Fort Carson, CO, on USTs. Implementation is under way at Fort Lee, VA; Fort Meade, MD; Fort Richardson, AK; Fort Wainwright, AK; and Aberdeen Proving Ground, MD. The Navy and the Air Force are also evaluating CP Diagnostic for use at their installations. A test version of the expert system module has been completed.

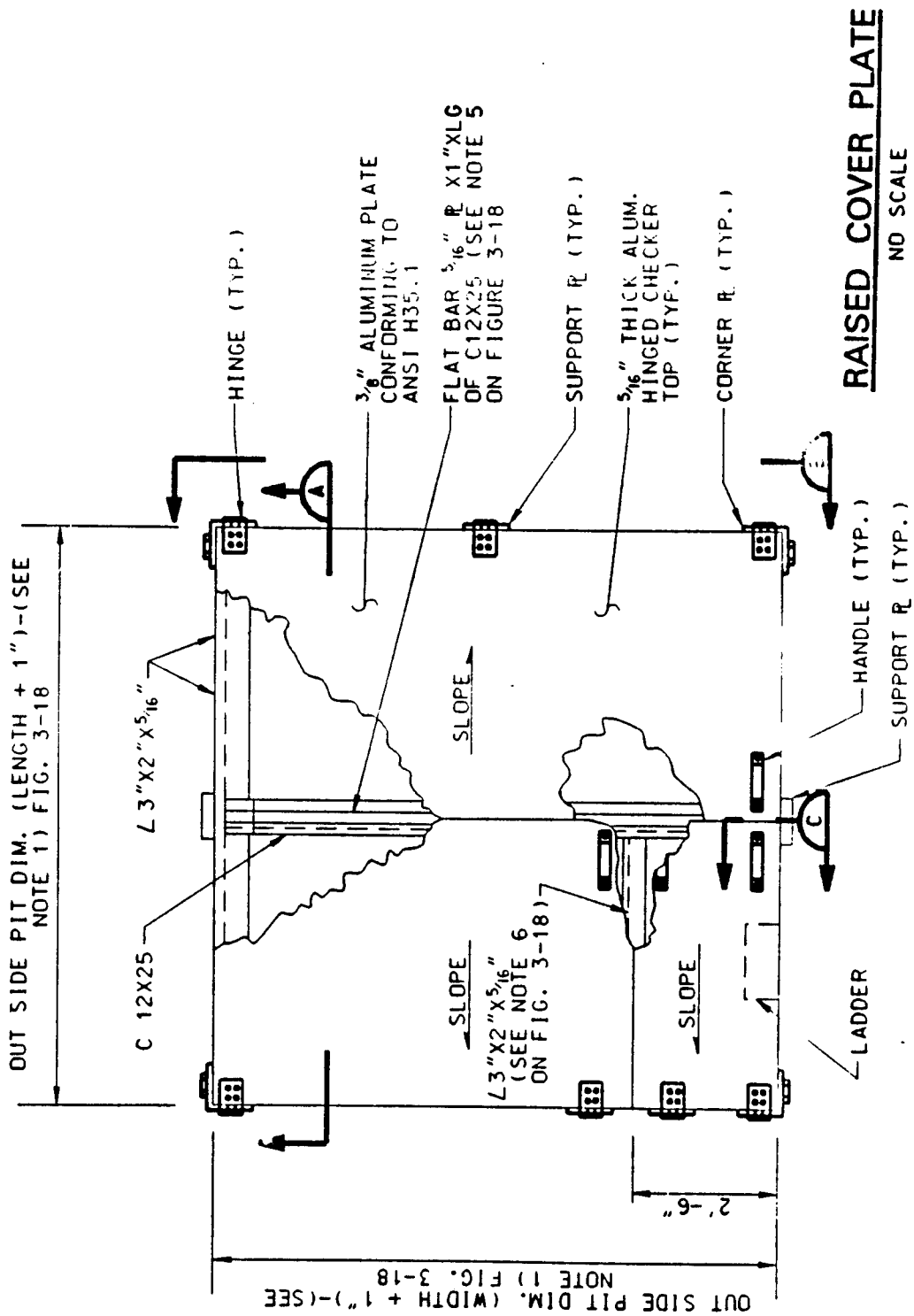
Points of Contact

USACERL POCs are Ms. Vicki Van Blaricum, COMM 217-373-6771, and Dr. Ashok Kumar, COMM 217-373-7235. Both can be reached toll-free 800-USA-CERL; FAX 217-373-6732; or USACERL, ATTN: CECER-FMC, P.O. Box 9005, Champaign, IL 61826-9005.

Figure I6. (Cont'd).

Appendix J: The Omaha Design for Manholes

The following figures are excerpted from Army TM 5-810-17 *Heating and Cooling Distribution Systems*. They provide information on the new "Omaha design" which should be used for new manhole construction.



Note to designer: Plate cover shown is designed for loadings up to 40 psf when spacing between sidewall and center supports is less than 3'6". Loadings or spacings greater than these must be designed for on a case-by-case basis.

Figure J1. Raised cover plate design.

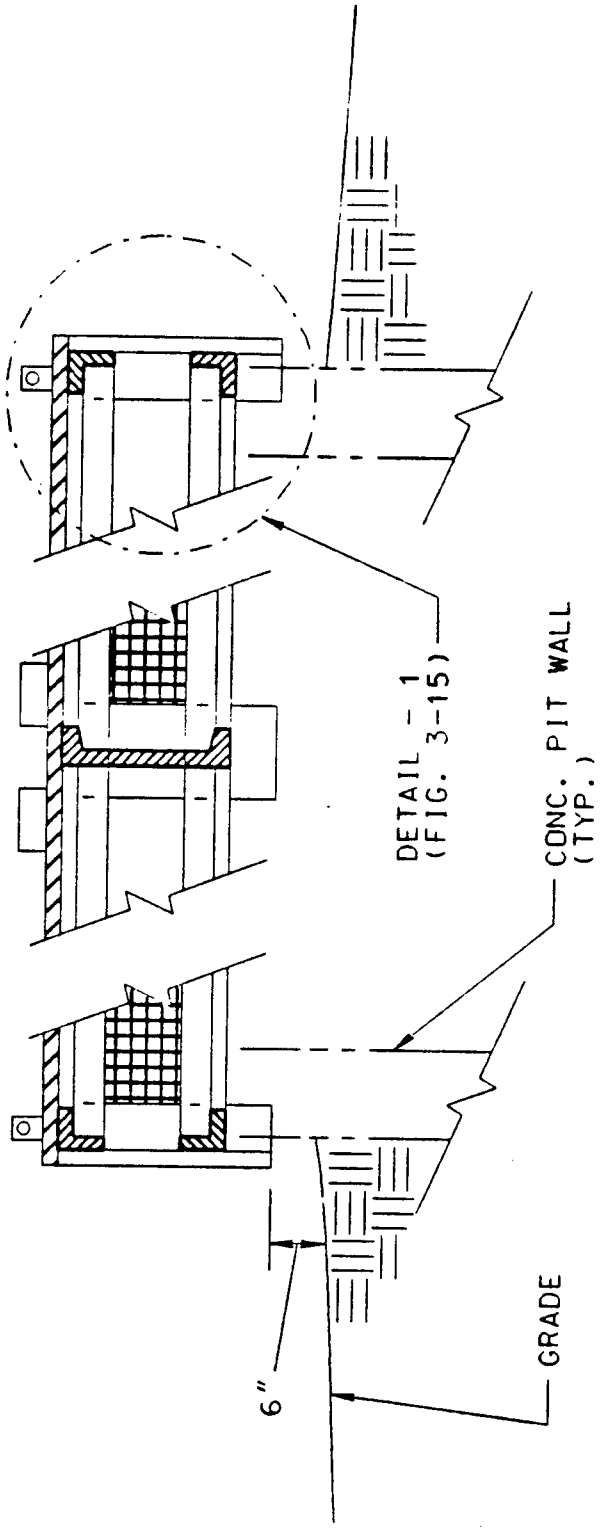


Figure J2. Section A-A of raised cover plate.

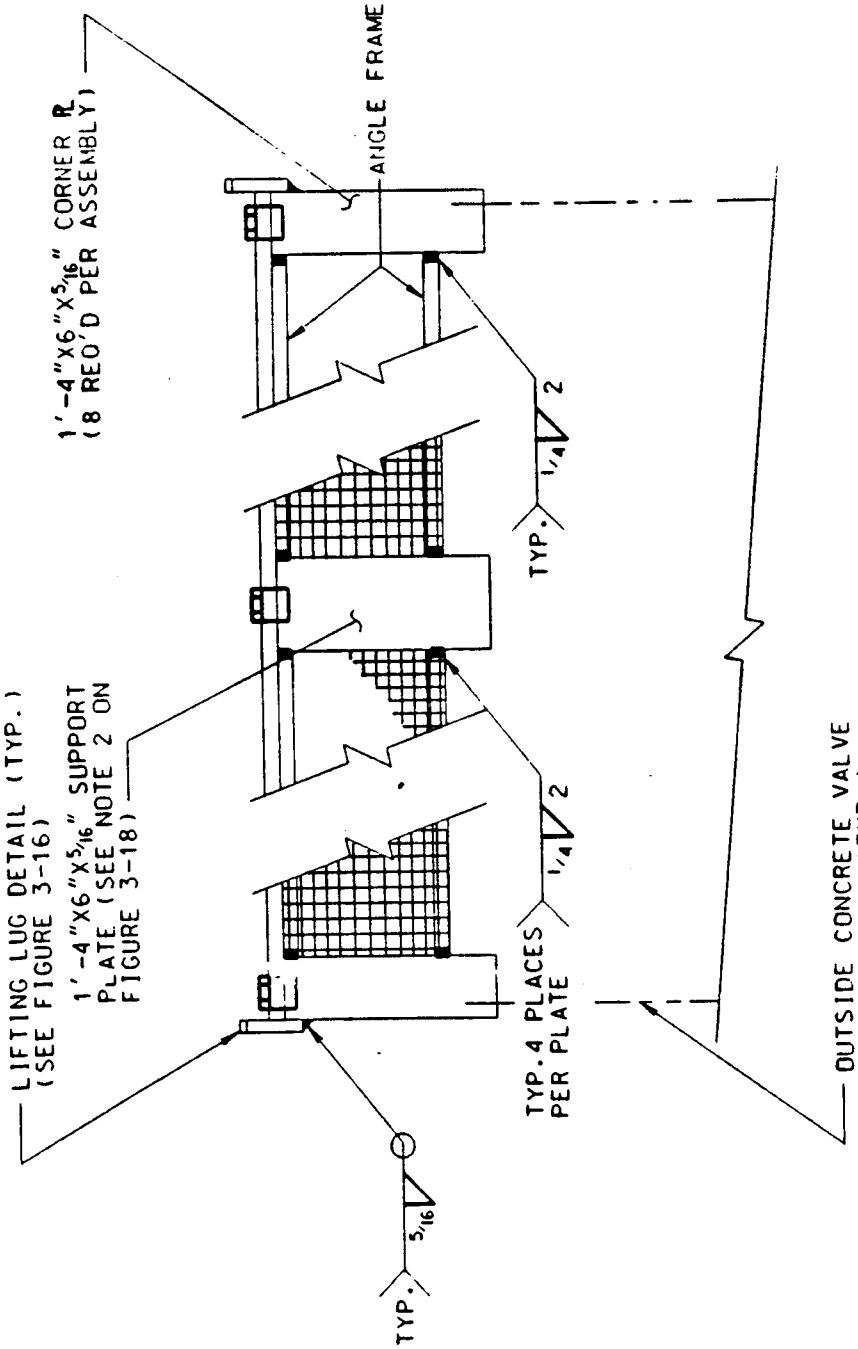


Figure J3. Section B-B of raised cover plate.

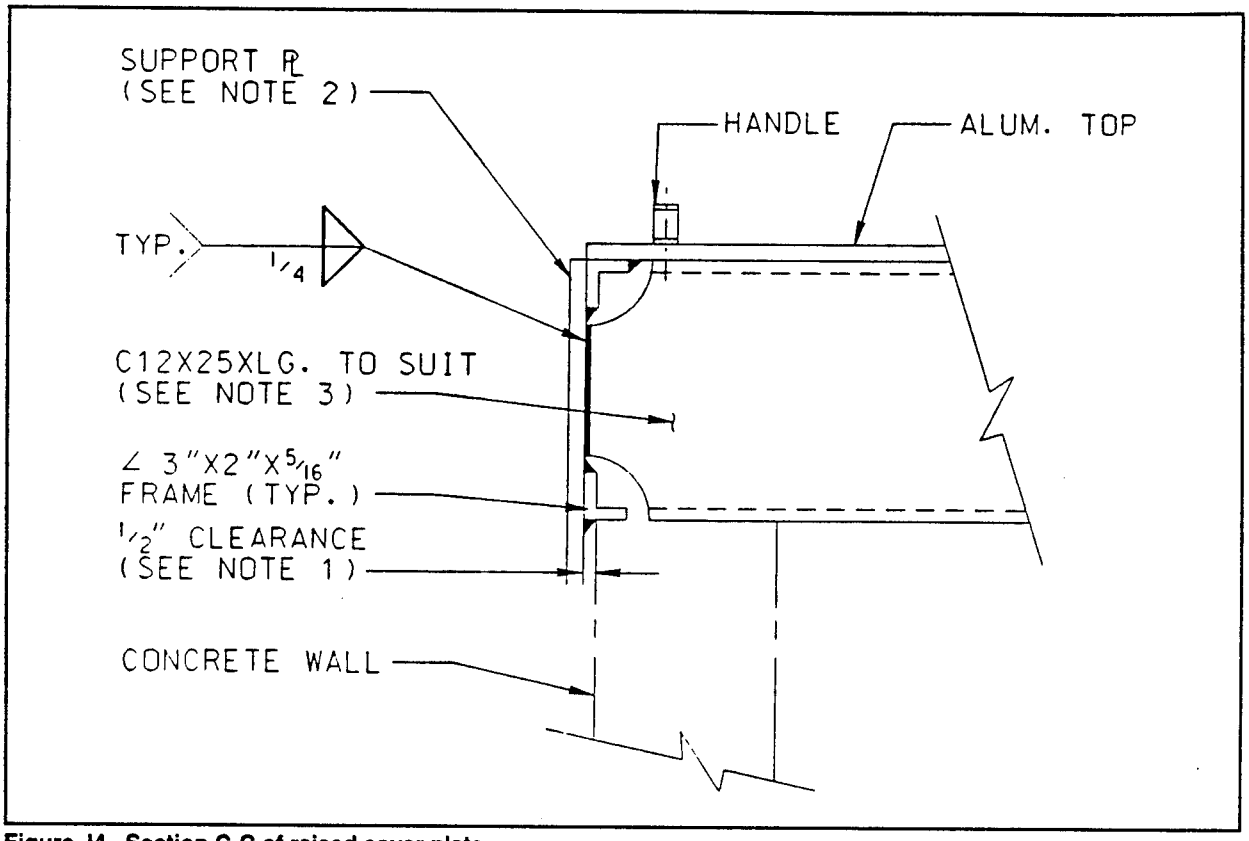


Figure J4. Section C-C of raised cover plate.

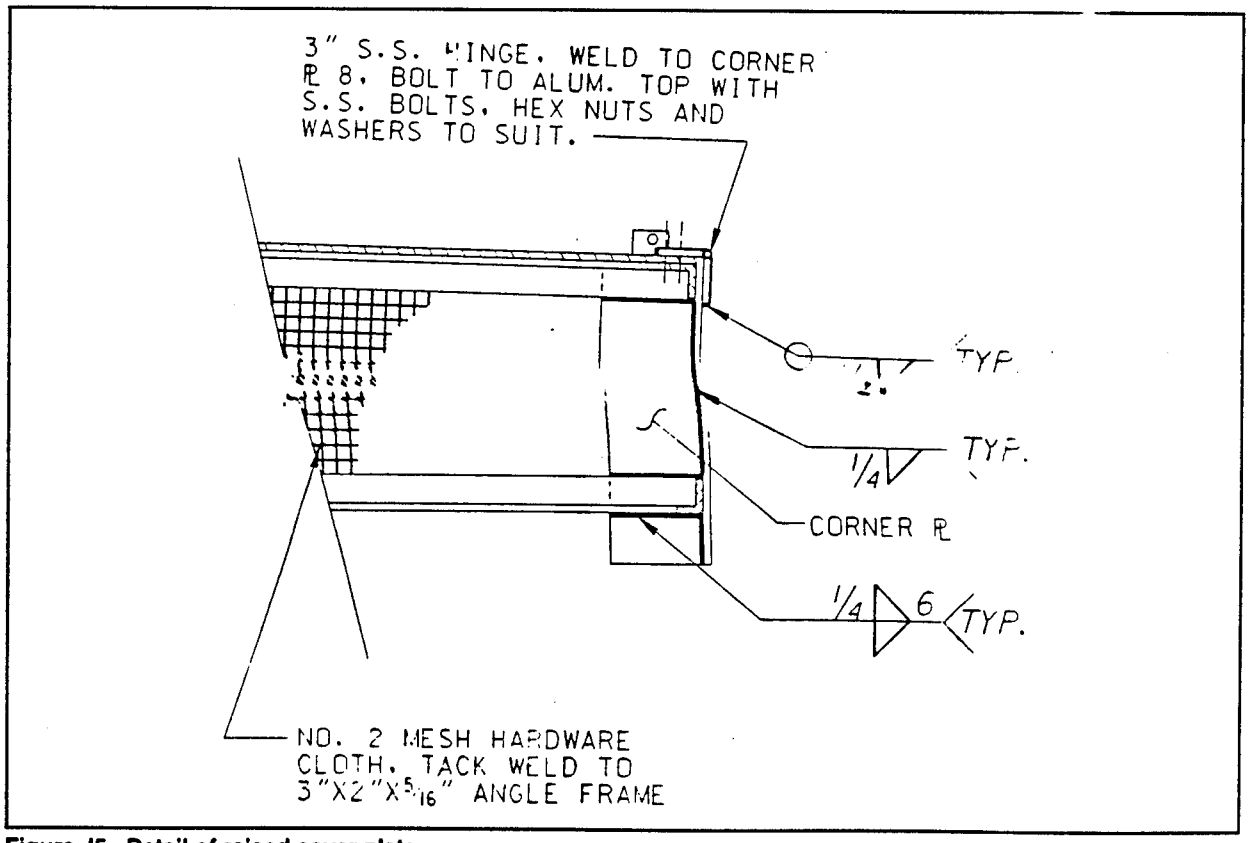


Figure J5. Detail of raised cover plate.

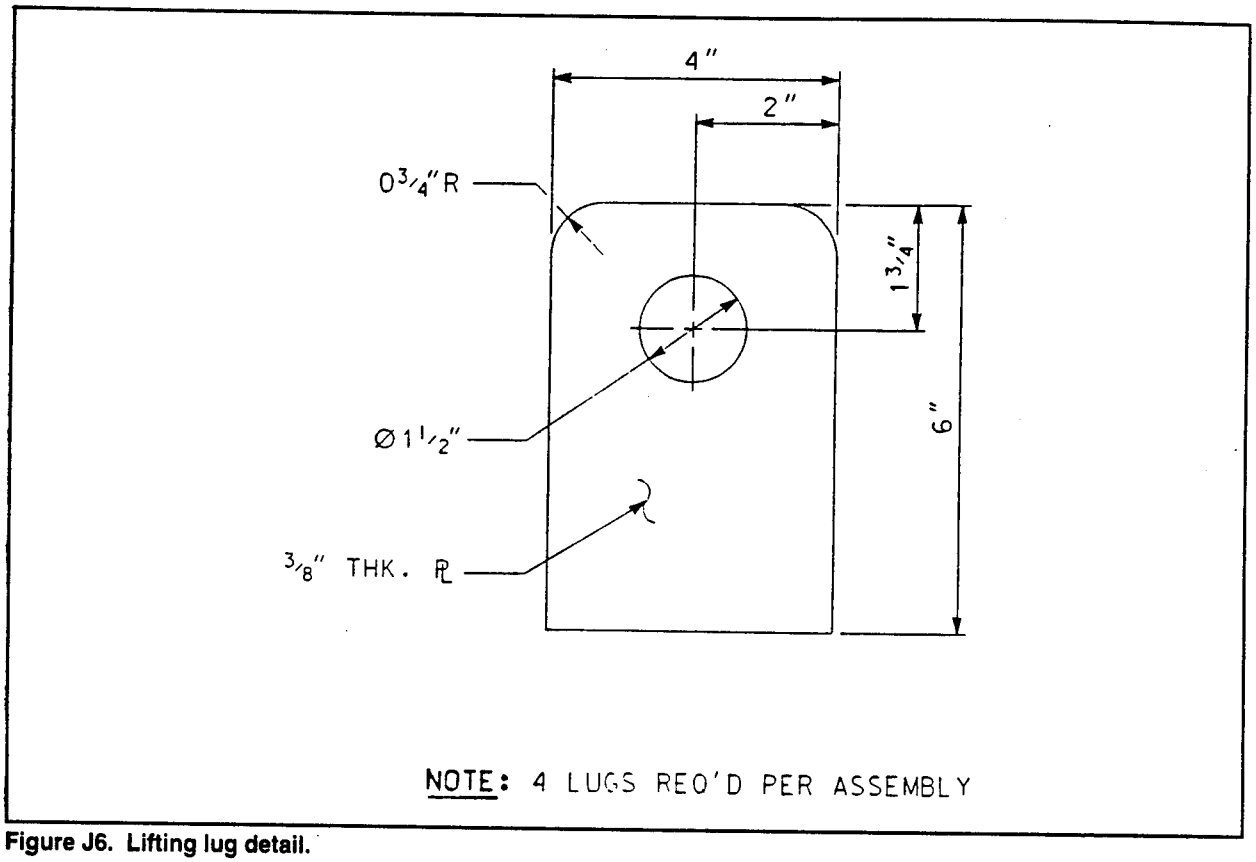


Figure J6. Lifting lug detail.

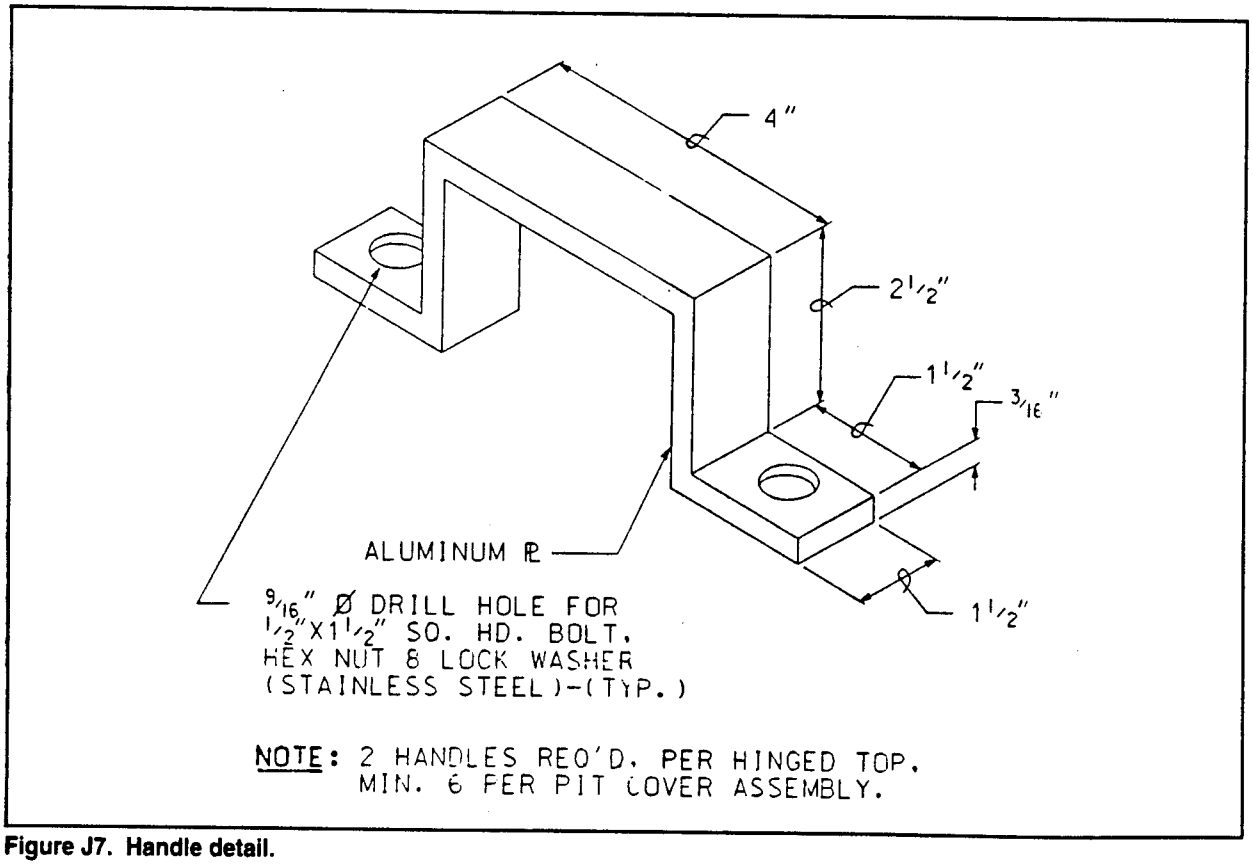


Figure J7. Handle detail.

1. FIELD VERIFY OUTSIDE DIMENSIONS OF NEW MANHOLE BEFORE CONSTRUCTING MANHOLE COVER ASSEMBLY. ADD 1" TO OUTSIDE MANHOLE DIMENSIONS (TO ALLOW FOR CLEARANCE) TO DETERMINE INSIDE ASSEMBLY DIMENSIONS.

2. EACH SUPPORT PLATE SHALL BE LOCATED HALFWAY BETWEEN CORNER PLATES AT 3 SIDES OF MANHOLE. 2 SUPPORT PLATES SHALL BE LOCATED BETWEEN 2 SPLIT ALUM. CHECKER TOP AT ONE SIDE OF MANHOLE.

3. SUPPORT CHANNELS SHALL BE C12X25XLG. TO EQUAL WIDTH OR LENGTH DIM. PLUS 1" TO SUIT INSIDE ASSEMBLY DIM. THE CHANNEL SHALL REST ON THE CONCRETE MANHOLE TOP AND THE ALUM. TOP SHALL REST ON THE FLAT BAR PLATE.

4. CHANNEL SUPPORT, CORNER PLATES, SUPPORT PLATES, ANGLE FRAME HARDWARE CLOTH, AND LIFTING LUGS SHALL BE HOT-DIPPED GALVANIZED BEFORE INSTALLATION ON VALVE MANHOLES.

5. FLAT BAR 5/16" THK. WELDED TO TOP OF C12X25 TO MAKE ALUM. CHECKER TOP SLIGHTLY SLOPED AS INDICATED. LOCATE ℄ FLAT BAR TO MATCH ℄ CHANNEL BEFORE WELDING.

6. ANGLE 3"X2"X5/16" WELDED TO C12X25 8 ∠3"X2"X5/16" AT EACH END LENGTH SHALL EQUAL HALF OF LENGTH OR WIDTH OF VALVE MANHOLE.

Figure J8. Notes for raised cover plates.

USACERL DISTRIBUTION

Chief of Engineers
ATTN: CEHEC-IM-LH (2)
ATTN: CEHEC-IM-LP (2)
ATTN: CECC-R
ATTN: CERD-L

CECPW 22310-3862
ATTN: CECPW-ES

Aberdeen Proving Ground
ATTN: STEAP-FE-PE 21005 (14)

Defense Tech Info Center 22304
ATTN: DTIC-FAB (2)

23
8/95

This publication was reproduced on recycled paper.