NUREG/CR-2101

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# Evaluation of Trench Subsidence and Stabilization at Sheffield Low-Level Radioactive Waste Disposal Facility

Sheffield, Illinois
Final Report
October 15, 1980 - March 30, 1981

Prepared by R. Kahle, J. Rowlands

**Ralph Stone and Company, Inc.**

**Prepared for**
**U.S. Nuclear Regulatory**
**Commission**

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Printed copy price: $6.00

and

National Technical Information Service
Springfield, Virginia 22161

NRC FORM 335
(7-77)

U.S. NUCLEAR REGULATORY COMMISSION

**BIBLIOGRAPHIC DATA SHEET**

1. REPORT NUMBER (Assigned by DDC)
NUREG/CR-2101

2. (Leave blank)

3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE (Add Volume No., if appropriate)
Evaluation of Trench Subsidence and Stabilization at
Sheffield Low-Level Radioactive Waste Disposal Facility

5. DATE REPORT COMPLETED
MONTH March | YEAR 1981

7. AUTHOR(S)
Richard Kahle, James Rowlands

DATE REPORT ISSUED
MONTH May | YEAR 1981

6. (Leave blank)

9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Ralph Stone and Company, Inc.
10954 Santa Monica Blvd.
Los Angeles, California 90025

8. (Leave blank)

12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Division of Waste Management
Washington, DC 20555

10. PROJECT/TASK/WORK UNIT NO.

11. CONTRACT NO.
FIN B6968

13. TYPE OF REPORT
Technical

PERIOD COVERED (Inclusive dates)
October 15, 1980 - March 30, 1981

15. SUPPLEMENTARY NOTES
None

14. (Leave blank)

16. ABSTRACT (200 words or less)

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Analyses were performed to determine subsidence trends and project future subsidence for 21 trenches into which the wastes were placed. The types of subsidence, potholes, sudden slumps, and long term area settlement were evaluated to develop future projections. The mechanisms evaluated as causing subsidence and settlement were: piping and settlement of the trench backfill soil into voids, consolidation of the trench backfill soil, and deterioration of the waste containers and wastes by corrosion and biodegradation. The engineering feasibility and costs of potential trench stabilization techniques were developed. Recommendations were made for stabilization, final capping, and future monitoring of each trench.

17. KEY WORDS AND DOCUMENT ANALYSIS

17a. DESCRIPTORS

Sheffield Low-Level Waste Disposal Facility

17b. IDENTIFIERS/OPEN-ENDED TERMS

18. AVAILABILITY STATEMENT
Unlimited

19. SECURITY CLASS (This report)
Unclassified

21. NO. OF PAGES

20. SECURITY CLASS (This page)
Unclassified

22. PRICE
$

NRC FORM 335 (7-77)

☆ U.S. GOVERNMENT PRINTING OFFICE : 1981 O - 347-763

8107070080

NUREG/CR-2101

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Located in Pocket

## ACKNOWLEDGEMENTS

The authors wish to express their appreciation to Mr. David Siefken, Project Officer, U.S. Nuclear Regulatory Commission, for his guidance in the conduct of the study and presentation of the results; to Russell Moore, Site Manager for Nuclear Engineering Company, Inc. at Sheffield for his cooperation during our site visits; and the following agencies and individuals who furnished additional data and information:

Nuclear Engineering Company, Inc. - Mr. Thomas Baer

Soil Conservation Service - Mr. Donald Pretsch, District Conservationist

U. S. Geological Survey - Mr. J. B. Foster

Illinois Department of Nuclear Safety - Mr. Bruce Myer

The report was prepared by Ralph Stone and Company, Inc. under the direction of Mr. Richard Kahle, Project Director and Mr. James Rowlands , Project Manager.

The authors wish to note the efforts of Mr. Michael Scholten and Ms. Mimi Doyle, Staff Engineers, for their valuable contributions in preparing this report.

# EVALUATION OF TRENCH SUBSIDENCE AND STABILIZATION AT SHEFFIELD LOW-LEVEL RADIOACTIVE WASTE DISPOSAL FACILITY, SHEFFIELD, ILLINOIS

## 1. INTRODUCTION

California Nuclear Company and the Illinois Department of Public Health signed a lease agreement on October 2, 1966, permitting the establishment of a low-level radioactive waste disposal site near Sheffield, Illinois. The burial of low-level radioactive wastes was first authorized on August 1, 1967. Nuclear Engineering Company, Inc. (NECO), succeeded the original site lessee, in March 19, 1968. Approximately three million cubic feet of waste material containing 60,000 curies of by-product material, 55 kilograms of special nuclear material and 600,000 pounds of source material in 21 trenches has been buried at the Sheffield site. The last waste burial was in April 1978. NECO was recently renamed US Ecology, Inc.

The objective of this study was to develop detailed information on trench subsidence trends and stabilization techniques for the site. Tasks to be accomplished were:

- o Visit the site to become familiar with the layout and surroundings.
- o Review, analyze and summarize NECO's site surface maintenance records.
- o Summarize available information on trench cap construction.
- o Estimate the locations, magnitudes, and rates of past trench subsidence.
- o Predict future subsidence and estimate the time for subsidence to reduce making it feasible to construct final trench caps for long-term site stabilization.
- o List, describe and estimate the costs of all reasonable techniques that could be used for stabilizing the trenches.
- o Assess the value of future monitoring of subsidence.

The work was accomplished from October 15, 1980 to January 30, 1981. All existing data on trench cap construction, placement of wastes in trenches, and records pertaining to maintenance and past trench subsidence were reviewed. The data has been used to estimate future subsidence, recommend feasible techniques for stabilization, and determine their costs. The analysis was accomplished in four stages beginning with a visit to the Sheffield site, becoming familiar with its layout, trench surface conditions and the general site area. The second stage was the collecting, reviewing, analyzing and summarizing Nuclear Engineering

Company's surface maintenance records of the Sheffield site. The third stage was accomplished by listing and describing all potentially feasible techniques for stabilizing the trenches to minimize future subsidence. The fourth stage was the assessment of the costs and benefits of future monitoring of subsidence.

# II. SITE DESCRIPTION

## A. LOCATION

The Sheffield low-level radioactive waste disposal site is located at approximately W89°47' longitude and N41°21' latitude, on 20 acres of rolling terrain, three miles southwest of the town of Sheffield in Bureau County, in northwestern Illinois. It is 120 miles west of Chicago, Illinois; 50 miles north of Peoria, Illinois and 45 miles east of Moline, Illinois, as shown in Figure 1 and 2. The site was developed in a coal mining area of Bureau County. The site is bordered to the north by rolling terrain, abandoned strip mines and a hazardous chemical waste disposal site operated by NECO. Further to the north and to the northeast and northwest exist abandoned coal mines of which little or no effort in land reclamation has been initiated. These pits now contain water and serve as narrow lakes which provide some fishing, swimming, and boating. The area is also used for hunting by local residents. The areas south of the site are used primarily for agriculture, including pasture and row crops and also recreation.

## B. GEOLOGY

The Sheffield area includes gentle slopes of surface glacial deposits. The agricultural soils are mainly the Fayetta and Strawn soil association as reported in the U.S. Department of Agriculture(1). Fayette and Strawn soils are light colored, generally well to moderately well drained and silty. The surface layers are dark grayish brown and are developed in a Teneriffe Silt or Peoria Loess Formation. The subsoil layers are dark yellowish brown, silty clay loam developed in the Glasford Formation. Generally, the waste disposal site was constructed in glacial deposits consisting of silt, clayey silt, silty clay, sand-silt-clay, pebbly sand and pebbly silty sand, as depicted in Table 1. These soils occupy nearly level to moderately steep areas of ridge tops and upper slopes. The nature of the soil (blocky, massive, granular, platy) and the slope of the terrain make erosion and prolonged dryness a serious problem with respect to loss of trench cap integrity, and subsequent infiltration of water into the trenches.

## C. HYDROLOGY

Groundwater essentially flows north and northeastward beneath approximately three-fourths of the site and south and southeastward beneath approximately one-fourth of the site. Figure 3 indicates this flow divide. The groundwater elevations depicted in Figure 3 indicate that the water table varies from approximately 15 to 45 feet below the ground surface shown in Plate 2.

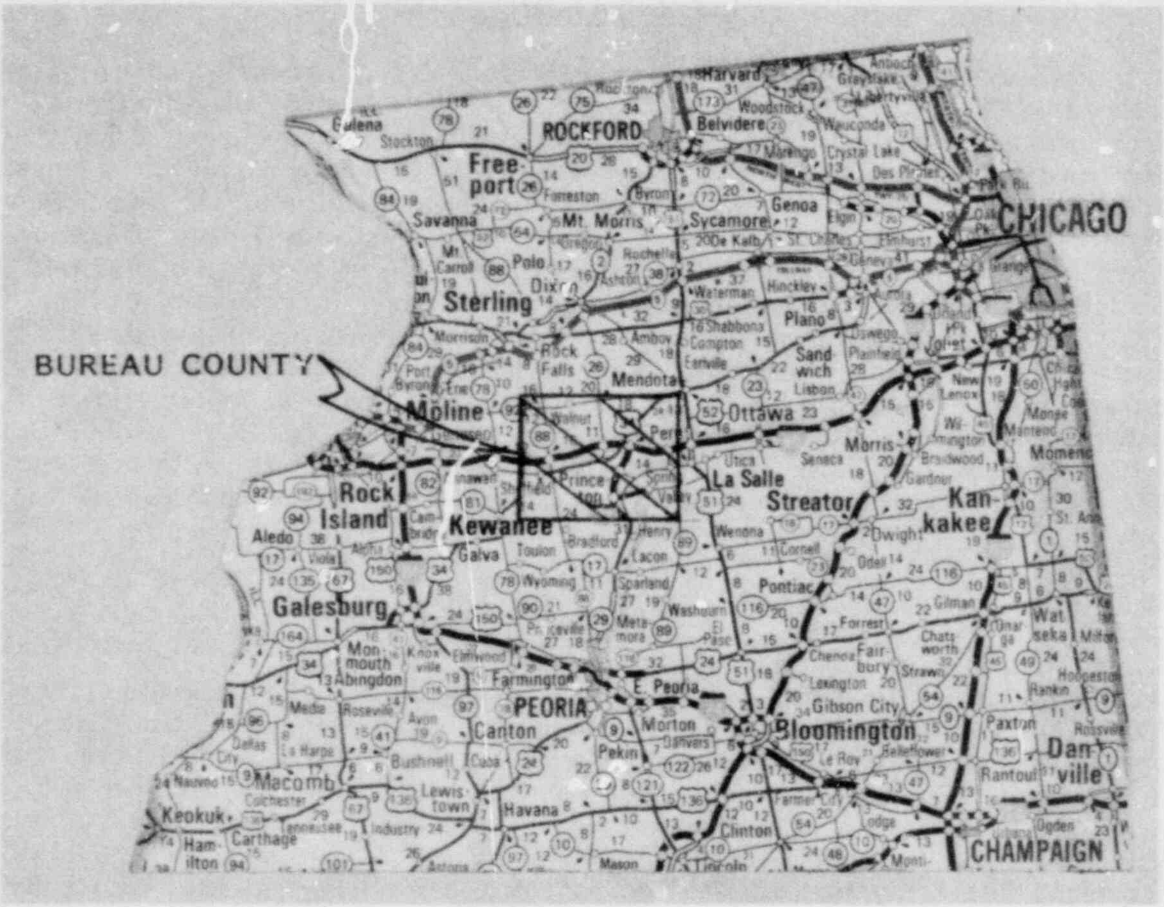


FIGURE 1 - VICINITY MAP

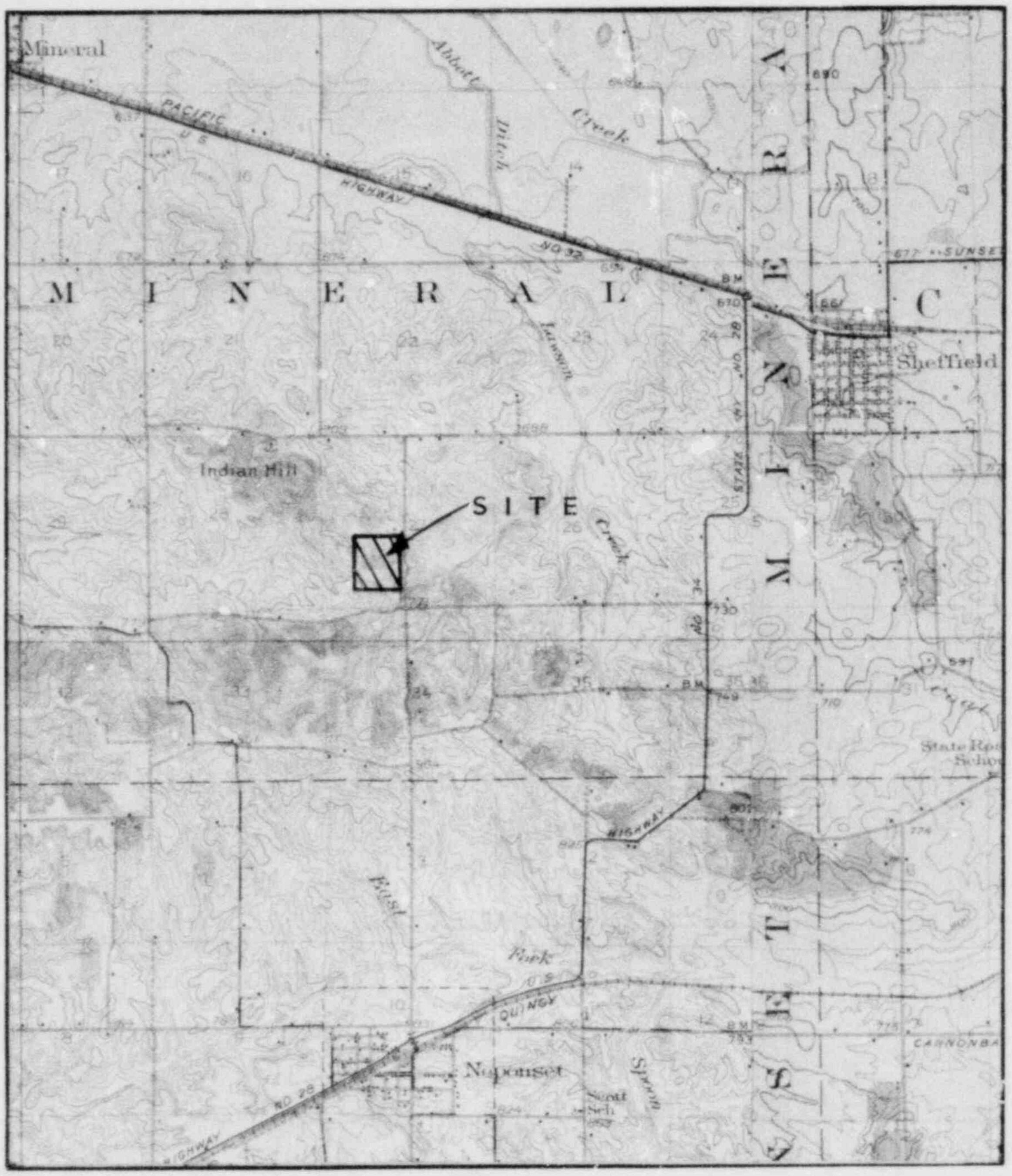


FIGURE 2 - APPROXIMATE SITE LOCATION

Source: U.S.G.S. Polyconic Projection of Annawan, Illinois and Buda, Illinois Quadrangles'

## TABLE 1 - SOIL IDENTIFICATION

| Trench No. | Lithologic Unit Below Trench | Soil Formation | Soil Structure |
|---|---|---|---|
| 1 | Clayey silt; silt; sand ;<br>silty clay | Peoria Loess<br>Glasford | Blocky; platy; massive<br>fine to coarse sand |
| 2 | Clayey silt; sandy silt; clay ;<br>silt; silty clay | Teneriffe Silt<br>Glasford | Platy to weak blocky<br>pebbly, massive |
| 3 | Clayey silt; sandy silt; clay;<br>silt; silty clay | Teneriffe Silt<br>Glasford | Platy to weak blocky<br>pebbly, massive |
| 4 | Clayey silt; silt ;<br>sand; silty clay | Peoria Loess<br>Glasford | Blocky; platy; massive<br>fine to coarse sand |
| 5 | Clayey silt; silt;<br>pebbly silty sand | Glasford | Massive to weak platy |
| 6 | Silt; clayey silt;<br>silty clay | Peoria Loess<br>Glasford | Massive, weak;<br>platy |
| 7 | Silt, clayey silt;<br>silty clay | Peoria Loess<br>Glasford | Massive , weak;<br>platy |
| 8 | Clayey silt; sand;<br>sandy silt clay | Glasford | Massive pebbly |
| 9 | Sand; clayey sand;<br>sandy silt clay;<br>pebbly | Peoria Loess<br>Glasford | Blocky to massive<br>Blocky to granular<br>Platy to massive |
| 10 | Sand; clayey silt;<br>Sandy silt clay; pebbly silty sand | Teneriffe Silt<br>Glasford | Sangamon Soil<br>Massive |
| 11 | Sand; sandy silty clay;<br>silty clay | Peoria Loess<br>Glasford | Weak platy - massive<br>Massive |
| 25 | Clayey silt; sand; | Glasford | Massive<br>pebbly |

## TABLE 1 - SOIL IDENTIFICATION (cont)

| Trench No. | Lithologic Unit Below Trench | Soil Formation | Soil Structure |
|---|---|---|---|
| 8A | Clayey silt; sand; sandy silt clay | Glasford | Massive pebbly |
| 8B | Clayey silt; sand; sandy silt clay | Glasford | Massive pebbly |
| 26 | Clayey silt; sand; sandy silt clay | Glasford | Massive pebbly |
| 24 | Clayey silt; sand; sandy silt clay | Glasford | Massive pebbly |
| 18 | Sand; sandy silt clay; pebbly silt sand, silty sand | Peoria Loess<br>Glasford | Massive calcareous |
| 25C | Clayey silt; sand sandy silt clay | Glasford | Massive pebbly |
| 23 | Sand; pebbly silt sand; clayey silt; silty clay | Peoria Loess<br>Glasford | Blocky to massive<br>Massive<br>Lacustrine |
| 14 | Clayey silt; sand; sandy silt clay | Peoria Loess<br>Glasford | Blocky to massive<br>Blocky to granular<br>Platy to massive |
| 14A | Clayey silt; sand; sandy silt clay | Peoria Loess<br>Glasford | Blocky to massive<br>Blocky to granular<br>Platy to massive |

Source: Preliminary Report on the Hydrogeology of a Low-Level Radioactive-Waste Dispcsal Site Near Sheffield, Illinois.(2)

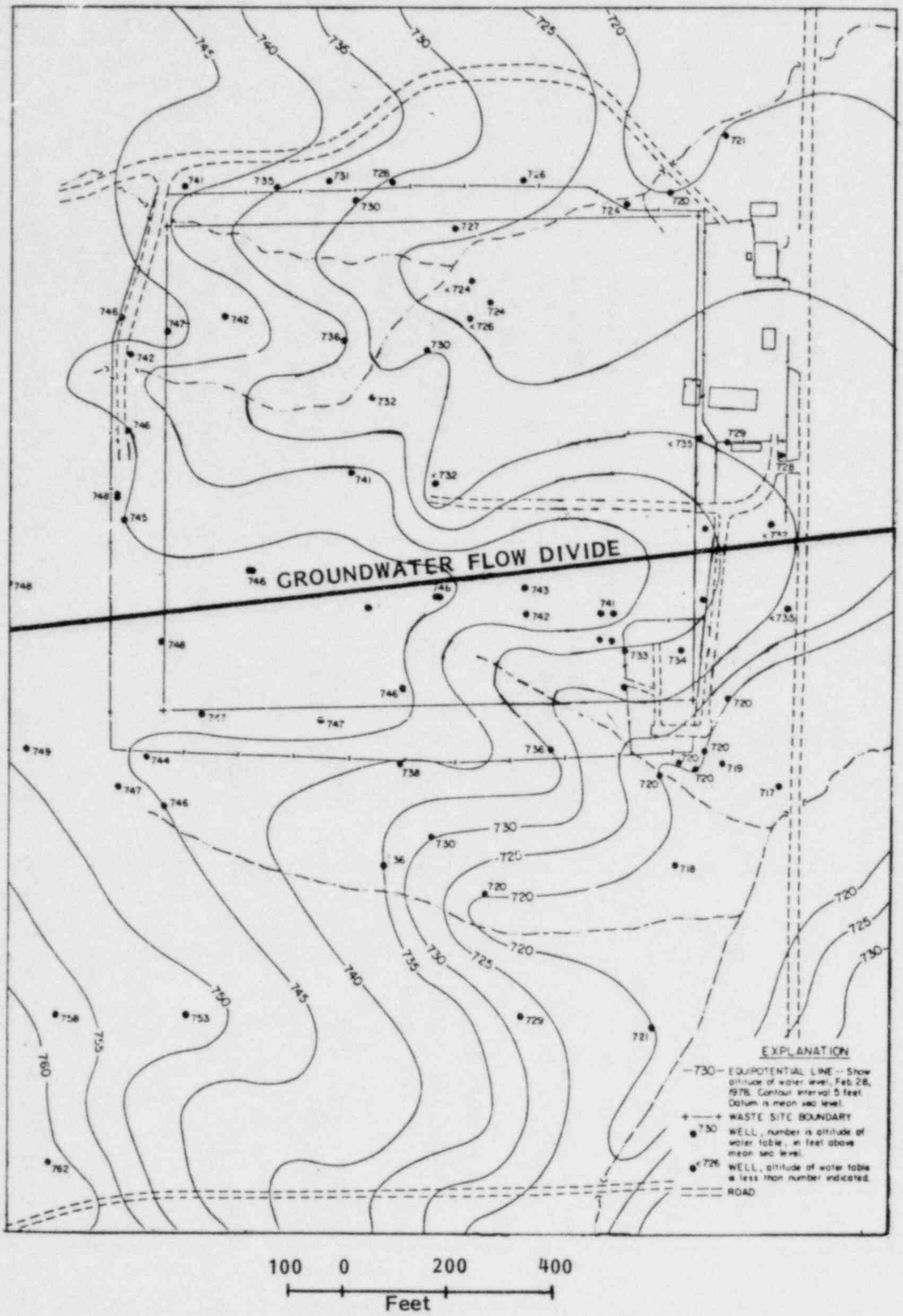


FIGURE 3 - EQUIPOTENTIAL LINES OF WATER TABLE

Source: Preliminary Report on the Hydrogeology of a Low-Level Radioactive-Waste Disposal Site near Sheffield, Illinois.(2)

The U. S. Geological Survey (USGS) has installed groundwater monitoring wells in order to determine the range of seasonal and annual fluctuations as a result of variations in seasonal and yearly rainfall. Water levels rise during the spring after the ground thaws and tend to decline during the summer and early fall.(2) The topographic conditions and the developed surface drainage provide for rapid runoff, anticipated to be from 12 to 15 inches per year.(2) It is also estimated that between one and two inches of recharge reaches the water table each year.(2) Approximately 20 inches of water are evapotranspired annually at the site.(2)

## D. CLIMATE

Bureau County, Illinois experiences typical continental climate ranging in temperature from summer highs in the upper 90°F to winter lows of -10°F to -15°F below zero. Summers are warm with July typically being the warmest month. Brief showers and thunderstorms and cool air from the north help prevent stagnation of summers hot, humid air masses. Northern Illinois's summer precipitation occurs mostly as the result of showers and thunderstorms of short duration. The annual precipitation rate on the site is approximatley 35 inches of water. January is normally the coldest month and annual snowfalls have averaged 26 inches. The total number of freezing days per year occur between mid-October to the end of April(3) making the cold season six months long. Frost depths have been recorded averaging three to four feet. The average monthly precipitation is shown in Figure 4.

## E. GENERAL SURFACE CONDITIONS

The major soil development of Bureau County is of a silt nature. When the trenches were excavated the spoil was left beside the open trenches and used as uncompacted backfill as the waste was deposited. After each trench except 14 and 14A, was filled the caps were constructed of this same soil type. An unknown amount of compaction was performed on each of these caps. On trenches 14 and 14A, "clay shale" was imported for the caps and compaction was tested to meet a specification of 90 percent of the maximum density as determined by the modified proctor test.

The Sheffield site is covered with a bromegrass and tall fescue except for the recent grading, slope and erosion repair areas which make up approximately 20 percent of the total acreage. Photographs of these repair areas are shown in Figure 5. The repairs that have been initiated on the drainage problem areas should be monitored until such time as the bromegrasses or other approved ground cover has been established.

Figure 6 depicts minor erosion which can develop into major gully erosion with surface runoff carrying away the topsoil of the caps and soil in the

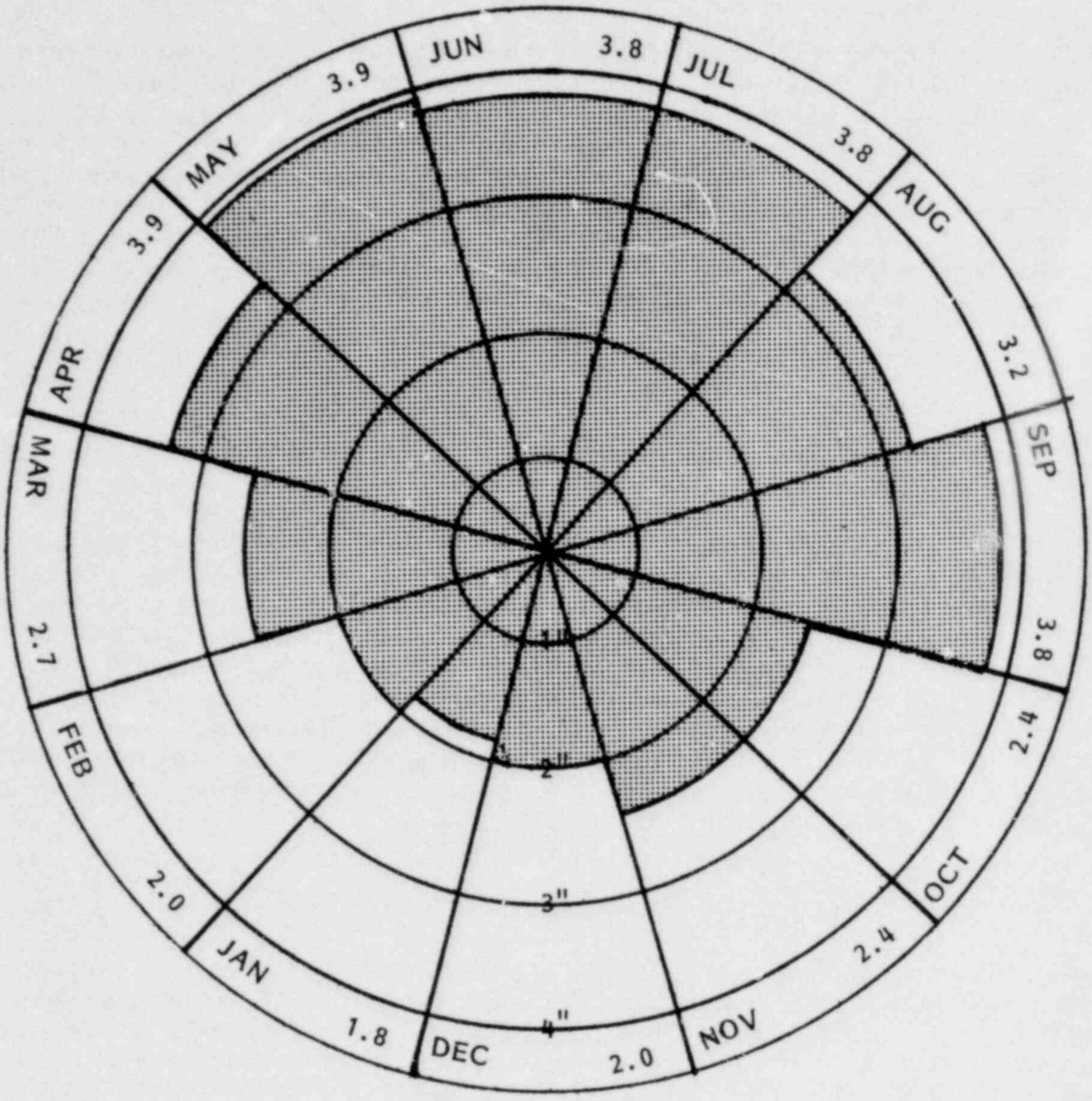
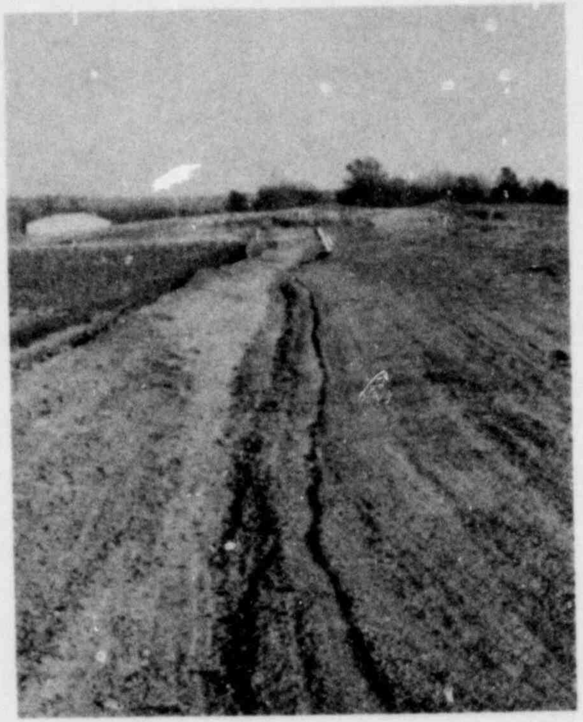
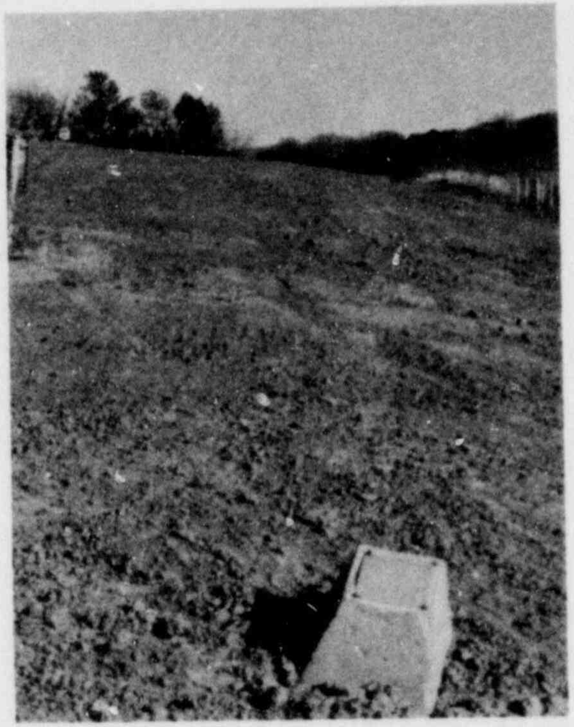


FIGURE 4 - AVERAGE MONTHLY PRECIPITATION

Source: Environmental Report for the Sheffield Low-Level Radioactive Waste Disposal Facility.(5)

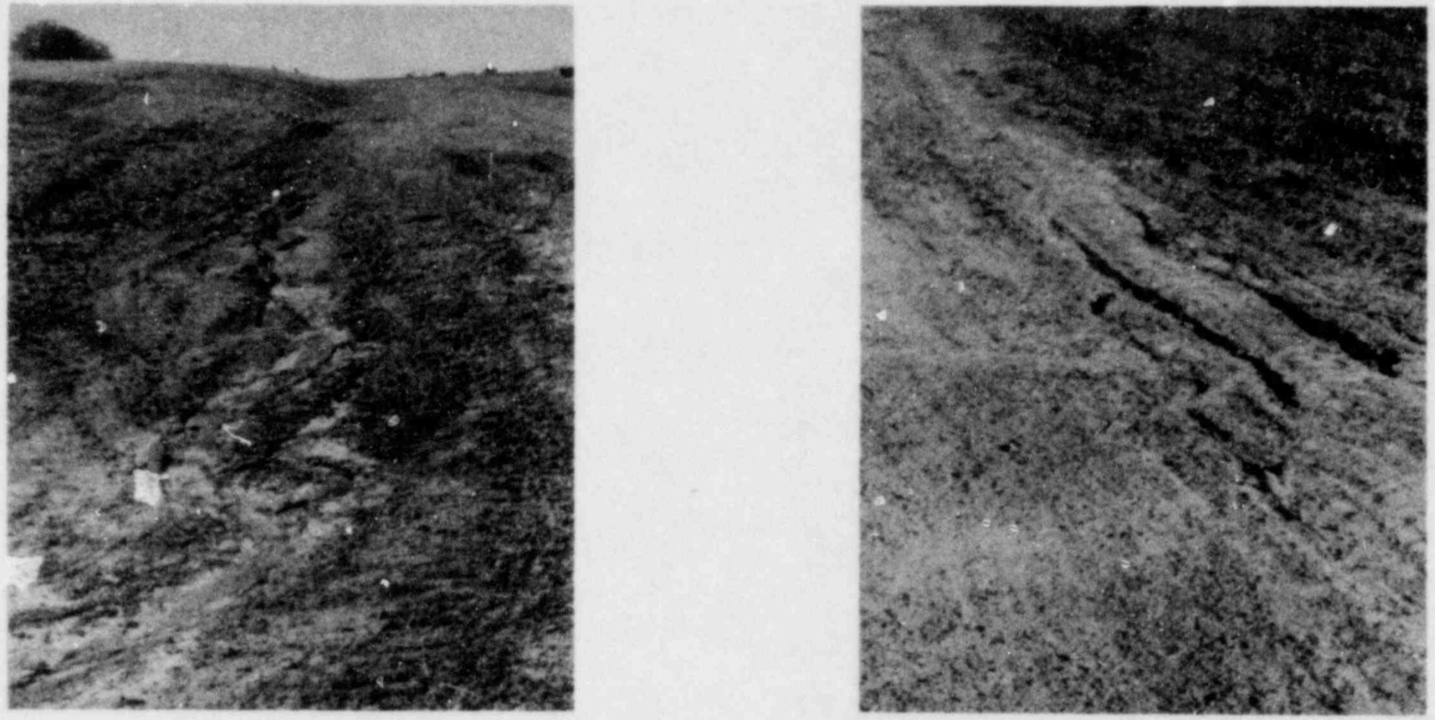


T-14 NORTH SIDE
LOOKING EAST



T-11 LOOKING EAST

FIGURE 5 - SURFACE REPAIRS - NOVEMBER 5, 1980



BETWEEN T-25C AND T-24
LOOKING WEST

EAST END OF T-25 LOOKING
EAST

FIGURE 6 - MINOR EROSION - NOVEMBER 5, 1980

areas between the trenches. Runoff occurs first as sheet flow which gradually develops into poorly defined rills upon the trench caps. The rills tend to form on the side slopes and run into developing swales along the side of the trenches. The swale water then follows the site topography and ultimately ends up in the well defined drainage channels at the northern end, Figure 7, or the southeastern end of the site, Figures 8 and 9. This erosion process can lead to damage to the caps, loss of cap integrity and will require regular future inspection of the existing caps to determine if rilling develops.

Other factors affecting cap integrity are areas of potential concentrated infiltration. Field observations indicate that present potential concentrated infiltration areas are maintenance vehicle tire tracks and low spots developed between the trenches as shown in Figure 10. These areas are located on Plate 2. There are numerous wells and sumps with PVC casings protruding above the ground surface throughout the site, Figure 11. If any of the casings were damaged, a point of concentrated infiltration could result.

A tunnel has been constructed by the U.S. Geological Survey (USGS) to provide access for monitoring radiation directly beneath Trenches 1, 2, 3, and 11. The six and one half foot diameter tunnel extends northward under Trench 11, then Trench 3, Trench 2, and Trench 1, respectively; for a total of 290 feet in length, as depicted in Figure 12. The USGS tunnel was extended southerly in December 1980 and the construction cut was filled and regraded to match the adjacent contour indicated in Plate 2.

DRAINAGE CULVERT LOOKING NORTH

EAST END OF T-18 LOOKING SOUTH

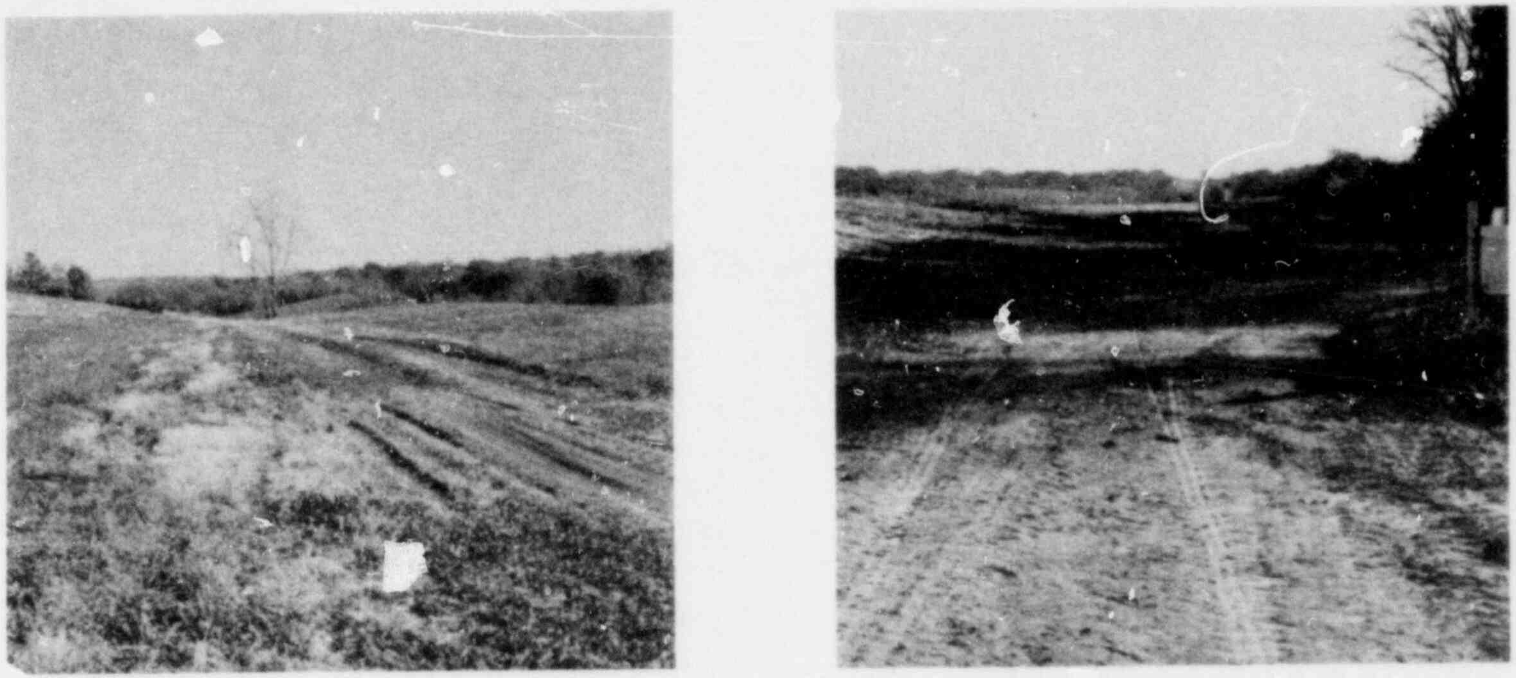
FIGURE 7 - NORTHERN DRAINAGE CHANNELS - NOVEMBER 5, 1980

DRAINAGE AT SOUTH END
OF SITE LOOKING SOUTH
FROM T-11

FIGURE 8 - SOUTHERN GULLY - NOVEMBER 5, 1980

SLOPE AT SOUTH END OF SITE LOOKING NORTH

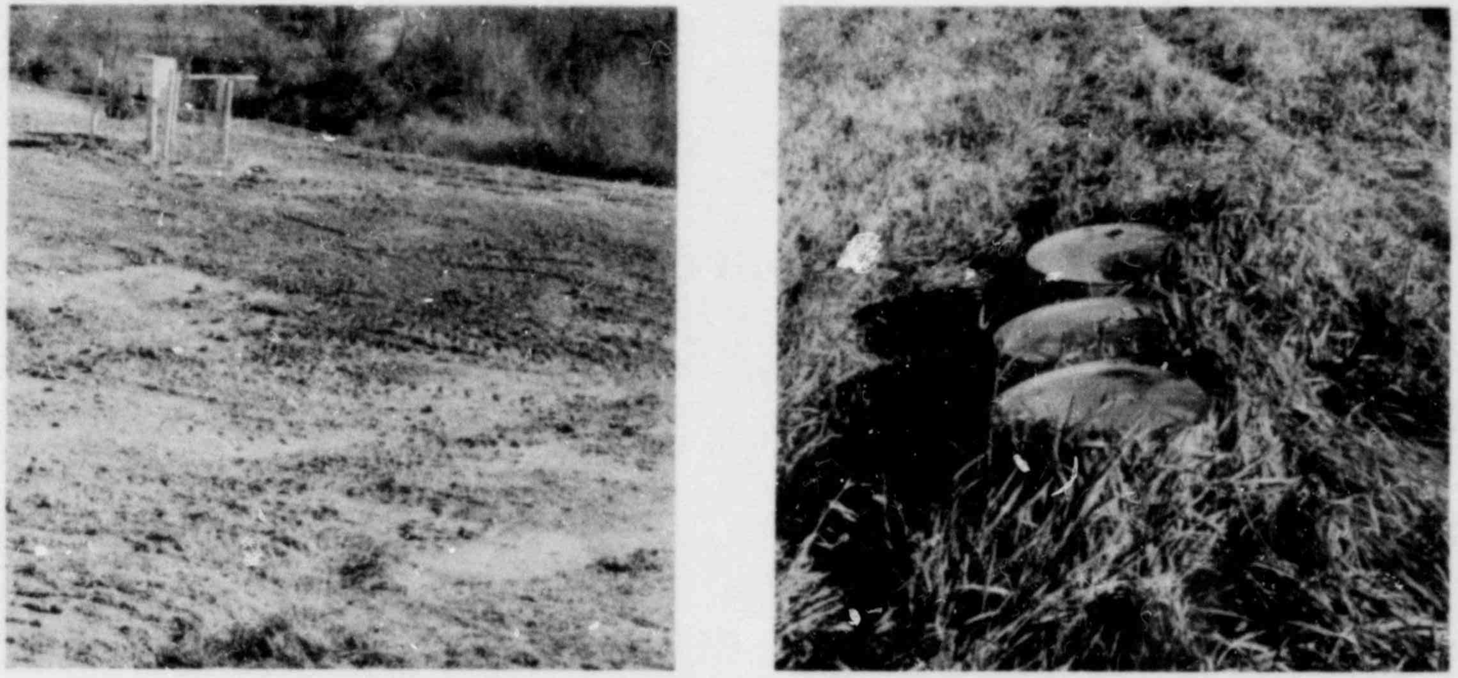
FIGURE 9 - SURFACE WATER SWALE - NOVEMBER 5, 1980



TIRE TRACKS AND LOWSPOTS
BETWEEN T-6 AND T-9

TIRE TRACKS ON WEST END OF SITE
LOOKING SOUTH

FIGURE 10 - POTENTIAL AREAS OF CONCENTRATED INFILTRATION - NOVEMBER 5, 1980



WELL CASINGS SOUTH
OF T-11

SPECIAL CASINGS NORTH SIDE
OF T-1 LOOKING EAST

FIGURE 11 - WELL AND SPECIAL BURIAL CASINGS - NOVEMBER 5, 1980

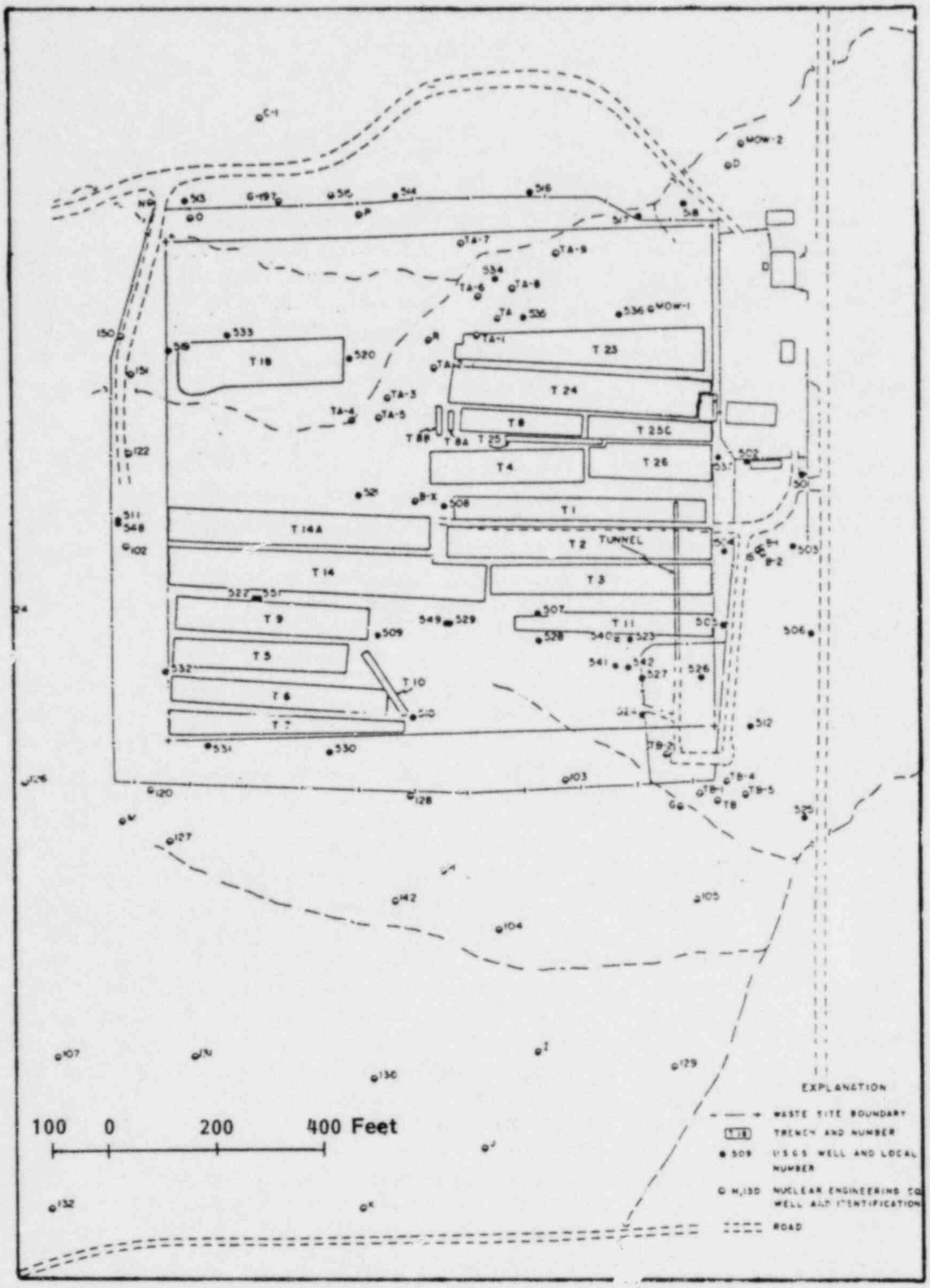


FIGURE 12 - LOCATION OF WELLS, BORINGS, TRENCHES, AND TUNNEL

Source: Preliminary Report on the Hydrogeology of a Low-Level Radioactive-Waste Disposal Site near Sheffield, Illinois.(2)

# III. TRENCH SUBSIDENCE

## A. TRENCH HISTORY

The history of the opening, closing, excavation size, and burial inventory by date was recorded monthly by NECO on trench status reports. The final trench status report for each trench is presented in Appendix A. For example, Trench 1 was opened in August 1967 and closed one year later in August 1968. It has a noted length of 450 feet, a width of 40 feet, no given depth and a noted waste volume of 144,817 cubic feet. This data for each trench is summarized in Table 2 along with known details of the types of waste containers and cap construction method as related by NECO.

The time sequencing of the opening and closing of the trenches is depicted graphically in Plate I. Wastes would be delivered to the site by truck in shielded containers constructed to keep radiation levels outside the containers lower than the maximum allowed by the Department of Transportation for transport. Wastes were deposited in cardboard boxes, plywood and wood crates, metal drums, and concrete septic tanks. Wastes were also solidified on-site for disposal.

There is no detailed inventory of waste characteristics by trench. All trenches were reportedly filled with the waste containers described above except for Trenches 8A, 8B and 10 which received Anafco tubs of solidified wastes. Trench 18 reportedly had sand filled concrete septic tanks placed on the bottom and metal drums with wastes above the tanks.

Generally, the trenches were initially totally excavated with the soil placed along their sides. Wastes were deposited in the trenches and covered with backfill. As the waste filled the trench, more backfill soil was added until the wastes were within three feet of the original grade. An approximately three foot thick soil cover cap was then placed and mounded above grade to provide for runoff. The placement equipment probably applied some compactive effort. No compaction was documented on any of the trenches except 14, 14A and 18. Trenches 14 and 14A were built above grade and the walls were compacted. Trench 18 was overexcavated and the bottom was recompacted up to its required grade as selected by the NRC prior to the burial of waste.

On Trenches 14 and 14A the outside walls were brought to a uniform grade by placing a compacted fill of clay shale and loess blend over the natural loess surface soil. These wall fills were placed as engineered fills and documented by Daley & Associates, Engineers, Incorporated. The compaction of the Trench 14 and 14A caps were also tested to meet 90 percent of the maximum density as determined by the Modified Proctor test. Trench 18 received a compacted blanket of fill over the bottom of the trench on which the filled septic tanks were placed.

## TABLE 2 - TRENCH DATA

| Trench No. | Date Opened/Closed | Trench Dimensions L-W-D (ft) | Trench Volume* (ft$^3$) | Waste Volume (ft$^3$) | Waste Containment | Cap Construction |
|---|---|---|---|---|---|---|
| 1 | 8-67/8-68 | 450-40-20 ++ | 360,000 | 144,817 | General** | N.D.*** |
| 2 | 8-68/3-71 | 460-60-25 | 690,000 | 231,235 | " | " |
| 3 | 3-71/5-72 | 400-55-25 | 550,000 | 191,201 | " | " |
| 4 | 5-72/4-73 | 280-60-20 | 336,000 | 197,898 | " | " |
| 5 | 4-73/8-73 | 350-50-20 | 350,000 | 136,419 | " | " |
| 6 | 8-73/3-74 | 390-45-20 | 351,000 | 211,677 | " | " |
| 7 | 3-74/6-74 | 400-30-20 | 253,200 | 133,709 | " | " |
| 8 | 7-74/8-74 | 200-45-11.5 | 103,500 | 49,364 | " | " |
| 9 | 7-74/2-75 | 350-58-22 | 446,600 | 185,237 | " | " |
| 10 | 7-74/1-75 | 130-17-15 | 33,150 | 13,945 | Anafco tubs | " |
| 11 | 12-74/6-75 | 350-40-20 | 183,200 | 92,410 | General | " |
| 25 | 2-75/5-75 | 100-8-18 | 43,200 | 14,525 | " | " |
| 26 | 5-75/8-75 | 180-64-23 | 264,960 | 166,138 | " | " |
| 8A | 5-75/5-75 | 35-8-18 | 5,040 | 3,178 | Anafco tubs | " |
| 8B | 5-75/6-75 | 51-8-18 | 7,344 | 2,653 | " | " |
| 24 | 6-75/5-76 | 455-62-17 | 479,570 | 227,696 | General | " |

### TABLE 2 - TRENCH DATA (cont)

| Trench No. | Date Opened/Closed | Trench Dimensions L-W-D (ft) | Trench * Volume (ft³) | Waste Volume (ft³) | Waste Containment | Cap Construction |
|---|---|---|---|---|---|---|
| 18 | 3-76/12-76 | 320-70-15 | 336,000 | 120,655 | Concrete tanks<br>Metal drums | N.D. |
| 25C | 4-76/8-76 | 218-35-18 | 137,340 | 65,579 | General | " |
| 23 | 8-76/1-77 | 440-54-18 | 427,680 | 184,450 | " | " |
| 14 | 1-77/9-77 | 580-54-25 | 783,000 | 394,400 | " | Compacted+ |
| 14A | 8-77/4-78 | 475-58-26 | 716,300 | 351,877 | " | " |
| TOTALS | | | 6,957,084 | 3,119,063 | | |

* Calculated from dimensions

** General-Cardboard, plywood, wood and boxes, metal drums, etc.

*** N.D.- Not documented

\+ Compacted to 90 percent maximum Proctor density

++ Depth estimated, Data not given

Source: NECO Trench Status Reports

## B. PAST SUBSIDENCE

Monitoring of trench subsidence began in October 1978, ten years from the time the first trench, T-1, was completed and six months after the last trench, T-14A, was completed. The site monitoring data was recorded by NECO in the trench inspection reports included as Appendix B, and represent observations made over the two year period from October 1978 through October 1980. These observations were recorded by site personnel as they inspected the surface of each trench. As surface subsidence, erosion and other incidents were recorded and if weather conditions permitted, the site personnel would initiate repairs. The completed repairs, consisting of filling the holes, were also noted on the trench maintenance records.

The subsidence data from these reports is summarized in Tables 3 and 4 for each trench together with the date on which the subsidence was noted, the elapsed years between the completion of the trench and the recorded subsidence and a brief description of the subsidence.

The number of incidences of recorded subsidence are plotted against chronological time in Figure 13 together with monthly precipitation from Table 5. Precipitation includes the liquid equivalent of snowfall. Spikes in the number of incidences of subsidence are preceded by historically high spikes in the amount of precipitation. For example, in March - April 1979, 56 subsidences were noted. This followed five months (November - March) with 13.00 inches of precipitation during which the 30 year normal for the same period was 9.28 inches. Also, normally, at the beginning of the winter season, moisture within the surface soil freezes, creating a hard impermeable frozen ground cover. During the winter months of 1978 and 1979 a frost depth was reportedly not established, due to the warmer than normal winter. Consequently, the snow that fell on the Sheffield site covered the surface soil before it froze, and when the snow melted, water infiltrated into and saturated the soil. Rain also occurred during the winter and heavily in the spring, which added to the saturated surface soil conditions and trench infiltration. The saturated soils then subsided in the spring of 1979 as shown in Figure 13.

All the recorded subsidences are tabulated by the age of the trench in Table 6. The age of the trench is divided into one year increments and the number of subsidences occurring in that time frame and the number of trenches on which they occurred are shown. Also indicated are the number of trenches of the given age and the number of the trenches out of 21 trenches which are not applicable because of the limited period of recorded data. It is seen that for the one trench for which the 0 - 1 year age is applicable, Trench 14A, 14 subsidences occurred. All but one subsidence occurred on the wall between Trenches 14 and 14A and reportedly in the direction of 14A. These occurred in a period of higher than normal precipitation.

## TABLE 3 - TRENCH SUBSIDENCE SUMMARY

| Trench | Date Subsidence Noted | Years Since Completion | Type of Subsidence | Probable Cause |  |  |
|---|---|---|---|---|---|---|
|  |  |  |  | Primary | Secondary | Remarks |
| 1 | 11/7/78 | 10.2 | 0.33' Diameter<br>10' Deep | Consolidation | Loose backfill | USGS Drilling |
| " | 12/26/79 | 11.3 | 5' Diameter<br>1' Deep | " | – | – |
| 2 | None | – | – | – | – | – |
| 3 | 4/17/80 | 7.9 | [illegible] Diameter<br>3' Deep | Precipitation | Consolidation | Noted on 4/15/80 Sheet |
| " | 7/80 | 8.0 | 6' Diameter<br>1.33' Deep | Consolidation | – | Reported by Harding and Lawson Associates |
| 4 | None | – | – | – | – | – |
| 5 | 3/23/79 | 5.4 | 3' Diameter<br>2' Deep | Precipitation | Consolidation | Snow Melt |
| 6 | 3/30/79 | 4.9 | 2' Diameter<br>0.5' Deep | " | " | " |
| " | " | " | 2' Diameter<br>0.5' Deep | " | " | Heavy Rains During Day |
| " | 4/4/79 | 5.0 | 5' X 2' | " | " | Snow Melt |
| " | " | " | Low Spot<br>No recorded dimensions | " | " | " |
| " | 5/4/79 | 5.1 | 3' Diameter<br>1' Deep | Precipitation | " | " |

## TABLE 3 - TRENCH SUBSIDENCE SUMMARY (cont)

| Trench | Date Subsidence Noted | Years Since Completion | Type of Subsidence | Probable Cause Primary | Probable Cause Secondary | Remarks |
|---|---|---|---|---|---|---|
| 7 | 3/23/79 | 4.7 | 15' Diameter<br>10' Deep | Precipitation | Snow Melt | Exposed Waste |
| " | " | " | 3' Diameter<br>1' Deep | " | " | - |
| " | 3/24/79 | " | 2' Diameter<br>1' Deep | " | " | Snow Melt |
| " | 3/30/79 | " | 1' Diameter<br>0.5' Deep | " | " | " |
| " | " | " | 1' Diameter<br>0.5' Deep | " | " | " |
| " | " | " | 1' Diameter<br>0.5' Deep | " | " | " |
| " | 4/4/79 | 4.8 | 3' X 2' | " | " | " |
| " | 4/16/79 | " | 2' Diameter<br>5' Deep | " | " | " |
| " | " | " | 3' Diameter<br>3' Deep | " | " | " |
| " | 4/26/79 | " | 5' Diameter<br>10' Deep | " | " | Exposed Waste |
| " | " | " | 1' Diameter<br>10' Deep | " | " | Snow Melt |
| " | 5/4/79 | 4.9 | 5' Diameter<br>1' Deep | " | " | - |

## TABLE 3 - TRENCH SUBSIDENCE SUMMARY (cont)

| Trench | Date Subsidence Noted | Years Since Completion | Type of Subsidence | Probable Cause | | Remarks |
|---|---|---|---|---|---|---|
| | | | | Primary | Secondary | |
| 7 | 5/4/79 | 4.9 | 2' Diameter<br>4' Deep | Precipitation | Consolidation | – |
| " | 4/15/80 | 5.8 | 3' Diameter<br>2' Deep | " | " | – |
| " | 4/17/80 | " | 3' Diameter<br>3' Deep | " | – | oted on 4/15/80<br>Sheet |
| 8 | None | – | – | – | – | |
| 9 | 10/31/78 | 3.7 | 1' Diameter<br>1' Deep | Consolidation | – | – |
| " | " | " | Low Spot<br>No Recorded Dimensions | Vehicular Traffic | – | Southside Holds Water |
| " | 3/23/79 | 4.1 | 3' Diameter<br>2' Deep | Consolidation | Precipitation | Snow Melt |
| " | 4/4/79 | 4.2 | Low Spot<br>No Recorded Dimensions | Vehicular Traffic | –<br>– | Southside Holds Water |
| 10 | " | " | 3' X 2' | Poor Drainage | Consolidation | Snow Melt |
| " | " | " | 3' X 2' | " | " | " |
| " | " | " | 3' X 2' | "<br>" | "<br>" | "<br>" |
| " | " | " | 3' X 2' | " | " | " |
| " | " | " | 3' X 2' | " | " | " |
| 11 | None | – | – | – | – | – |
| 25 | " | – | – | – | – | – |
| 8A | " | – | – | – | – | – |

## TABLE 3 - TRENCH SUBSIDENCE SUMMARY (cont)

| Trench | Date Subsidence Noted | Years Since Completion | Type of Subsidence | Probable Cause Primary | Probable Cause Secondary | Remarks |
|---|---|---|---|---|---|---|
| 8 B | None | - | - | - | - | - |
| 26 | 4/12/79 | 3.6 | 2' Diameter 1' Deep | Precipitation | Consolidation | - |
| " | " | " | 1' Diameter 2' Deep | " | " | - |
| " | 10/11/79 | 4.2 | Depression No Recorded Dimension | Consolidation | - | - |
| 24 | 3/23/79 | 2.8 | 10' Diameter 4' Deep | Precipitation | Consolidation | Snow Melt |
| " | 4/26/79 | 2.9 | 20' Diameter 5' Deep | " | " | Exposed Waste |
| 18 | 12/19/78 | 2.0 | 2' Diameter 4' Deep | " | " | Settlement on Wall |
| " | 3/23/79 | 2.3 | 3' Diameter 4' Deep | " | " | Snow Melt<br>High water table |
| " | " | " | 10' Diameter 2' Deep | " | " | " |
| " | " | " | 4' Diameter 1' Deep | " | " | " |
| " | 4/2/79 | 2.3 | 3' Diameter 2' Deep | " | " | Rain |
| " | " | " | 2' Diameter 3' Deep | " | " | " |
| " | " | " | 1' Diameter 1' Deep | " | " | " |

## TABLE 3 - TRENCH SUBSIDENCE SUMMARY (cont)

| Trench | Date Subsidence Noted | Years Since Completion | Type of Subsidence | Probable Cause | | Remarks |
|---|---|---|---|---|---|---|
| | | | | Primary | Secondary | |
| 18 | 4/2/79 | 2.3 | 1' Diameter<br>4' Deep | Precipitation | Consolidation | High Water Table |
| " | " | " | 4' Diameter<br>1' Deep | " | " | Depression |
| " | 8/17/79 | 2.7 | 1' Diameter<br>2' Deep | " | " | Settlement on Wall |
| " | 9/14/79 | 2.8 | 6' Diameter<br>3' Deep | " | – | High Water Table |
| 25C | 3/23/79 | 2.6 | 4' Diameter<br>5' Deep | " | " | Snow Melt |
| " | " | " | 1' Diameter<br>1' Deep | " | " | – |
| " | " | " | 1' Diameter<br>1' Deep | " | " | – |
| " | 4/12/79 | 2.7 | 2' Diameter<br>1' Deep | " | " | – |
| " | 1/18/80 | 3.4 | 4' Diameter<br>2' Deep | " | " | Occurring Around Monument and Sump Pipe |
| " | 4/15/80 | 3.7 | 1' Diameter<br>2' Deep | " | – | " |
| " | " | " | 3' Diameter<br>1' Deep | " | – | Around Sump Pipe |
| 23 | 11/20/78 | 1.8 | 3' Diameter<br>6' Deep | " | Consolidation | Rain |
| " | 3/23/79 | 2.1 | 20' Diameter<br>6' Deep | " | " | Snow Melt |

TABLE 3 - TRENCH SUBSIDENCE SUMMARY (cont)

| Trench | Date Subsidence Noted | Years Since Completion | Type of Subsidence | Probable Cause |  |  |
|---|---|---|---|---|---|---|
|  |  |  |  | Primary | Secondary | Remarks |
| 23 | 3/23/79 | 2.1 | 4' Diameter 1.5' Deep | Precipitation | Consolidation | Snow Melt |
| " | " | " | 5' Diameter 1' Deep | " | " | " |
| " | 4/4/79 | 2.2 | 3' X 2' | " | " | " |
| " | 4/12/79 | " | 10' Diameter 0.5' Deep | " | " | " |
| " | 12/26/79 | 2.8 | 5' Diameter 7' Deep | " | " | Settlement around sump pipe |
| Wall between 14 and 14A | 12/15/78 | 0.6 | 3' Diameter 4' Deep | " | Slumping of Trench Walls | Loss of subgrade support. Failures into 14A. |
| " | " | " | 3' Diameter 4' Deep | " | " | " |
| " | " | " | 3' Diameter 4' Deep | " | " | " |
| " | 3/23/79 | 0.8 | 4' Diameter 3' Deep | " | " | Snow Melt |
| " | " | " | 4' Diameter 3' Deep | " | " | " |
| " | " | " | 8' Diameter 6' Deep | " | " | " |

## TABLE 3 - TRENCH SUBSIDENCE SUMMARY (cont)

| Trench | Date Subsidence Noted | Years Since Completion | Type of Subsidence | Probable Cause |  | Remarks |
|---|---|---|---|---|---|---|
|  |  |  |  | Primary | Secondary |  |
| Wall between 14 and 14A | 3/23/79 | 0.8 | 10' Diameter 6' Deep | Precipitation | Snow Melt | Exposed Waste |
| " | " | " | 10' Diameter 5' Deep | " | " | Rain |
| " | 3/29/79 | " | 2' Diameter 4' Deep | " | " | " |
| " | 4/2/79 | 0.9 | 1' Diameter 3' Deep | " | " | " |
| " | 4/16/79 | " | 3' Diameter 1' Deep | " | " | " |
| " | 4/21/79 | " | 3' Diameter 1' Deep | " | " | " |
| 14A | 3/23/79 | 0.8 | 6' Long 6" Deep | " | " | " |
| " | 4/3/79 | 0.9 | 2' Diameter 4' Deep | " | " | " |
| 14 | 12/26/79 | 2.2 | 2' Diameter 1' Deep | " | " | – |

Source: NECO Monthly Trench Inspection Reports, October 1978 to October 1980, unless otherwise noted.

## TABLE 4 - CHRONOLOGICAL TRENCH INSPECTION SUMMARY

| Date Recorded | Number of Subsidences | Number of Trenches | Trench Numbers | Remarks |
|---|---|---|---|---|
| 10/12/78 | 0 | 0 | | Erosions Noted |
| 10/31/78 | 2 | 1 | 9 | Erosions Noted |
| 11/7/78 | 1 | 1 | 1 | USGS Drilling |
| 11/20/78 | 1 | 1 | 23 | Caused by Heavy Rains |
| 12/15/78 | 3 | 1 | Between 14 & 14A | Caused by Settling |
| 12/19/78 | 1 | 1 | 18 | Settling |
| 1/31/79 | - | - | - | Three Feet of Snow |
| 2/27/79 | - | - | - | Covered with Snow |
| 3/23/79 | 20 | 9 | 5, 7, 9, 14 14A, 18, 23, 25C, 24 | Exposed Waste |
| 3/24/79 | 1 | 1 | 6 | - |
| 3/29/79 | 2 | 2 | 7, between 14 & 14A | - |
| 3/30/79 | 5 | 2 | 6, 7 | Heavy Rains |
| 4/2/79 | 4 | 2 | 18, between 14 & 14A | - |
| 4/3/79 | 1 | 1 | 14A | - |
| 4/4/79 | 10 | 5 | 6, 7, 10, 23, 9 | - |
| 4/12/79 | 4 | 3 | 23, 25C, 26 | End Loader Got Stuck |
| 4/16/79 | 3 | 2 | 7, between 14 & 14A | - |
| 4/19/79 | 0 | - | - | - |
| 4/21/79 | 3 | 2 | 18, between 14 & 14A | - |
| 4/26/79 | 3 | 2 | 7, 24 | 1.7 inches of rain |
| 5/4/79 | 3 | 2 | 6, 7 | |
| 5/25/79 | 0 | - | - | - |
| 6/20/79 | 0 | - | - | - |
| 7/30/79 | 0 | - | - | - |

## TABLE 4 - CHRONOLOGICAL TRENCH INSPECTION SUMMARY (cont)

| Date Recorded | Number of Subsidences | Number of Trenches | Trench Numbers | Remarks |
|---|---|---|---|---|
| 8/17/79 | 1 | 1 | 18 | Around side sump |
| 8/20/79 | 0 | – | – | Erosions after 9 inches of rain in one weekend |
| 9/14/79 | 1 | 1 | 18 | – |
| 10/11/79 | 1 | 1 | 26 | Repaired Erosions |
| 10/25/79 | 0 | – | – | – |
| 12/26/79 | 3 | 3 | 1, 14, 23 | – |
| 1/18/80 | 1 | 1 | 25C | – |
| 1/30/80 | 0 | – | – | – |
| 2/29/80 | – | – | – | All snow covered |
| 3/12/80 | 0 | – | – | – |
| 3/28/80 | 0 | – | – | – |
| 4/15/80 | 3 | 2 | 7, 25C | |
| 4/17/80 | 2 | 2 | 3, 7 | Noted on 4/15/80 Sheet |
| 5/27/80 | 0 | – | – | – |
| 6/27/80 | 0 | – | – | – |
| 7/23/80 | 0 | – | – | – |
| 8/29/80 | 0 | – | – | – |
| 10/31/80 | 0 | – | – | – |

Source: NECO Monthly Trench Inspection Reports, October 1978 to October 1980.

## TABLE 5 - PRECIPITATION* IN INCHES

| Month | 30 Year Normal** | 1978 | 1979 | 1980 |
|---|---|---|---|---|
| January | 1.63 | 0.59 | 2.72 | 1.31 |
| February | 1.25 | 0.67 | 1.02 | 1.55 |
| March | 2.61 | 0.78 | 2.77 | 1.74 |
| April | 3.72 | 3.02 | 4.01 | 2.34 |
| May | 4.01 | 4.65 | 2.86 | 4.01 |
| June | 4.40 | 3.50 | 2.85 | 4.97 |
| July | 4.22 | 3.24 | 4.40 | 3.46 |
| August | 3.51 | 2.47 | 6.94 | 9.09 |
| September | 3.74 | 3.91 | 0.02 | 2.94 |
| October | 2.63 | 1.95 | 2.51 | 1.63 |
| November | 2.08 | 3.32 | 2.13 | 7.00 |
| December | 1.71 | 3.17 | 2.27 | 2.75 |
| Annual | 35.51 | 31.27 | 34.50 | 42.79 |

*Includes liquid equivalent of snowfall

**1940-1979

Source: Weather Assistance, Moline, Illinois (1980)
U.S. Department of Commerce, NOAA (1941-1979)

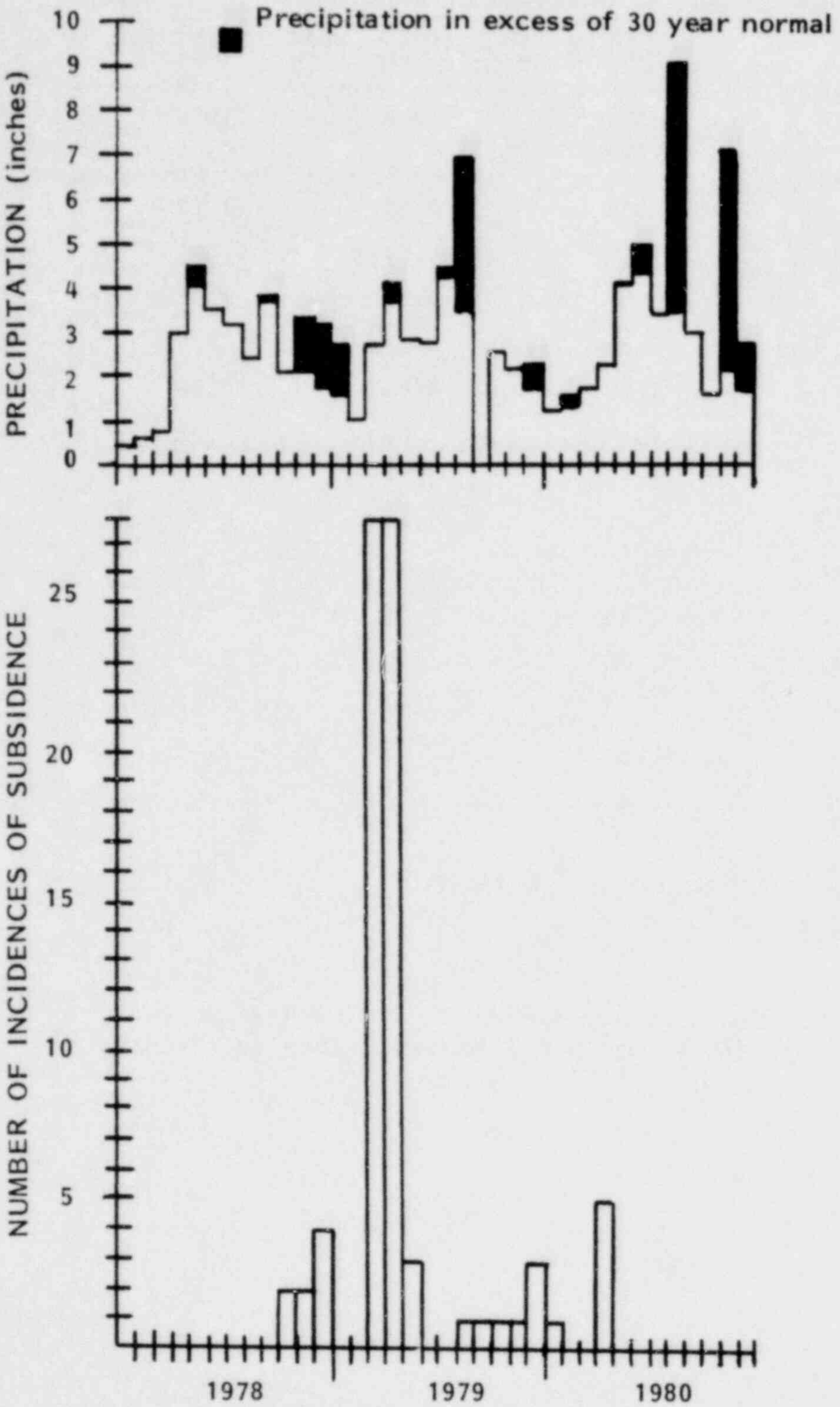


FIGURE 13 - CHRONOLOGICAL TRENCH SUBSIDENCE DURING TWO YEARS OF MONITORING

## TABLE 6 - SUBSIDENCE BY AGE OF TRENCH

| Years Since Completion | Number of | | Number of Trenches of Given Age* During the Two Year Period of Monitoring | Number of Trenches Not Applicable |
|---|---|---|---|---|
| | Subsidences | Trenches Involved | | |
| 0-1 | 14 | 1 | 1 | 20 |
| 1-2 | 2 | 2 | 3 | 18 |
| 2-3 | 23 | 5 | 7 | 14 |
| 3-4 | 7 | 3 | 12 | 9 |
| 4-5 | 25 | 5 | 12 | 9 |
| 5-6 | 4 | 3 | 10 | 11 |
| 6-7 | - | - | 6 | 15 |
| 7-8 | 1 | 1 | 4 | 17 |
| 8-9 | 1 | 1 | 2 | 19 |
| 9-10 | - | - | 1 | 20 |
| 10-11 | 1 | 1 | 1 | 20 |
| 11-12 | 1 | 1 | 1 | 20 |
| 12-13 | - | - | 1 | 20 |

* Determined back from period of recorded subsidences, October 1978 and October 1980.

Twenty three subsidences occurred on five trenches in the 2-3 year age category for which seven trenches were applicable. In the older age grouping a smaller number of subsidences were noted but the available number of applicable trenches of the given age was also greatly reduced due to the limited recorded data period.

All the instances of recorded subsidence from October 1978 to 1980 are plotted by relative size and identified in chronological groupings in Plate 2. The groupings were chosen around the extreme weather conditions of early snowfall, reduced ground freezing and heavier than normal precipitation which occurred in the Winter to Spring of 1978 to 1979.

Plate 3 shows the incidences and locations of subsidence for the period from 0-3 years of completion of each trench for which the recorded data period covers the time after which the trench was completed. As noted, Plate 3 is applicable to only seven of the 21 trenches. The recorded data reviewed on subsidence does not cover 14 of the trenches.

Plate 4 depicts the locations of subsidences for the period 3-6 years from completion of each trench for which the recorded data period covers the time after a trench was completed. Four of the 21 trenches shown on Plate 4 are not applicable as noted.

Plate 5 depicts the subsidences occurring for the period 6 - 12 years following trench completion. As noted it is not applicable to 13 of the 21 trenches.

Figure 14 presents the accumulated waste volume plotted against time from the opening of Trench 1 to the closing of the last trench and shows an increasing quantity of waste placed in later years. Based on our experience with solid waste handling, trench integrity may have been affected by the rate at which waste came into the trenches. The average volume buried from 1967 to 1972 was approximately 119,000 cubic feet per year. For the period 1972 to 1974 the average volume of waste buried at the Sheffield site was 145,000 cubic feet per year, an approximate annual 22 percent increase over the previous period. For the period of 1974 to 1978 an average of 451,000 cubic feet per year was buried. This was an average increase of over 210 percent over the 1974 to 1978 period.

Knowing the distribution of subsidence sizes may prove useful in the design of the final trench caps. Figure 15 is a plot of the diameter of recorded subsidences against the number of incidences of that particular size. The figure indicates that most subsidences were 10 feet in diameter or less, with

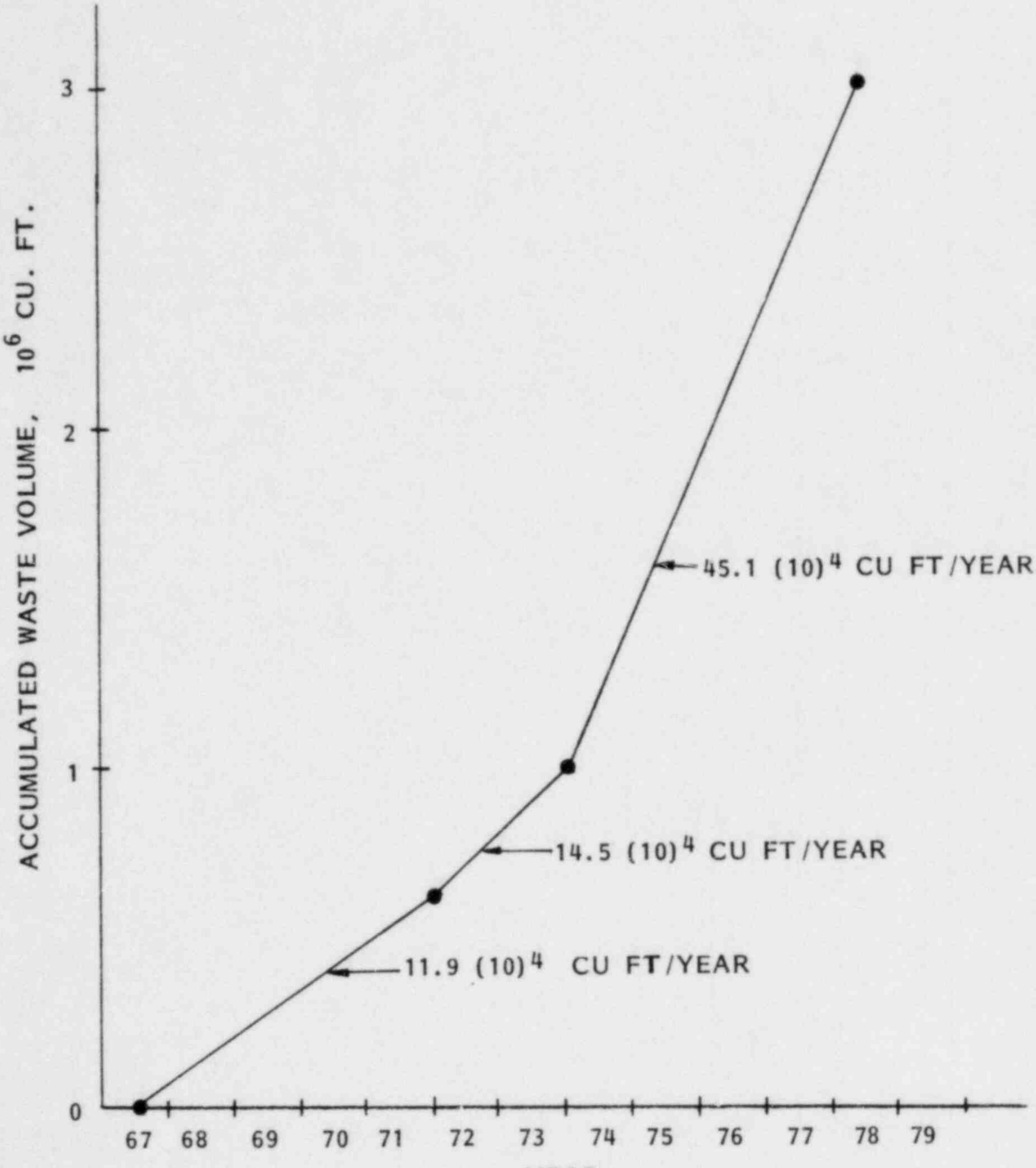


FIGURE 14 - ACCUMULATED WASTE VOLUME PER YEAR

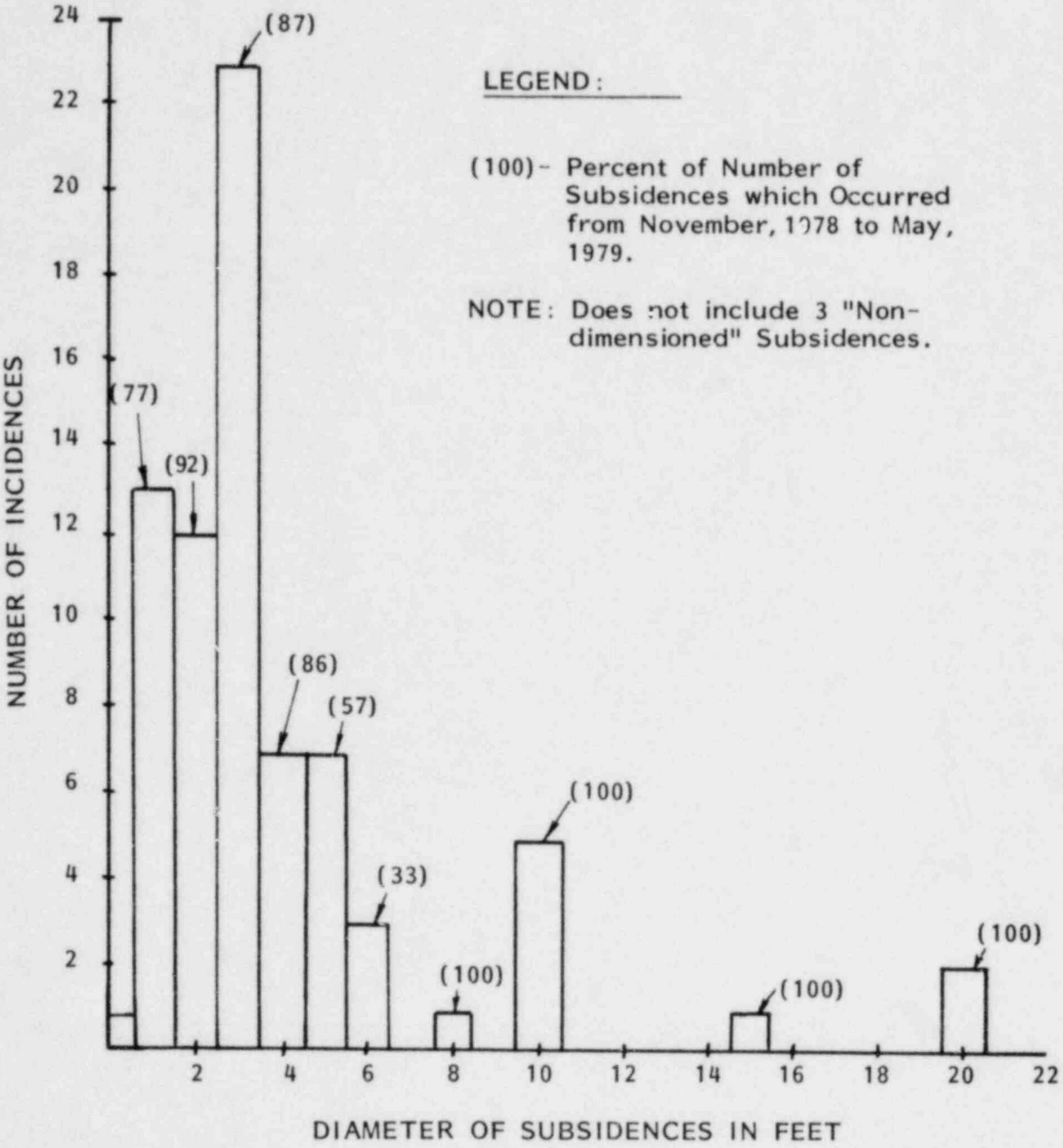


FIGURE 15 - SUBSIDENCE SIZE DISTRIBUTION

a few larger than 10 feet in diameter. The occurrence of one subsidence being less than one foot in diameter as is plotted may be due to the observer estimating its diameter too accurately to less than one foot. The impact of the Winter 1978-1979 is again indicated by percent of subsidences which occurred at that time.

A discussion of each trench follows:

## Trench 1

The burial of waste in Trench 1, once NECO assumed operation of the Sheffield site, was continued from approximately 60 feet from the east end and completed westerly by August 16, 1968. While drilling a monitoring well on the south side of Trench 1, the USGS perforated a container of hospital or laboratory waste as indicated in the monthly trench report, November 7, 1978. The four inch wide subsidence was ten feet deep and was filled with cement and bentonite.

On December 26, 1979, a subsidence was recorded as five feet in diameter and one foot deep occurring around a sump pipe. It was filled the same day. The subsidence occurred over eleven years after the trench was completed.

Trench 1 also had three special culverts on its north side installed as the trench was excavated in order to facilitate the burial of tritium, cesium, cobalt, and other special waste. These special casings were filled with concrete and capped with metal lids, Figure 11, in 1977 according to NECO.

## Trench 2

There has been no subsidence noted on Trench 2 within the 2 year period that NECO has been recording subsidence data.

## Trench 3

There was one subsidence on Trench 3 recorded on sheet dated April 15, 1980, and noted as found on April 17, 1980. The subsidence was five feet in diameter and three feet deep. Soft ground hampered filling the hole. It was completed by April 21, 1980.

The Harding Lawson report, submitted to the NRC, July 31, 1980, reports a six foot diameter and 1.33 feet deep subsidence on the southwest end of Trench 3 recorded on July 23, 1980. It was not mentioned in the trench maintenance records Stone received from NECO covering the period of October 1978 to October 1980. It was not visable on the site in November 1980 or January 1981 and is assumed to have been repaired shortly after the Harding Lawson report was published.

### Trench 4

There have been no subsidences on Trench 4 during the two year monitoring period.

### Trench 5

One subsidence was recorded on March 23, 1979 on the east end of the trench following the winter of 1978-1979. It was three feet in diameter and two feet deep.

### Trench 6

Subsidences were noted on Trench 6 on March 30, April 4 and May 4, 1979 following noted adverse climatic conditions. Also, a low spot located between Trench 5 and Trench 6 was cited on April 4, 1979. This low spot was identified as a possible point of concentrated infiltration.

### Trench 7

Trench 7 has had the most incidences of subsidence of all the trenches. The subsidences occurred during and after the spring of 1979.

The first recorded subsidence, 15 feet in diameter and 10 feet deep, was noted as being on the west end of the trench in March 23, 1979. That same day a three foot diameter, one foot deep subsidence was noted on the north side of the trench. On March 24, 1979 a two foot diameter, one foot deep subsidence was noted between Trench 6 and Trench 7. On March 24, 1979 one subsidence was recorded existing on the north side of the trench two feet in diameter and one foot deep. On March 30, 1979 three subsidences were noted on the north side of the trench. All were one foot in diameter and half of one foot deep. On April 4, 1979 a three foot diameter two foot deep subsidence was noted on the north west side of the trench. On April 16, 1979 a two foot diameter five foot deep and three foot diameter three foot deep subsidence were noted on the south side. On approximately the same location on April 26, 1979 on the southside of Trench 7 another subsidence one foot in diameter and 10 feet deep was recorded. On that same day on the west end of the trench a five foot diameter, 10 feet deep subsidence was noted. During May 1979 a five foot diameter one foot deep and a two foot diameter four foot deep subsidence was noted on the trench toward the west end of the trench. On the April 15, 1980 report there were two subsidences noted, one was three feet in diameter and three feet deep and the other was three feet in diameter and two feet deep.
Some of these subsidences were noted as exposing waste materials.

### Trench 8

There was no subsidence recorded on Trench 8 during the two years of data.

## Trench 9

Subsidences were noted in October 1978 along the south side of the trench. There were vehicle tire marks and low spots along the trench's sides that could facilitate water infiltration. On March 23, 1979 one subsidence was noted as three feet in diameter and two feet deep on the south side of Trench 9.

## Trench 10

Five subsidence features occurred on the south end of the trench and were recorded and repaired on April 4, 1979. The trench is oriented northwest to southeast on the site compared with east and west, the alignment of most of the other trenches. The subsidence is blamed by site personnel on having the drainage from the west directed over the trench. Drainage is now directed around the north end of the trench.

## Trench 11

There is no record of subsidence for Trench 11, during the two year monitoring period. Trench 11 has the steepest finished surface slope of all the trenches on the site and as a result is subject to erosion. Because of the extreme slope, water tends to sheet off of the south surface of the trench at a velocity fast enough to erode the top soil causing rilling and gullying. For this reason the regraded trench surface has been seeded again for the establishment of ground cover. Stone's three visits occurred too soon after reseeding to determine whether the erosion problem on this steep slope will be controlled.

## Trench 25, 8A, and 8B

There is no record of subsidence for Trenches 25, 8A and 8B during the two year monitoring period. Trenches 8A and 8B reportedly received Anafco tubs of solidified waste and were open only a short time.

## Trench 26

Trench 26 has three subsidences, two of which were reported in April 1979. One was two feet in diameter and one foot deep and the other was one foot in diameter and two feet deep. In October 1979 a small depression was noted and repaired on the east end of the trench.

## Trench 24

On March 23, 1979 a ten foot diameter, four foot deep subsidence was noted at the southeast corner. On April 26, 1979 a 20 foot diameter five foot deep subsidence exposing waste was noted. It was also noted as being filled the same day after 1.7 inches of rainfall.

## Trench 18

Trench 18 is the only trench that appears to intercept the existing water table[4]. The bottom of all the trenches were required to be seven to ten feet above the surface of the water table at its highest point[5].

During a NRC staff visit to the Sheffield site in June of 1976, a damp zone was observed in the walls of an unfilled portion of Trench 18 to a height of 15 feet from the trench bottom[6]. This observation lead to the conclusion that perhaps a zone of groundwater had been intercepted by the trench excavation. Revised requirements for burial of waste then required that replacement soil of clay shale and silt had to be used and compacted to raise the level of the trench bottom. The compacted fill was selected to have a lower permeability than the natural soil. Additionally, the buried waste was restricted to low activity material. The waste containers consisted of concrete septic tanks and large steel bins.

Plate 2 shows all of the incidences of subsidence on Trench 18 to have occurred on or within the vicinity of the southern wall of the trench. The majority of these subsidences occurred during the spring of 1979 and ranged in size from one to ten feet in diameter. One subsidence was noted on December 19, 1978. It was two feet in diameter and four feet deep, located on the west end of the southern wall of Trench 18.

Three subsidences were also reported on March 23, 1979. One of them was ten feet in diameter and two feet deep and the others were both less than four feet in diameter and depth.

Three subsidences were also reported on April 2, 1979 and all were less than four feet in diameter and less than four feet deep. Two subsidences were also noted on April 2, 1979. One was four feet in diameter and one foot deep and the other one foot in diameter and four feet deep.

Two subsidences were noted on August 17, 1979 and September 14, 1979. They were one foot in diameter and two feet deep, and six feet in diameter and three feet deep, respectively.

The adverse climatic conditions occurring during the winter to spring of 1979 and having a major drainage path paralleling the south side of Trench 18 contributed to water percolating toward the trench's south wall and probable piping and locally saturating the subsoils. The trench wall soils could have then piped and or slumped into voids and less dense areas of the trench resulting in the subsidences concentrated along the trench's south wall. Variations in the level of the water saturated soils will also cause soil settlements.

### Trench 25C

There were a total of seven subsidences on Trench 25C recorded during the two year data period. Four of them were noted during the Spring 1979. One was four feet in diameter and five feet deep and the other two were one foot in diameter and one foot deep, recorded on March 25, 1979. One subsidence was also recorded on April 12, 1979 as two feet in diameter and one foot deep.

Three subsidences occurred after the spring of 1979. One was noted in January 1980 as a four foot diameter, two foot deep depression around the trench's monument and sump pipe. Two others were noted in April 1980 around the same monument and sump pipe. One was one foot in diameter and two feet deep and the other was three feet in diameter and one foot deep. This could be indicating water is entering down along the sump pipe causing the subsidence.

### Trench 23

Trench 23 was constructed on relatively flat ground and has good ground cover on its easterly end. It was recently regraded and reseeded on the west end after the recent installation of a drainage culvert to the southwest.

Seven subsidences, related to periods of heavy rain, have been recorded since the trench's completion in 1977. One of these subsidences occurred during the winter of 1978 and was noted on November 20, 1978 on the wall between Trenches 23 and 24 as a three foot diameter and six feet deep hole caused by heavy rains as noted on the inspection report. Three subsidences were noted on March 23, 1979. One was 20 feet in diameter and six feet deep occurring in approximately the same location as the subsidence that was noted during November 1978. Because of the rain conditions, the saturated fill and undisturbed wall soils may have piped or slumped into a trench void adjacent to the wall interface. The second one was four feet in diameter and one and one half feet deep and the third one was five feet in diameter and one foot deep. Two more subsidences were noted on April of 1979. One was recorded on April 4, 1979 as three feet in diameter and two feet deep and the other on April 12, 1979 as ten feet in diameter and one half of one foot deep. The seventh subsidence was recorded on December 26, 1979 as five feet in diameter and seven feet deep settling around a sump pipe.

### Trenches 14 and 14A

Trenches 14 and 14A were constructed during the period that "maximum site utilization" was being practiced. The site walls were constructed to level grade with a minimum ten foot thickness. The cap and wall soils were reportedly compacted to ninety percent of their maximum density as determined by the modified Proctor test and layed directly over the natural loess surface soil.

It is evident from maintenance records that 12 out of 15 of the subsidences occurred on the wall separating the two trenches. The composition of the wall is a blend of loess and clay shale which was compacted for additional strength. Loess by nature is a fine grained deposit characterized by a very uniform grain size, a high void ratio and possibly a slight cementation in its natural deposit. The cementation is destroyed when the soil is disturbed or partially or fully saturated. Modified forms of loess, those mixed with clay, will retain some cohesion even when submerged. They must be compacted properly to develop full strength. It is our opinion that these subsidences occurred as a result of the natural loess beneath the sidewall fills failing and removing support from the fills. The direction of the failure was probably into the trench and they were noted following periods of heavy precipitation.

Three other subsidences occurred on Trenches 14 and 14A. Trench 14A had two noted on March 23, 1979 and April 3, 1979, six feet long by six inches deep and two feet in diameter by four feet deep, respectively. The one on Trench 14 was noted on December 26, 1979 as two feet in diameter and one foot deep.

## C. MECHANISMS OF SUBSIDENCE

Subsidence, evidenced by the formation of pot holes and sudden slumps, and gradual settlement of the trenches at the Sheffield site is caused by the following mechanisms:

- Slumping of the trench soil cover caused by the filtering of fine soil particles into the voids and interstices in the backfill soils and around the waste containers.
- Deterioration and collapse of the waste disposal containers.
- Consolidation of the backfill soil in the trenches.
- Deterioration and long term settlement of the buried waste materials and containers.

The first mechanism cited is primarily due to the travel of water through the soil and is directly related to the infiltration of precipitation through the existing trench caps. It has probably been primarily responsible for most of the subsidences recorded between October 1978 and October 1980 and especially those in the spring of 1979.

The rate and magnitude of subsidence and settlement due to the aforementioned mechanisms are influenced by several factors such as the initial degree of compaction of the waste containers and backfill soil in the trenches, the orientation of placement of waste containers, the degree of saturation of the trench materials due to infiltration of rainfall and melting snow, and the drainage characteristics of the backfill and cover soil.

Except for Trenches 8A, 8B, and 10, the waste containers were sometimes placed and sometimes dumped into the trenches at the Sheffield site instead of always being placed in orderly rows and layers. In the other three trenches Anafco tubs filled with solidified wastes were reportedly stacked in a more orderly manner. The dumping of waste containers in the majority of trenches would result in a random orientation of containers as shown in Figure 16. The random orientation would result in voids from soil bridging between containers and open spaces beneath containers.

## C.1. Piping and Slumping of Trench Soil Cover

Subsidence of the trenches may be caused by filtering of the fine cover soil particles into the voids and interstices which occur between and beneath the waste containers in the trenches. Voids include spaces left beneath containers and collapsing of the soil bridges between containers. Sifting of the soil particles causes piping in the trench soil cover and the creation of seepage channels and points of concentrated infiltration in the trench caps. This results in loss of trench cap integrity and increases the probability of undermining the soil caps and backfill soil to result in the formation of potholes and sudden slumps.

The potential for piping to occur increases with saturation of the trench cover soil, and the resulting infiltration of water from rainfall and melting snow. In the past, loss of trench cap integrity has been accelerated by vehicles and equipment used to construct and maintain the site. Surface damage was caused by vehicle wheels and people treading upon areas devoid of sufficient ground cover thereby establishing a potential for soil erosion. This gradual erosion causes water infiltration which can also lead to leaching of radioactivity. Trench integrity is also affected by soil shrinkage which occurs after prolonged dry periods. Cracks occur in the site's surface clayey soils, which are expansive, leading to soil erosion and the creation of points of entry for water infiltration.

Changing climatic conditions also have an affect on trench integrity. Freezing and subsequent thawing of surface and subsurface soils can also create cracks leading to water infiltration and sudden slumps in the trench caps. This type of subsidence is random and may tend to decrease in frequency over time as voids fill and less compact areas densify.

## C.2. Consolidation of Backfill Soil

The loosely placed backfill soil consolidates due to its own weight, water

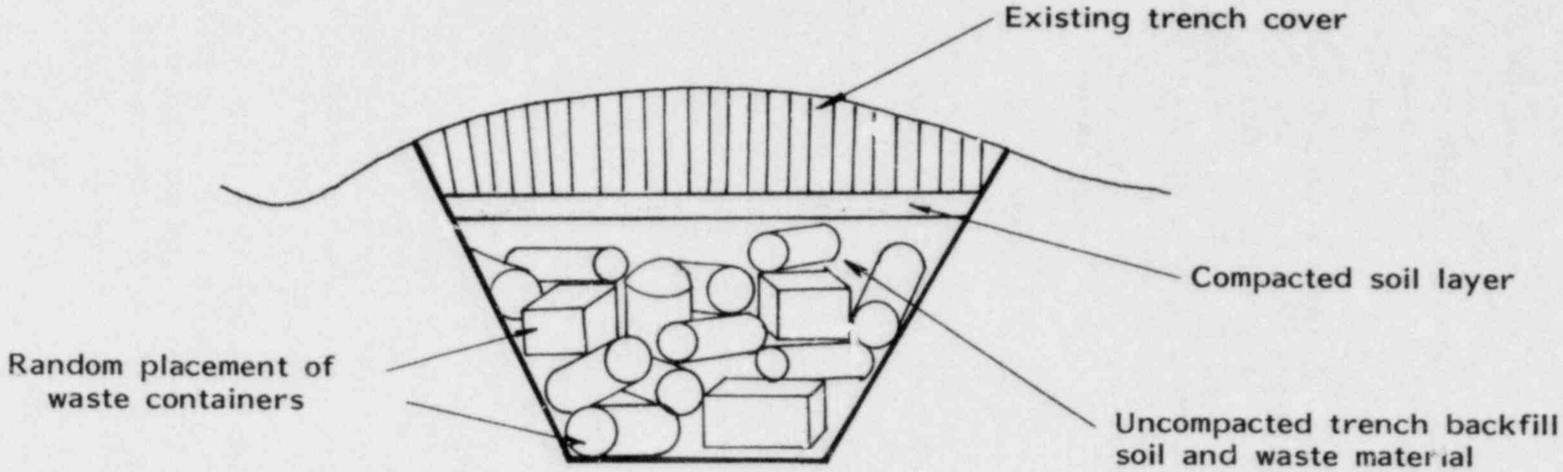


FIGURE 16 - SCHEMATIC ILLUSTRATION OF RANDOM PLACEMENT OF WASTE CONTAINERS

movement, and particle adjustments. The settlement occurs gradually over a long time period. Repeated moisture saturation and drying of the soils can result in cycles of consolidation.

## C.3. Deterioration of Containers

Containers will deteriorate and then collapse as a result of one or more of the following mechanisms:

a. Structural collapse of containers.

Structural collapse due to weakened containers and partial crushing or fracturing of containers by compaction equipment during disposal. Some structural collapse will occur relatively soon after the trench is filled when the weight of the soil and other wastes causes structural failure. In discussions with operating personnel at the Sheffield site it was stated that the tops came off some of the drums when they were dumped into trenches. The loss of a top would remove some structural support from the drum which could result in collapse of the open end under the weight of cover soil and equipment. Voids within the trench which may occur shortly after completion of the trenches may be caused by structural collapse of the containers. The surface potholing and sudden slumping may increase after rainfall infiltration due to piping of soils into the voids left by collapsing containers.

b. Corrosion of metal drums.

The corrosive action of soil and moisture on metal drum surfaces resulted ultimately in structural failure. The corroded drums will collapse various amounts due to the weight of soil and other wastes above. The amount of drum collapse will depend upon the quantity and types of wastes in a drum. If a drum is loosely packed with compressible materials (plastic, rubber, cloth or paper), or the drum is partially filled with any material its collapse could cause sudden localized surface subsidence (potholes and sudden slumps). Rainfall infiltration into voids will increase the incidents of potholing and slumping.

c. Biodegradation of wood, plywood and cardboard containers.

Plywood, wood and cardboard containers are decomposed by bacterial action. When cardboard, wood, or plywood containers collapse, localized subsidence may result as described above for drum corrosion. The cardboard will decompose more rapidly than wood and plywood containers.

### C.4. Biodegradation of Organic Materials

Organic materials in the wastes as well as collapsed cardboard, wood, and plywood container materials will undergo decomposition by bacterial action. The rate of biodegradation is slow and will result in long term gradual settlement of trench surfaces. The settlement will occur over a large area or the entire area of each trench where wastes were placed. Also continual corrosion of metals will occur with the same long term effects. Soil and waste may bridge voids or less dense areas, for some time before sufficient underlying support is lost to cause sudden failure.

## D. PREDICTION OF FUTURE SUBSIDENCE

### D.1. Piping and Slumping Subsidence

The prediction of future subsidence due to piping and sudden slumping is qualitative. This subsidence should eventually occur wherever voids occur in the trench, as less dense material becomes more dense with time, or as water travels from saturated cap areas causing piping into voids. It is difficult to predict accurately where it will occur , how large the resulting slumping and piping will be,or the number of subsidences that will occur. These kinds of subsidences should continue to occur they have in the past. Under precipitation and ground freezing climatic conditions similar to those which occurred in Winter-Spring, 1978-1979, the number of subsidences should be expected to increase over the number occurring during periods of normal or below normal precipitation.

### D.2. Consolidation Subsidence

The theory of consolidation of compressible soils provides a method for a quantitative evaluation of the time-settlement prediction for the trenches. To apply the theory, it is usually necessary to conduct one-dimensional consolidation tests on specially prepared undisturbed samples representative of the material under investigation. Due to the scope of this investigation the following analysis is not based on tested samples, but on several estimates of the properties of the trench backfill soil to derive a time frame in which settlement, due to consolidation of the trench backfill soil, should occur. These time estimates are not conservative and longer times than those predicted may occur due to the media not being saturated continuously. The analysis gives an order of magnitude to the lower bound in time, relative to other mechanisms for this particular mechanism to occur.

### D.2.1. Theory of Consolidation

Consolidation is a gradual process which involves a slow expulsion of water or moisture from the void spaces in a soil. The resulting settlement is a time-dependent deformation. Figure 17 illustrates a typical settlement-time curve for compressible soil. The time rate of settlement due to primary consolidation is controlled by the rate at which water can be expelled from the void spaces in the soil. During secondary compression the speed of settlement is controlled largely by the rate at which the soil skeleton itself yields and compresses. The transition time between the two processes is identified as that time when excess pore water pressure becomes zero. In Figure 17, $t_1$ corresponds to the 100 percent primary consolidation point.

Terzaghi's theory(7) may be applied to the theoretical study of one-dimensional consolidation. Equations may be set up from which the change in overall thickness of the compressible strata after an interval of time can be determined. The theory assumes a saturated stratum for

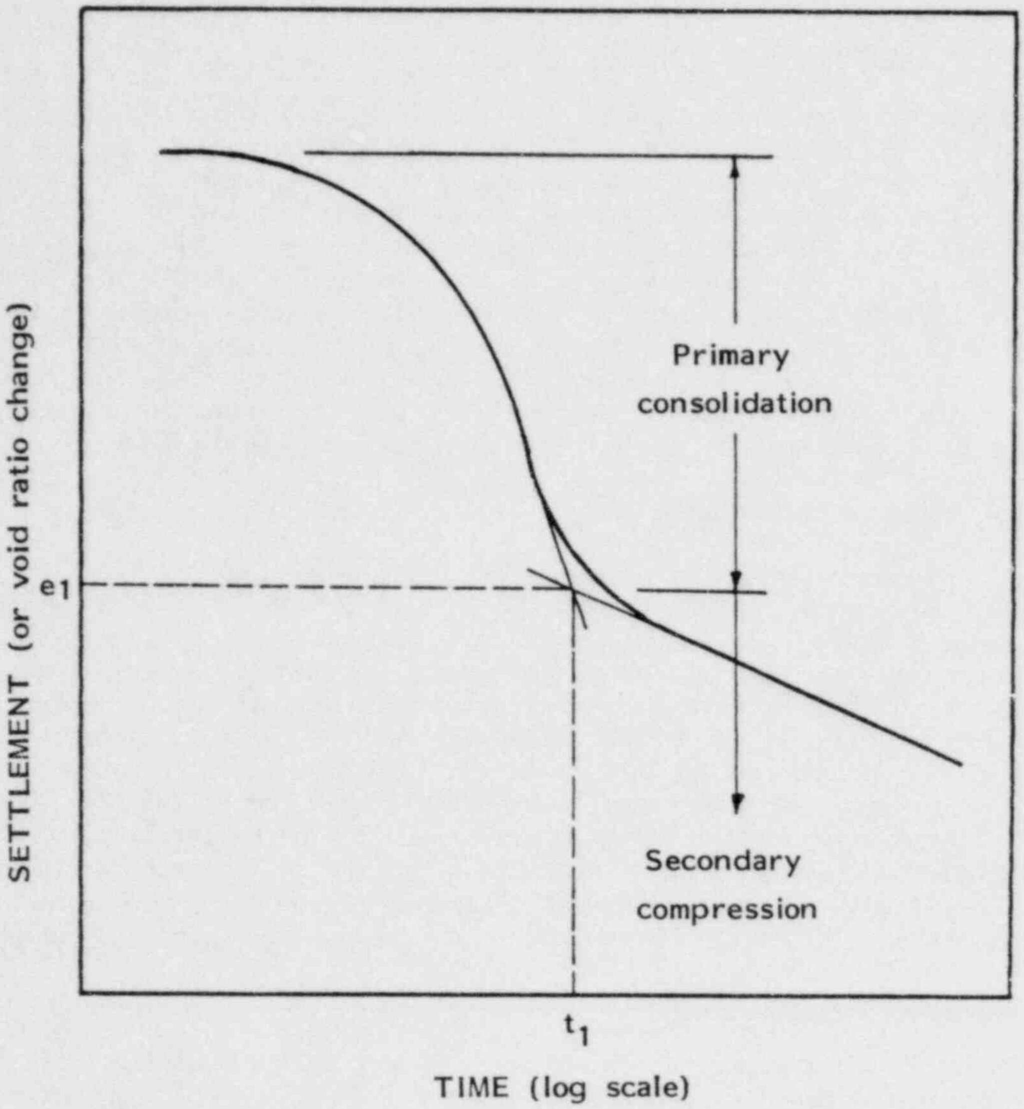


FIGURE 17 - TYPICAL TIME - SETTLEMENT CURVE FOR SOIL

analysis.

At any time during consolidation and the time at which ultimate or 100 percent primary consolidation occurs, the progress of settlement can be described by the average degree of consolidation $U_{(t)}$:

$$U_{(t)} = \frac{S_{(t)}}{S} \qquad (1.1)$$

Where, $S_{(t)}$ = the settlement of the stratum at time t

$S$ = ultimate settlement

$U_{(t)}$ = can be related to the distribution of excess pore water by:

$$U_{(t)} = 1 - \frac{\int_o^H u_e\ (z,t)\ dz}{\int_o^H (u_e)\ \text{initial}\ dz} \qquad (1.2)$$

Where, $u_e(z,t)$ = the vertical distribution of excess pore water pressure at the time t

$(u_e)$ initial = the vertical distribution of excess pore water pressure at $t = c$

$H$ = the length of the longest drainage path

Analytical solutions of the integral for some practically useful initial distribution of excess pore water pressure are presented in Tables 7 and 8(7).

These tables give the relationship between $U_{(t)}$ and time t, expressed as a dimensionless time factor T:

$$T = \frac{C_v t}{H^2} \qquad (1.3)$$

$C_v$ = the coefficient of consolidation and is defined by:

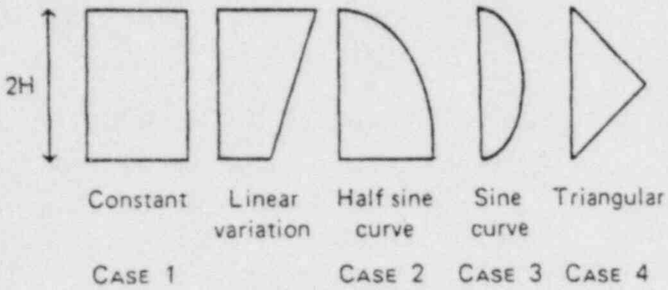
$$C_v = \frac{K(1+e_o)}{a_v\ Y_w} \qquad (1.4)$$

In which, $K$ = the coefficient of permeability of soil, feet/second.

$Y_w$ = the unit weight of water, pounds/cubic foot

# TABLE 7 - ONE-DIMENSIONAL CONSOLIDATION THEORY SOLUTIONS FOR FOUR CASES OF INITIAL EXCESS PORE WATER PRESSURE DISTRIBUTION

(a) Distributions of initial excess pore water pressure.



(b) Average degree of consolidation for various values of $T$.

| $T$ | *Average Degree of Consolidation, U (%)* Case 1 | Case 2 | Case 3 | Case 4 |
|---|---|---|---|---|
| 0.004 | 7.14 | 6.49 | 0.98 | 0.80 |
| 0.008 | 10.09 | 8.62 | 1.95 | 1.60 |
| 0.012 | 12.36 | 10.49 | 2.92 | 2.40 |
| 0.020 | 15.96 | 13.67 | 4.81 | 4.00 |
| 0.028 | 18.88 | 16.38 | 6.67 | 5.60 |
| 0.036 | 21.40 | 18.76 | 8.50 | 7.20 |
| 0.048 | 24.72 | 21.96 | 11.17 | 9.60 |
| 0.060 | 27.64 | 24.81 | 13.76 | 11.99 |
| 0.072 | 30.28 | 27.43 | 16.28 | 14.36 |
| 0.083 | 32.51 | 29.67 | 18.52 | 16.51 |
| 0.100 | 35.68 | 32.88 | 21.87 | 19.77 |
| 0.125 | 39.89 | 36.54 | 26.54 | 24.42 |
| 0.150 | 43.70 | 41.12 | 30.93 | 28.85 |
| 0.175 | 47.18 | 44.73 | 35.07 | 33.06 |
| 0.200 | 50.41 | 48.09 | [illegible] | 37.04 |
| 0.250 | 56.22 | 54.17 | 46.03 | 44.32 |
| 0.300 | 61.32 | 59.50 | 52.30 | 50.78 |
| 0.350 | 65.82 | 64.21 | 57.83 | 56.49 |
| 0.400 | 69.79 | 68.36 | 62.73 | 61.54 |
| 0.500 | 76.40 | 76.28 | 70.88 | 69.95 |
| 0.600 | 81.56 | 80.69 | 77.25 | 76.52 |
| 0.700 | 85.59 | 84.91 | 82.22 | 81.65 |
| 0.800 | 88.74 | 88.21 | 86.11 | 85.66 |
| 0.900 | 91.20 | 90.79 | 89.15 | 88.80 |
| 1.000 | 93.13 | 92.80 | 91.52 | 91.25 |
| 1.500 | 98.00 | 97.90 | 97.53 | 97.45 |
| 2.000 | 99.42 | 99.39 | 99.28 | 99.26 |

Source: Foundation Engineering Handbook, Page 187. (7)

# TABLE 8 - ONE-DIMENSIONAL CONSOLIDATION THEORY. TIME FACTOR FOR VARIOUS AVERAGE DEGREES OF CONSOLIDATION

| | *Time Factor T* | | | |
|---|---|---|---|---|
| *U(%)* | *Case 1* | *Case 2* | *Case 3* | *Case 4* |
| 0 | 0 | 0 | 0 | 0 |
| 5 | 0.0020 | 0.0030 | 0.0208 | 0.0250 |
| 10 | 0.0078 | 0.0111 | 0.0427 | 0.0500 |
| 15 | 0.0177 | 0.0238 | 0.0659 | 0.0753 |
| 20 | 0.0314 | 0.0405 | 0.0904 | 0.101 |
| 25 | 0.0491 | 0.0608 | 0.117 | 0.128 |
| 30 | 0.0707 | 0.0847 | 0.145 | 0.157 |
| 35 | 0.0962 | 0.112 | 0.175 | 0.187 |
| 40 | 0.126 | 0.143 | 0.207 | 0.220 |
| 45 | 0.159 | 0.177 | 0.242 | 0.255 |
| 50 | 0.197 | 0.215 | 0.281 | 0.294 |
| 55 | 0.239 | 0.257 | 0.324 | 0.336 |
| 60 | 0.286 | 0.305 | 0.371 | 0.384 |
| 65 | 0.342 | 0.359 | 0.425 | 0.438 |
| 70 | 0.403 | 0.422 | 0.488 | 0.501 |
| 75 | 0.477 | 0.495 | 0.562 | 0.575 |
| 80 | 0.567 | 0.586 | 0.652 | 0.665 |
| 85 | 0.684 | 0.702 | 0.769 | 0.782 |
| 90 | 0.848 | 0.867 | 0.933 | 0.946 |
| 95 | 1.129 | 1.148 | 1.214 | 1.227 |
| 100 | ∞ | ∞ | ∞ | ∞ |

Source: Foundation Engineering Handbook, Page 188.(7)

$e_o$ = the initial void ratio

$a_v$ = the one-dimensional coefficient of compressibility, square foot/ton

The settlement $S_{(t)}$ of a compressible stratum due to consolidation is approximately given by:

$$S_{(t)} = \left(\frac{\Delta e}{1 + e_o}\right) H' \qquad (1.5)$$

Where, $\Delta e$ = void ratio change

$e_o$ = initial void ratio

$H'$ = thickness of stratum

### D.2.2. Time-Settlement Prediction for Trenches

The trenches at the Sheffield site range in length from 35 to 580 feet, in width from 8 to 70 feet and in depth from 18 to 26 feet, and may be grouped into three trench types in consideration of their cross-sections. The trenches are categorized in Table 9 and Figure 18.

In the evaluation of trench settlement due to the mechanism of consolidation of the backfill soil, trench side wall effects will be ignored to simplify the analysis. It is assumed that the volumetric strains within the consolidating stratum and the accompanying settlements occur only vertically. Such an assumption is reasonable when the geometry and boundary conditions of the trenches are such that vertical strains dominate. This is likely to occur when the dimension of the consolidating area are large relative to the thickness of the compressible stratum. Trench Type I, Figure 18, satisfies the geometric conditions for one-dimensional consolidation settlement.

The majority of the trenches at the Sheffield site fall into the category of Trench Type I and that is the type evaluated here.

The following assumptions are made for purposes of simplifying the analysis using Terzaghi's theory for one-dimensional consolidation:

- o Ignore trench side wall effects. From consideration of the cross-section of Trench Type I, trench side wall effects will have negligible effect on the consolidation settlement. Consideration of the side wall effects will cause an increase in the time for settlement.
- o Consider the trench to consist of a saturated mass of silty soil. Terzaghi's theory applies only to saturated soils. The analysis will not produce a conservative estimate of settlement time because the backfill soil is not saturated and natural settlement would take longer

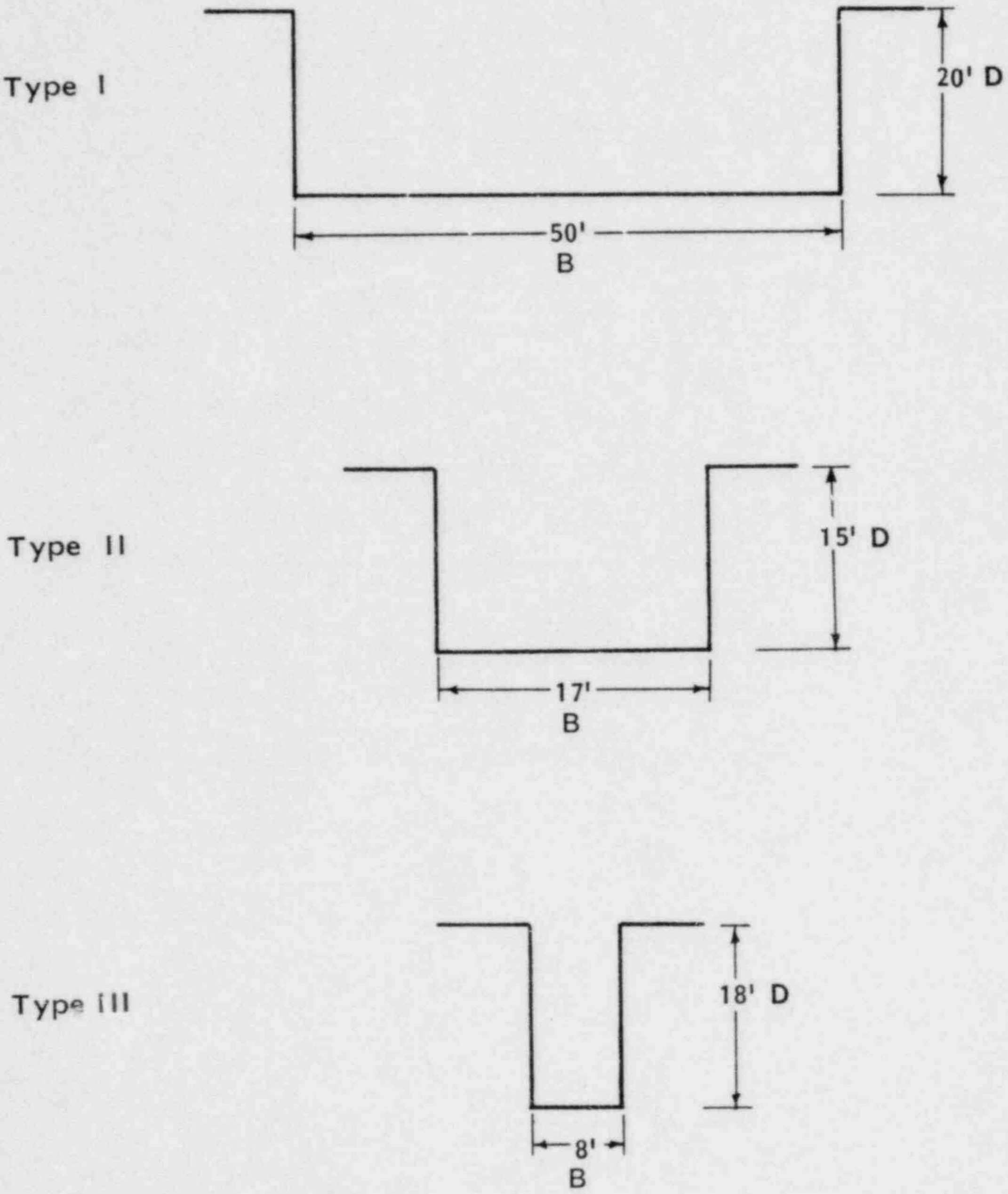


FIGURE 18 - TRENCH TYPES BY CROSS-SECTION

## TABLE 9 - SUMMARY OF TRENCH TYPES

| Type | Trenches |
|---|---|
| I | T-1,2,3,4,5,6,8,9,11,14<br>T-14A,18,23,24,25C,26 |
| II | T-7,10 |
| III | T-8A,8B,25 |

if it were analyzed. The trench soils reportedly predominantly consist of silty fine-grained type soils.

- Consider a single drained stratum. The length of the longest drainage path is the full thickness of the compressible stratum. The analysis will produce a more conservative estimate of settlement times than one assuming a double drained stratum, where one-half the thickness of the stratum is considered.

- The thickness of the compressible stratum is taken as 20 feet, the most common depth reported for trenches of Type 1 in Table 2.

- The coefficient of consolidation of a silty soil is taken to be approximately 0.01 square inch per minute(7).

- The initial excess pore pressure distribution is taken as uniform (Use Case 1 in Table 8) due to the lack of experimental data on the actual properties.

Then from equation (1.3)

$$T = \frac{C_v t}{H^2}$$

and rearranging,

$$t = \frac{H^2}{C_v} \cdot T$$

Substituting and making the time conversion,

$$t = \frac{(20)^2(144)}{(0.01)(60)(24)} \cdot T$$

and,

$$t = 4000 \text{ T days}$$

Substituting various values of T for Case 1 in Table 8, the time (t) taken to settle corresponding to different degrees of consolidation (U) can be determined. These calculated times are presented in Table 10.

The results in Table 10 indicate that nearly all primary consolidation settlement may occur within thirteen years of trench completion if all simplifying assumptions of this analysis are met. Not all the assumptions are applicable, such as complete saturation, because only partial saturation is understood to exist in the trench backfill soils. It is anticipated that the results presented in Table 10 will be non-conservative estimates but may be used to establish an approximate time frame for future settlement

## TABLE 10 - TIME-SETTLEMENT* PREDICTION FOR TRENCH TYPE I

| Degree of Consolidation $U_{(t)}$ | Time Factor (T) | Time (t) | |
|---|---|---|---|
| | | Days | Years |
| 0 | 0 | 0 | 0 |
| 0.20 | 0.0314 | 126 | 0.34 |
| 0.30 | 0.0707 | 283 | 0.77 |
| 0.40 | 0.126 | 504 | 1.38 |
| 0.50 | 0.197 | 788 | 2.16 |
| 0.60 | 0.286 | 1144 | 3.13 |
| 0.70 | 0.403 | 1612 | 4.42 |
| 0.80 | 0.567 | 2268 | 6.21 |
| 0.90 | 0.848 | 3392 | 9.29 |
| 0.95 | 1.129 | 4516 | 12.37 |

* Due to consolidation subsidence mechanism

of the trenches due to only the consolidation subsidence mechanism of the backfill soils.

The time data calculated in the analysis was matched against the date of completion of each individual trench of Type 1, to arrive at an estimate of time remaining to arrive at 95 percent consolidation as summarized in Table 11. Due to the consolidation mechanism alone, years remaining on all trenches except T-1 exceed two years and range up to nearly ten years for Trench 14A. The analysis is not conservative and time should be expected to be increased due to the analysis method's required assumptions not being entirely applicable. This analysis and Table II show the earliest time that consolidation subsidence could occur in, provided all assumptions previously stated were to be in existence, which is probably doubtful at best.

## TABLE 11 - SUMMARY OF TRENCH SETTLEMENT LEAST TIME PREDICTION

| Trenches | Year Completed | Type | Years for 95 percent Consolidation to Occur* | Years Since Completion** | Years Remaining for 95 percent Consolidation to Occur |
|---|---|---|---|---|---|
| 1 | 1968 | 1 | 12.4 | 12.3 | 0.1 |
| 2 | 1971 | 1 | " | 9.8 | 2.6 |
| 3 | 1972 | 1 | " | 8.6 | 3.8 |
| 4 | 1973 | 1 | " | 7.7 | 4.7 |
| 5 | 1973 | 1 | " | 7.3 | 5.1 |
| 6 | 1974 | 1 | " | 6.7 | 5.7 |
| 8 | 1974 | 1 | " | 6.3 | 6.1 |
| 9 | 1975 | 1 | " | 5.8 | 6.6 |
| 11 | 1975 | 1 | " | 5.5 | 6.9 |
| 26 | 1975 | 1 | " | 5.3 | 7.1 |
| 24 | 1976 | 1 | " | 4.6 | 7.8 |
| 18 | 1976 | 1 | " | 4.0 | 8.4 |
| 25C | 1976 | 1 | " | 4.3 | 8.1 |
| 23 | 1977 | 1 | " | 4.0 | 8.4 |
| 14 | 1977 | 1 | " | 3.3 | 9.1 |
| 14A | 1978 | 1 | " | 2.7 | 9.7 |

* From Table 10.

** As of December 1980.

## D.3. Deterioration Subsidence

Deterioration will be evaluated as a two-stage mechanism for effects on subsidence: first the waste containers will deteriorate and ultimately collapse creating localized subsidence; and second the wastes in the containers will deteriorate at a more uniform rate creating gradual settlement over moderate areas. These two stages will occur sequentially for each type of container and its wastes (cardboard, plywood, and metal). The stages for the different containers may overlap. For example, the plywood containers may collapse (first stage) while the cardboard container waste contents are undergoing second stage deterioration.

### D.3.1. First Stage Deterioration

The first stage mechanism of container material deterioration and collapse will be due to corrosion of metal drums and biodegradation of cardboard and plywood containers.

#### D.3.1.1 Metal Drum Corrosion

The rate of corrosion of buried metal drums is dependent upon the following parameters which are listed with estimated values for the Sheffield site:

| | |
|---|---|
| Drum material | steel |
| Drum surface protection | some with paint, others bare metal |
| Ground soil temperature | 50 degrees F. |
| Soil moisture content | range assumed - 10 to 100 percent by weight |
| Soil pH | range 7-7.5 |
| Oxygen in soil | negligible to 6 percent of pore volume |
| Drum wall thickness | 0.0324 inches or 0.0478 inches |
| Electrical resistivity of soil | 1770-2980 ohm/cm(@60F) for silt(8) |

Values for drum material and surface protection, and soil temperature and pH were obtained from Sheffield site data. Some drums were painted and others were bare metal. The range of moisture content is considered to cover a range of site conditions. Landfills have negligible to 6 percent oxygen content below 5-foot depths when organics are present. Due to the lower organic content of the Sheffield trenches, the oxygen content may be nearer the higher value. Low oxygen content produces concentrated pitting and can proceed rapidly if oxygen content varies over the drum surface. Standard 55-gallon steel drums are 18 or 20 gage which are equal to the values shown. NECO personnel stated that standard 55-gallon drums were used. The soil resistivity values shown were for typical silts similar to the loess. When soil moisture is near the saturation level the resistivity varies by only 10 percent as moisture increases above saturation. The resistivity values given are for pH 7.3 and 7.6 and moisture was at saturation levels. The corrosivity maximum pit depths for the two resistivity values are 29 and 39 mils in 12 years for the electrical resistivity values of 1,770 and 2,980, respectively. Using these corrosion rates estimates were made for the two steel drum thicknesses, assuming no protective coating, by the following method:

$$\frac{\text{metal thickness, inches}}{\text{corrosivity/12 years}} = \frac{0.0324}{0.039} \times 12 = 10 \text{ years, time for pit penetration}$$

The results of the calculated pit penetration periods are summarized below:

| Steel thickness, in. | Corrosivity, inches/12 yrs | Pit Penetration, Yrs |
|---|---|---|
| 0.0324 | 0.029 | 13.5 |
| | 0.039 | 10.0 |
| 0.0478 | 0.029 | 20.0 |
| | 0.039 | 14.5 |

Depending upon the drum thickness and soil corrosivity level the time for the metal drums to be penetrated by corrosion pits could vary from 10 to 20 years. The pit penetration time would be the maximum period to collapsing. Penetration of bare drum walls by pits can occur over 100 percent or less of the drum surface area depending upon the drum metallurgy and corrosion parameters. A lesser percentage of surface area may be penetrated on drums having surface protective coatings. The drums would be structurally weakened prior to pit penetration and thus could collapse sooner. If load carrying capacity decreased to where collapse would occur upon penetration of 70 percent of the drum thickness, the drum collapse could occur from 7 to 14 years after disposal. The drum contents and orientation in the trenches will effect the load carrying capacity. Since these are random and unknown, the above assumption of 7 to 14 years is a best approximation for the occurrance of localized drum corrosion subsidence. Many containers may take even longer to reach collapsing point.

### D.3.1.2. Cardboard and Plywood Container Biodegradation

Cardboard and plywood containers will degrade by bacterial action. The rate of biodegradation depends upon the following parameters, some of which are known:

| | |
|---|---|
| Soil/waste temperature | 50 degrees F |
| Moisture content | range assumed 10 to 100 percent by weight |
| Quantity of organic material in trenches | less than the waste container volume range of 33 to 64 percent |
| Soil/moisture pH | 7-7.5 |
| Types of organic materials (includes solidified wastes) | wood, cardboard, paper, plastic, rubber, textiles |
| Depth of waste (excludes solidified wastes) | 33 to 60 percent of trench depth |

A coefficient of decomposition would have to be determined for the specific parameters, which is not available. Data is also not available on the effect of biodegradation on cardboard and plywood container structural strength. Thus, no projection of time to collapse can be made. Some general observations from other landfill sites have indicated that plywood can remain structurally intact for over 10 years. Cardboard loses structural strength when wet and thus the sides of the cardboard containers may collapse if the trench is compacted or saturated with moisture. If the cardboard containers have wood frames only the cardboard sides would collapse thus reducing the degree of subsidence that could result. It is possible that some of the potholing and sudden slumping that occurred in early 1979 following the heavy rains and warm winter were caused by collapse of saturated cardboard containers.

### D.3.2. Second Stage Settlement from Waste and Container Deterioration

Second stage settlement will result from further corrosion and biodegradation of the wastes in the containers and of the containers. The rate of deterioration and resulting change in volume will be small. Thus the effect on trench surfaces will be to cause long-term area settlement rather than short-term potholing and slumping. The parameters involved are the same as discussed for first stage deterioration. A summary of waste volume to trench volume for each trench is given on Table 12. The overall potential for deterioration given on Table 12 was based upon the percentage of trench volume occupied by the waste container volume, consideration of the type of waste in the trench where it was known, and the relative decomposition potential of the waste.

The rate of biodegradation depends upon the types of wastes. Plastics may require hundreds of years to degrade whereas paper and textiles may take 30 to 100 years to degrade. The trend usually observed in landfills with organic wastes is for an initial settlement of 2 to 3.5 percent of the landfill depth during the first two years after waste disposal. After about 2 years the settlement rate may vary from negligible up to one-half percent per year, at decreasing rates each year, depending on the parameters previously discussed. Since the Sheffield trenches contain 33 to 64 percent of waste by volume and assumed the same by depth, the long term settlement by biodegradation could vary from negligible in trenches 8A, 8B, and 10 up to 0.06 feet per year in trench 14A. This assumes the organics volume to be equal to container volumes which is not likely to occur. Thus actual long term settlement rates due to biodegradation could be much less depending upon the actual volume of organics in containers.

### D.3.3. Effects of Deterioration on Trench Surfaces

The major effects of container collapse will be localized potholing and slumping. This could occur randomly over the long term. The major effect on trench surface subsidence will occur if several containers of the same materials are located in one place in any trench. If they all collapsed

# TABLE 12 - TRENCH ESTIMATED RELATIVE DETERIORATION POTENTIAL

| Trench No. | Waste Vol / Trench Vol (%)* | Relative Deterioration Potential** |
|---|---|---|
| 1 | 40 | Moderate |
| 2 | 33 | Moderate |
| 3 | 35 | Moderate |
| 4 | 59 | Major |
| 5 | 39 | Moderate |
| 6 | 60 | Major |
| 7 | 53 | Major |
| 8 | 41 | Moderate |
| 9 | 44 | Moderate |
| 10 | 42*** | Negligible |
| 11 | 50 | Moderate |
| 25 | 33 | Moderate |
| 8A | 63*** | Negligible |
| 8B | 64*** | Negligible |
| 26 | 36 | Moderate |
| 24 | 47 | Moderate |
| 18 | 36 | Moderate |
| 25C | 48 | Moderate |
| 23 | 43 | Moderate |
| 14 | 50 | Moderate |
| 14A | 49 | Moderate |

*The ratio of waste volume divided by total trench volume.

**Negligible- solidified, encapsulated waste; Moderate-ratio 50 or less; Major-ratio greater than 50.

***Slit trenches for disposal of Anafco tubs of solidified waste.

within a short period a slump could result on the trench surface whose size would depend upon the number of containers and the area they occupy. The frequency and size of subsidences will be random due to the unknown locations of each type of container in all trenches except 8A, 8B, and 10 (these contain solidified wastes in Anafco tubs).

Biodegradation settlement of wastes exposed after containers collapse will be negligible. Such small settlement could occur for up to 100 years after waste disposal. Long term settlement due to biodegradation may vary at different locations in a trench depending upon the distribution of organic wastes in the trench.

In summary, there are many conditions that effect the mechanism of deterioration as a cause of subsidence. The above discussion is a qualitative assessment of the mechanism and is not a precise quantitative analysis due to the unavailability of waste data and deterioration rates in the trenches.

# IV. TRENCH STABILIZATION TECHNIQUES

## A. INTRODUCTION

Feasible techniques for stabilizing the trenches so as to minimize future subsidence are evaluated in the following sections. The choice of techique is dictated by the estimated degree of compaction achievable at the present time which will minimize future subsidence, the relative cost of each method, and potential for radiological releases.

## B. COMPACTION TECHNIQUES

### B.1. Deep Compaction Methods

The trenches at the Sheffield site vary in depth from eight to twenty-six feet. Deep voids and interstices which may be present in the trench backfill soils and between the waste containers may be collapsed and decreased in size by the application of high energy impacts. Collapse of large voids and improved densification of the poorly compacted backfill soil and waste materials may result in significant initial settlement of the trenches, minimization of future void collapse, and reduction in the formation of pot holes and sudden slumps. The following deep compaction methods were considered for stabilization of the trenches:

- Dynamic Consolidation
- Pile Drivers and Compaction Piles
- Surcharging
- Blasting

#### B.1.1. Dynamic Consolidation

Dynamic consolidation for deep compaction was developed by Menard, in Europe(9). The method employs heavy tamping, in which high energy impacts applied to the surface of the site result in settlements. The method has been found to be effective to depths of 50 feet and surface settlements of 5 to 15 percent of the total deposit thickness can be achieved(9).

The method involves dropping 5 to 40 ton weights from heights of 20 to 100 feet according to a predetermined pattern evaluated for the particular site. A high capacity crane is employed to lift and release the weight, which is dropped several times at one location before moving on to the next impact location. After the initial pass over the entire site, subsequent passes are accomplished at time intervals, which may be up to three weeks depending upon the type of soil at the site.

In granular and non-saturated soils, the high energy impact is believed to cause partial liquefaction of the material, thereby allowing the soil mass to settle into a denser state.(9) However, the principle of dynamic consolidation of fine-grained saturated soils is not so well understood. Menard and Broise(9) hypothesized that in saturated cohesive soils, the shock waves and high stresses resulting from repeated high energy impacts cause gradual liquefaction and consolidation of the soil mass. The creation of tension cracks around the impact points increase the permeability of the soil mass so that percolation of the existing pore water is assisted.

The technique appears applicable, with reservations as described below, to stabilization of the trenches at the Sheffield site. The impact of the selected weights should be sufficient to collapse deep voids and the waste containers. Interstices between the containers and large voids formed by the collapse of the containers may also be filled by soil during the dynamic consolidation treatment. The overall trench stability may therefore be improved by reducing voids and future container collapsing.

Applied at the Sheffield site, a minimum of six feet of extra soil cover over the existing surface of the trenches may be required to provide sufficient material to fill anticipated voids in the trenches. During the heavy tamping operation, significant collapse of the containers, without sufficient soil cover over the trenches, may result in uncovering of radioactive waste materials and release of radioactive gases. The potential exists for contamination of the tamping weight and exposure of personnel to radiological releases. Significant lateral ground vibrations produced by the high energy impacts should not adversely affect structures on the relatively open site. However, adjacent trenches may be affected by the vibrations causing slumping and ground cracking and the resulting loss of trench cap integrity.

Figure 19 illustrates compaction of the trenches by dynamic consolidation. The heavy tamping weight may be hauled in, or possibly cast of concrete in a steel bin at the site. The reduction of void ratio of the trenches may be observed from the surface by monitoring the settlements occurring during the treatment. It will also be necessary to apply final surface grading and compaction, following dynamic consolidation of the trenches.

### B.1.2. Pile Drivers and Compaction Piles

Driving of piles to densify deep soil deposits has been practiced for many years. The compaction technique is most suitable for densification of loose cohesionless soils but partly saturated clayey soils and loess have also been successfully compacted(9). Densification results from two effects:

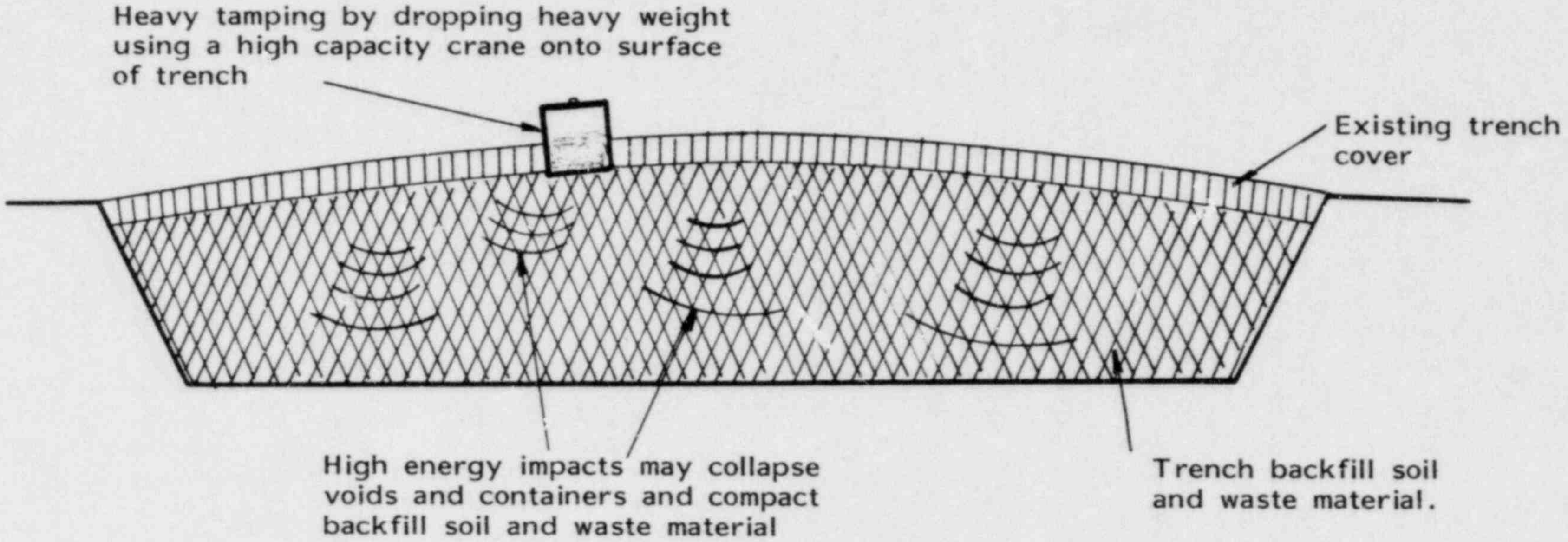


FIGURE 19 - DYNAMIC CONSOLIDATION

displacement of material equal to the volume of the pile and the vibratory effect of the driving of the pile.

The method involves driving wood piles, at close centers on a grid pattern, into the soil deposit to be densified. Alternately, compaction piles consisting of sand, gravel or crushed stone have been found to be effective. Such piles are constructed by driving a hollow steel madrel with a false bottom to the required depth, filling the madrel with cohesionless material, withdrawing the madrel and leaving the column of self compacting backfill material in the hole.

Deep compaction of the trenches may be achieved using these techniques which have just been described. Penetration of the pile into the trenches and the accompanying vibratory effects of the pile driving operation may cause voids and containers to collapse and compact the less dense trench backfill soil and waste materials. The overall trench stability will therefore be improved by reducing future void and container collapsing and subsequent sudden slumping of the trench surfaces.

During the pile driving operation the penetrating equipment may puncture the containers and be exposed to the waste materials contained in them. Consequently, radioactive gases may be released. Radioactive waste materials may also adhere to the equipment as it is withdrawn from the trenches. It may be necessary to dispose of the contaminated equipment by burying them in trenches. Care must also be taken to insure that the pile is not driven to a depth that would penetrate into the french drains or sumps which are constructed at the bottom of each trench. Figure 20 illustrates compaction of the trenches by pile driving.

### B.1.3. Surcharging

When foundation loads are applied to a cohesive soil, there is a tendency for volumetric strain, which is manifested in an increase in pore water pressure.(7) With sufficient elapsed time, water flows out of the soil voids, accompanied by dissipation of the excess pore pressure and resulting in consolidation settlement. The application of a surcharge load in advance of construction may eliminate most or all of the post construction primary consolidation and the accompanying settlements. The technique of surcharging is most suitable for soft clays, silts and organic deposits.(9) The maximum effective treatment depth is variable and depends on the type of soil, surcharge load intensity and surcharging period.

The materials used for surcharging may consist of concrete slabs, rock fills, or earth fills. The surcharging period and load intensity depend on the coefficient of consolidation of the soil, degree of saturation, and the drainage path. These parameters control the rate at which excess pore pressures are dissipated. Surcharging periods may, in some cases, be reduced by the use of sand drains and wicks to accelerate consolidation of thick layers of soft, fine-grained soils with low permeability.

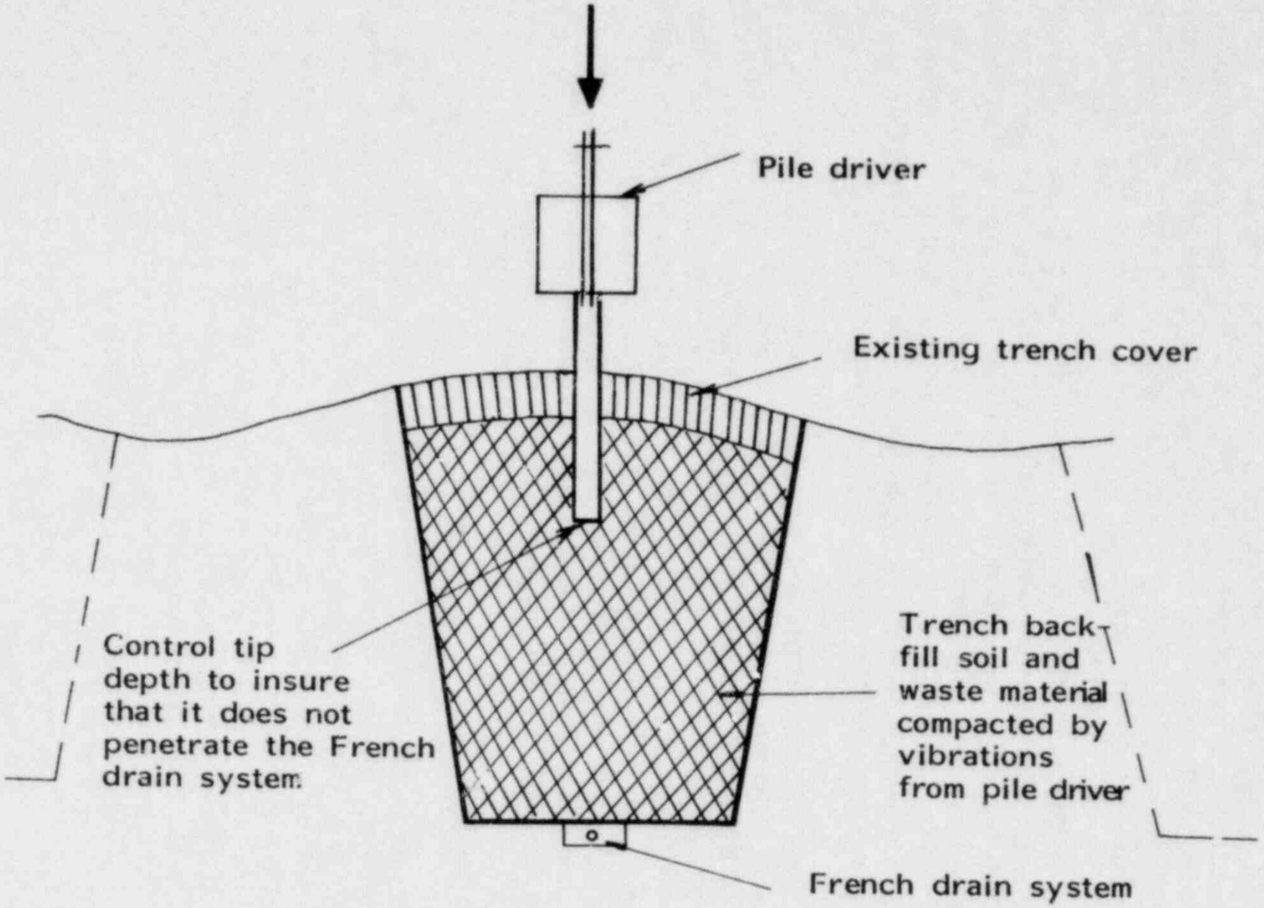


FIGURE 20 - COMPACTION BY PILE DRIVER

The technique of surcharging may be applied to stabilization of the trenches at the Sheffield site.(4) Soil mounds may be placed over the surface of the trenches, so that consolidation settlement of the trench backfill soil may be accelerated. Some of the weaker waste containers may also be collapsed by the surcharge weight. Figure 21 illustrates compaction of the trenches by surcharging with soil mounds.

It may be necessary to import and place high soil mounds over the trenches for a relatively long period of time because of the large depths of some of the trenches, and hence the significant length of the drainage path. Periodic monitoring of the mounded trenches using piezometers and strategically placed settlement plates would provide verification and correction factors for predictions concerning loading times and intensities. At the end of the preloading period, the surcharge soil may be removed and used as surcharge on adjacent trenches or hauled for other earthwork in the vicinity. The compaction technique is non-penetrative and exposure of personnel and equipment to radioactive waste materials and gases is limited.

### B.1.4. Blasting

The technique of blasting using explosives can sometimes be applied to deep compaction of saturated and partly saturated sands and saturated silts.(9)

The general procedure for densification by blasting is as follows:

- Drive a pipe to the desired depth, usually two thirds the thickness of the stratum to be densified.
- Lower an explosive charge to the bottom of the pipe.
- Withdraw the pipe.
- Backfill the hole.
- Fire charges according to a pre-established pattern.

The generated shock waves and vibrations may cause localized spontaneous liquefaction within the soil mass, and the subsequent expulsion of pore water. Displacement, remolding and densification of the soil mass then follows.

Applied to the trenches at the Sheffield site, the shock waves and vibrations produced by the explosives may cause collapse of deep voids and waste containers, so as to reduce future container and soil void collapsing. However, applicability of the technique to densification of the backfill soil will be limited due to the unsaturated condition of the silty fine-grained soil.

The technique requires pipes to be driven into the trenches, and the

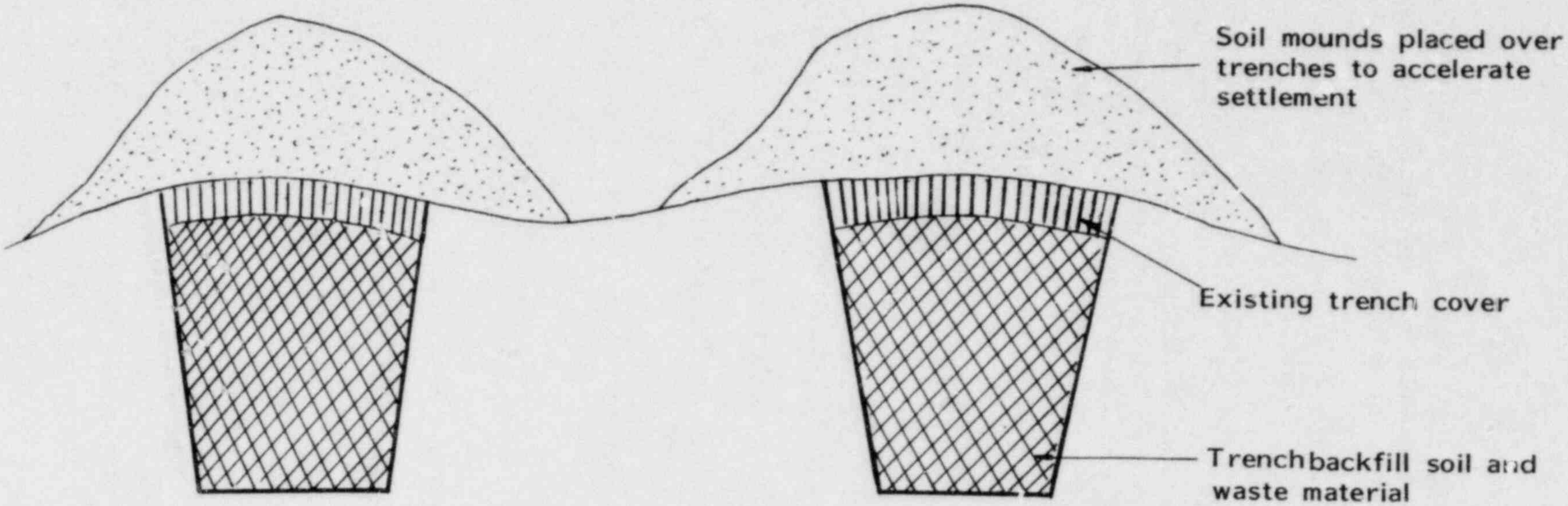


FIGURE 21 -COMPACTION BY SURCHARGING WITH HEAVY SOIL MOUNDS

potential exists for contamination of equipment and worker exposure to the radioactive waste materials. Inherent in the blasting operation may also be the release of radioactive gases and worker exposure to these releases. The technique also requires strict control and expert personnel to handle the potentially dangerous material and operation.

### B.2. Shallow Compaction

Surface compaction of the top few feet of the trench surface soils would be required following application of deep compaction methods such as dynamic consolidation and pile driving. The stabilization techniques generally loosen and disrupt the surface soils, creating surface voids in the existing trench soil caps.

Compaction of the trench surface soils would generally follow standard construction grading techniques wherein for a compactive effort a definite moisture-density relationship exists for a soil and there is an "optimum" moisture content which results in the greatest dry density or maximum compaction. Figure 22 illustrates the moisture-density relationship, which can be determined in a laboratory testing following ASTM 1557. In the field, specifications for compaction require the soil to be compacted near the optimum value of moisture content, and to a dry density stated as a percentage of the laboratory standard. It is usual to specify a compacted fill density of 90 to 95 percent of the standard laboratory (ASTM 1557) maximum dry density.

The energy which is required to cause compaction can be supplied by a variety of mechanical equipment. Table 13(7) presents a list of compaction equipment which may be suitable for compaction of a variety of soil types. The depth of compaction achievable with the equipment should be on the order of zero to six feet.

Applied to the Sheffield site, the disrupted trench surface soils may be removed to within a few feet of the top of the buried waste materials and recompacted in layers by rolling, the aim being to get the optimum compaction for the least number of passes with the equipment. Precautions should be taken to insure that the surface soil is not removed to a depth that would expose the waste materials. The compaction technique is illustrated in Figure 23.

## C. GROUTING TECHNIQUES

Future void collapse and subsidence of the trenches may be reduced by injection of certain chemical grouts and soil-cement grout. The grouting materials would mix with the trench backfill soil to form an improved strength, settlement resistant mass. Large voids and low density areas which exist in the trench backfill soil and between the waste containers

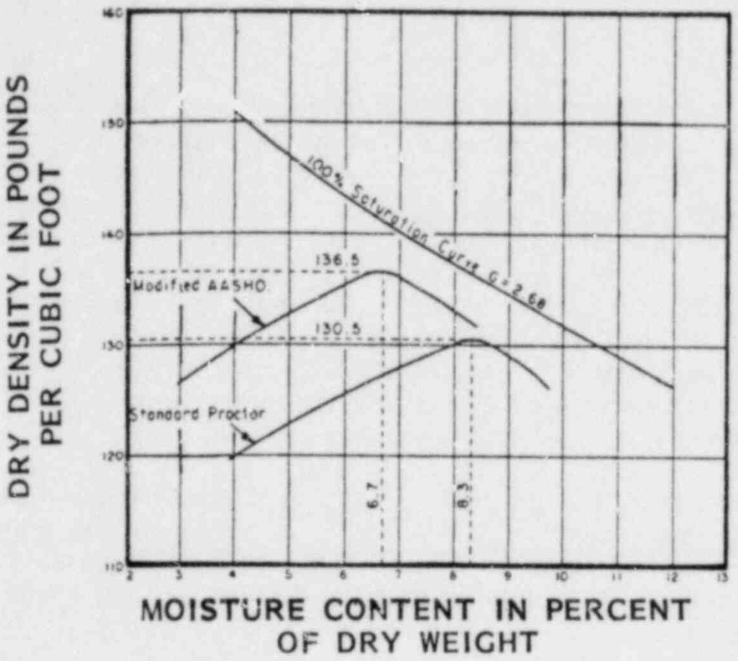


FIGURE 22 - MOISTURE-DENSITY CURVES OF A COHESIVE SOIL FOR DIFFERENT COMPACTIVE EFFORTS

## TABLE 13 - COMPACTION EQUIPMENT AND METHODS

| | | | Requirements for Compaction of 95% to 100% Standard Proctor Maximum Density. | |
|---|---|---|---|---|
| Equipment type | Applicability | Compacted lift thickness, in. | Passes | Dimensions and weight of equipment |
| Sheepsfoot rollers | For fine-grained soils or dirty coarse-grained soils. | 6 | 4 to 8 | Foot contact area: 5 to 14 in.$^2$<br>Foot contact pressures: 50 to 500 psi. |
| Rubber tire rollers | For clean, coarse-grained soils. | 10 | 3 to 5 | Tire inflation pressures of 60 to 80 psi for clean granular material. Wheel load 18,000 to 25,000 lb. |
| | For fine-grained soils or well-graded, dirty coarse-grained soils | 6 to 8 | 4 to 6 | Tire inflation pressures in excess of 65 psi for fine-grained soils of high plasticity. For uniform clean sands or silty fine sands, use large size tires with pressure of 40 to 50 psi. |
| Smooth wheel rollers | For compaction of well graded sand-gravel mixtures. | 8 to 12 | 4 | Tandem-type rollers for base course or subgrade compaction. 10 to 15 ton weight 300 to 500 lb per lineal inch of width of rear roller. |
| | For fine grained soils other than earth dams. | 6 to 8 | 5 | 3-wheel roller for compaction of fine grained soil: weights from 5 to 6 tons for materials of low plasticity to 10 tons of materials of high plasticity. |
| Vibrating baseplate compactors | For coarse-grained soils. | 8 to 10 | 3 | Single pads and plates should weigh no less than 200 lb. |
| Crawler tractor | For coarse-grained soils. | 10 to 12 | 3 to 4 | No smaller than D8 tractor with blade, 34,500 lb weight, for high compaction. |

## TABLE 13 - COMPACTION EQUIPMENT AND METHODS (cont)

| | | Requirements for Compaction of 95% to 100% Standard Maximum Density | | |
|---|---|---|---|---|
| Equipment type | Applicability | Compacted lift thickness, in. | Passes | Dimensions and weight of equipment |
| Power tamper or rammer | For difficult access, trench backfill. Suitable for all inorganic soils. | 4 to 6 in. for silt or clay, 6 in. for coarse-grained soils. | 2 | 30-lb minimum weight. |

Source: Foundation Engineering Handbook, Page 269.(7)

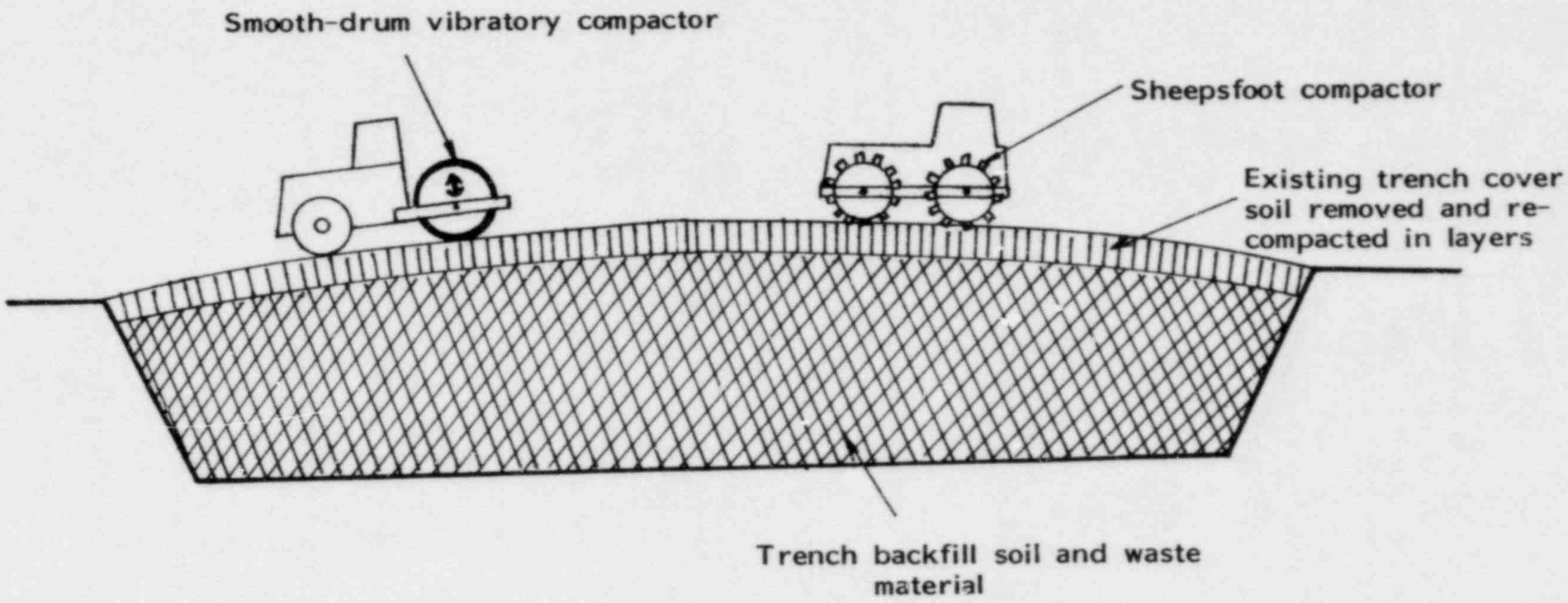


FIGURE 23 – COMPACTION BY HEAVY COMPACTION EQUIPMENT

may be initially filled with a soil-cement grout, so that they may be decreased in size before being grouted using a more expensive chemical grout, if found necessary. The interstitial grout may also act as a structural web to minimize eventual collapse of the waste containers.

The principles involved in grouting using chemicals and soil-cement differ slightly and a discussion of each technique follows:

## C.1. Compaction Grouting Using Soil-Cement

Compaction grouting is a process which involves extrusion of a highly viscous soil-cement grout into the voids of a compressible soil mass. The injected grout remains in a homogeneous mass and acts as a radial hydraulic jack, displacing and compacting the surrounding soil particles in place.

Large voids within the trench backfill soil and waste may be filled with the soil-cement grout. Densification of the poorly compacted trench materials may also be achieved by expansion of the low slump grout which is pumped under pressure.

The grout is usually composed of a cement sandy-loam mixture. The gradation and consistency of the sand used in the grout has considerable influence upon the injection behavior and effectiveness of the grout. It is also desirable to minimize the clay content in the mixture, so as to eliminate excessive shrinkage of the grout. A cement content of about 12 percent will provide the grout strengths which are adequate for most applications(11).

Compaction grouting is usually done in stages, only a few feet of the hole being grouted at a time. The grout may be applied either from the top down or from the bottom up. The following sequence of operations is generally followed for grouting from the top down:

- A hole is drilled from the surface to the top of the zone to be densified or a minimum of about four feet.
- A steel casing is inserted in the hole and securely cemented in place to its full depth .
- The hole is then extended several feet (three to eight feet) by

drilling through the casing .

- A low slump grout mixture is pumped into the hole until there is a slight movement of the ground surface, or to refusal.

- After hardening of the previously placed grout, the hole is redrilled inside the casing and grout, and advanced several feet for the next stage of grout injection.

Figure 24 illustrates the process of compaction grouting.

The technique of compaction grouting requires detailed preliminary investigations and planning. Successful execution of grouting requires proper layout of the grout holes, sequencing of grouting, pumping procedures of the grout mixture, and the service of specialist contractors. It is rarely feasible and practical to lay out the grout holes and plan the grouting program in advance. The spacing of the grout holes vary according to the soil properties and individual job requirements, and are usually on the order of five to 15 feet(11). The holes are generally laid out on a basic grid, with the rows offset to give a triangular pattern of roughly equidistant spacing. Continuous logs for drilling and detailed grouting records should be maintained and analyzed to determine whether the grout holes should be relocated and injection changes made as appropriate.

The grouting technique to achieve stabilization of the trenches requires grout holes to be drilled through the trench backfill soil and waste materials and radioactive gases may be released during the operation. The grout mixture may be contaminated and becomes a safety hazard if backflow of the material occurs up the grouting pipe. Problems may then arise with disposal of the grouting mixture. Contamination of the drilling equipment and steel casings by radioactive waste materials may require them to be buried onsite in trenches or hauled to another low-level disposal site.

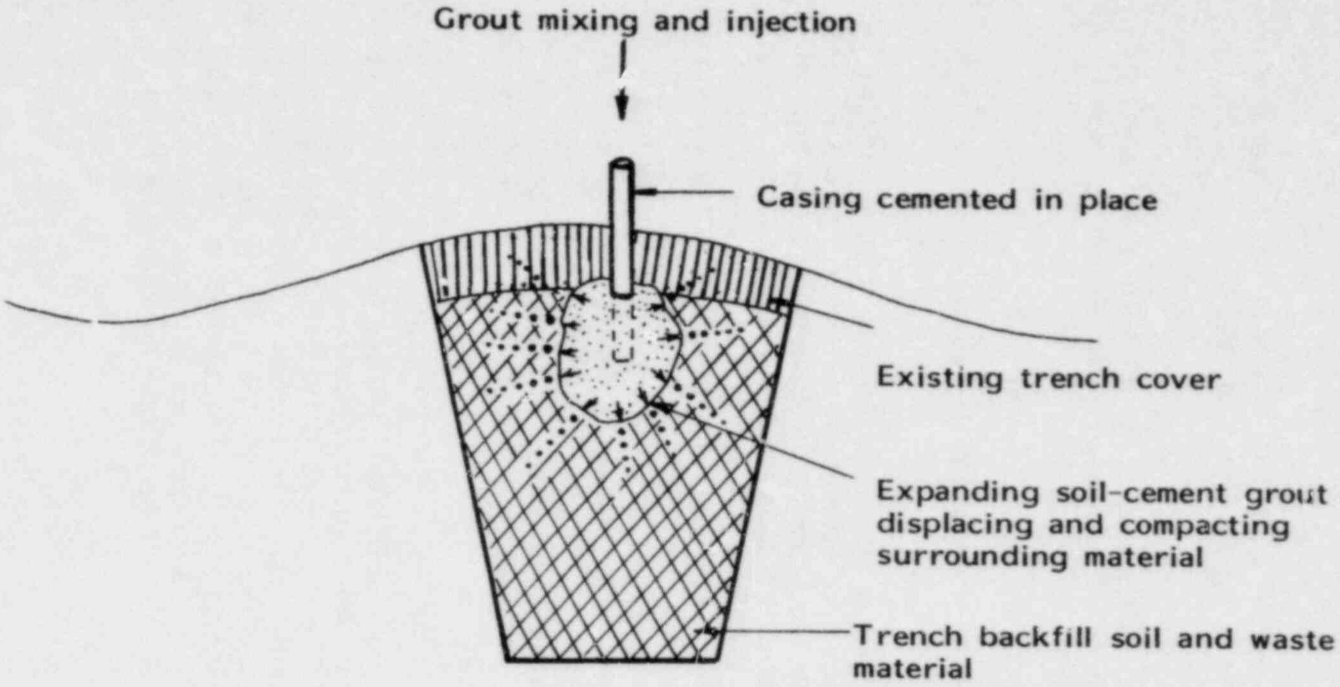


FIGURE 24 - COMPACTION GROUTING PROCESS

### C.2. Chemical Grouting

The soil which was used for backfilling the trenches is of a silt nature. A suitable chemical grout for stabilization of the trenches after the larger voids have been initially filled with soil-cement, is a solution of Acrylamide, consisting of two organic monomers. The viscosity of the solution is quite low and penetrates readily into silt, consolidating the silt and rendering it impervious(12).

The process of grouting using Acrylamide involves injection of the solution into the soil in a "one shot" process. Reaction of the low viscosity organic monomer takes place in-situ and polymerizes into a stiff gel. Addition of fillers, such as cement or silica flour, can be used to increase the strength of the gel(12). The grouting technique is illustrated in Figure 25. The grouting technique requires grout holes to be drilled through the trench backfill soils and waste materials and problems may be presented due to the possible release of radioactive gases and contamination of equipment.

## D. BIOLOGICAL TECHNIQUE

The maintenance of a suitable aerobic environment accelerates decomposition of organic wastes, by promoting the rapid growth of cellulose-consuming microbes and by increasing the internal temperature(13). The aerobic chemical reactions can be theoretically expressed as follows:

$$\underset{\text{cellulose}}{(C_6H_{12}O_6)n} + \underset{\text{oxygen}}{6n(O_2)} = \underset{\substack{\text{carbon}\\ \text{dioxide}}}{6n(CO_2)} + \underset{\text{water}}{6n(H_2O)} + \underset{\text{heat energy}}{n(688,000 \text{ calories})}$$

Oxygen is an essential requirement for the aerobic stabilization process, and the temperature of the environment has been recognized as one of the key factors affecting the biological activity.

In the process of aerobic decomposition, only the organic portion of the waste material is subject to biological breakdown. It has been estimated(14) that an organic content of 60 to 70 percent of the total volume, may be required for effective aerobic decomposition of solid waste materials. The low level radioactive waste materials were packed in a variety of cardboard and plywood containers and metal drums. In general, the organic content of the buried containers and waste materials at Sheffield is 60 percent or less of the trench volume and the biological technique is of limited applicability to stabilization of the trenches at the Sheffield site.

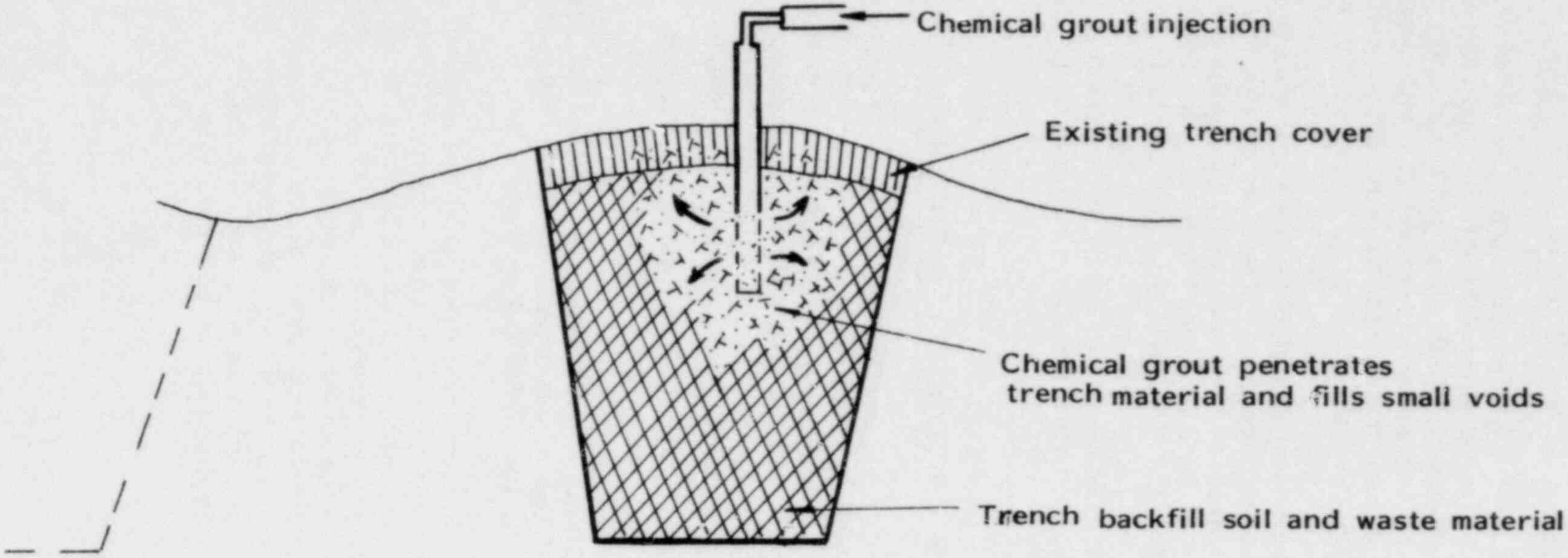


FIGURE 25 - PENETRATION CHEMICAL GROUTING

## E. COST ANALYSIS AND SUMMARY OF TECHNIQUES

Details of the initial construction cost estimates are presented in Appendix C. The estimates are based on costs as of December 1980. These costs can be updated in the future by using the December 1980 and future construction cost indices. The costs are developed for a "typical" trench with surface dimensions of 350 feet by 50 feet. The cost elements that have been included in the estimates are labor, materials and equipment. It is assumed that the additional soil that may be needed to fill the trench caps following stabilization will be imported relatively short distances to the Sheffield site.

Maintenance costs are based on the general surface maintenance of the site. Details of the maintenance costs estimates are presented in Appendix C. It is anticipated that inspection of the site will be performed on a regularly scheduled basis and repairs carried out on areas indicating erosion and subsidences. A program of revegetating repaired areas of the site with grasses, and regular maintenance of the vegetative cover is also anticipated to be in operation.

The useful life of the stabilization techniques is indirectly dependent on the general maintenance of the site and trench soil caps. If the final trench caps are properly constructed and the site is regularly inspected and maintained to prevent erosion and infiltration of water into the trenches it is anticipated that many of the stabilization techniques which have been evaluated in the study would have an indefinite useful life. An indefinite useful life is used because potholes or sudden slumps may occur over 100 or 200 years as the waste containers decompose and collapse.

Table 14 summarizes the construction costs and the effectiveness and applicability of the various feasible trench stabilization techniques.

## TABLE 14 - COST, EFFECTIVENESS AND APPLICABILITY OF STABILIZATION TECHNIQUES SUMMARY

| Stabilization Technique | Initial Cost* $K/typical trench | Effectiveness | Applicability |
|---|---|---|---|
| A. Dynamic Consolidation | 59 | 0-50 feet<br>Cohesionless soils most suitable, but may be extended to alluvial soils and clay. | High energy impacts should cause collapse of deep voids and waste containers.<br>Interstices between the waste containers and large voids may also be filled by soil during the compaction treatment.<br>A minimum of six feet of extra soil cover may be required over the existing surface of the trenches.<br>The potential exists for exposure of personnel and equipment to radioactive wastes and radiological releases.<br>Significant lateral ground vibrations produced by the high energy impacts should not adversely affect structures on the relatively open site, although some effect may be felt by adjacent trenches. |

TABLE 14 - COST, EFFECTIVENESS AND APPLICABILITY OF STABILIZATION TECHNIQUES SUMMARY(cont)

| Stabilization Technique | Initial Cost* $K/typical trench | Effectiveness | Applicability |
|---|---|---|---|
| B. Pile Drivers and Compaction Piles | 106 | 0 - 50 feet<br>Loose cohesionless soils most suitable and has been used to compact partly saturated clayey soils and loess. | Vibrations during pile driving may cause collapse of deep voids and containers.<br>Compaction of the backfill soil and waste materials should also be achieved by penetration of the piles.<br>Wood piles or piles consisting of sand, gravel or crushed stone could be driven into the trenches at close centers on a grid pattern.<br>Requires control to avoid penetration into the french drains or sumps constructed at the bottom of the trenches.<br>Potential for exposure of personnel and equipment to radioactive wastes and radiological releases. |

## TABLE 14 - COST, EFFECTIVENESS AND APPLICABILITY OF STABILIZATION TECHNIQUES SUMMARY (cont)

| Stabilization Technique | Initial Cost* $K/typical trench | Effectiveness | Applicability |
|---|---|---|---|
| C. Surcharging | 49 | Effective treatment depth is variable.<br>Suitable for soft clays, silts and organic deposits. | Heavy soil mounds may be placed over the surface of the trenches to accelerate settlement of the backfill soil.<br>Some of the weaker waste containers may be collapsed by the surcharge weight.<br>The degree of compaction could be controlled by varying the magnitude and period of application of the surcharging load.<br>The large depths of some of the trenches may require high soil mounds to be placed for an extended period of time.<br>The surcharge soil could be used on adjacent trenches.<br>Exposure of personnel and equipment to radioactive wastes or contaminated gases is limited since this is the only non-penetrative technique. |

## TABLE 14 - COST, EFFECTIVENESS AND APPLICABILITY OF STABILIZATION TECHNIQUES SUMMARY(cont)

| Stabilization Technique | Initial Cost* $K/typical trench | Effectiveness | Applicability |
|---|---|---|---|
| D. Surface Compaction by Heavy Equipment | 19 | 0-6 feet.<br>Fine-grained soils-sheepsfoot rollers, rubber tire rollers, smooth wheel rollers.<br>Coarse-grained soils - vibrating rollers. | Applied to the surface of the trenches after application of deep compaction techniques which loosen and disrupt the surface soils.<br>The disrupted surface soils may be removed to within a few feet of the top of the buried waste and recompacted in layers.<br>Potential for release of radioactive gases and uncovering of wastes if excessive surface soil is removed. |
| E. Compaction Grouting Using Soil-Cement | 361 | Unlimited depth.<br>Suitable for filling or compacting large voids. | Large deep voids in the trenches and interstices between the waste containers may be filled or compacted with a soil-cement grout.<br>The trench backfill soil may also be compacted.<br>Grout holes may be laid out on a basic grid at 5 to 15 feet centers, and drilled into the trenches. |

## TABLE 14 - COST, EFFECTIVENESS AND APPLICABILITY OF STABILIZATION TECHNIQUES SUMMARY(cont)

| Stabilization Technique | Initial Cost* $K/typical trench | Effectiveness | Applicability |
|---|---|---|---|
| E. Compaction Grouting Using Soil-Cement (cont) | | | Potential for contamination of equipment and release of gases. Backflow of the grout which may be contaminated, would also present disposal problems. |
| F. Grouting Using Soil-Cement and Acrylamide | 854 | Unlimited depth.<br>The chemical grout, Acrylamide, penetrates readily into silts. | The chemical grout, Acrylamide, may be applied to the trenches after the larger voids have been initially filled and decreased in size with soil-cement grout.<br>The injected chemical grout may polymerize into a stiff gel and react with the backfill soils to form a strong impervious mass.<br>Potential for release of radioactive gases and contamination of equipment by radioactive waste materials. |

* Detailed in Appendix C

## V. FUTURE MONITORING

Future monitoring of the Sheffield site trenches will be required to identify areas of potential infiltration resulting from precipitation and runoff. Early identification of erosion problem areas, low spots and small slumps followed by immediate remedial measures of backfilling, regrading and erosion mitigation measures will correct small problems before they become larger problems, thereby limiting the potential for infiltration.

Methods of future monitoring studied for the Sheffield site consisted of visual observations, direct survey measurements, and review of topographic maps and aerial photographs.

### 1. Visual Observations

Visual observation monitoring has been underway at the Sheffield site since October 1978. Observations have fallen into a routine pattern of approximately monthly checks, or more often when weather conditions warrant. The method consists of an observer walking the site to inspect for subsidence, pot-holes, sudden slumps and other settled areas requiring maintenance attention. The observer estimates the diameter, or width and length and depth, and notes these by trench location on a data sheet map of the site. Dimensions are estimated to the nearest foot. These visual observations should be continued on the existing schedule. The visual observation data is gathered at low cost, approximately four hours per inspection by on-site personnel. The additional data will not increase the accuracy of future projections, because subsidences are effected by variable climatic conditions. The inspections are primarily required to adequately identify site surface problems requiring remedial maintenance, which if not corrected will lead to slumps and increased infiltration.

### 2. Aerial Photographs

A review of historical aerial photographs indicated that the detail is not sufficient to identify subsidences on the order of 20 feet in diameter and smaller. It is our opinion that aerial photographs could be obtained by special low-level reconnaissance flights but their cost and the time involved in review and evaluation is much greater than actual visual observation without significantly increasing the accuracy and usefulness of the visually obtained data.

### 3. Topographic Maps

Existing topographic maps are not detailed enough to show small subsidences. The least costly topographic maps are compiled from aerial photographs and therefore cost more than just aerial photographs discussed above. Topographic maps of the site do not have sufficient accuracy or details of elevation to determine significant changes in overall elevation of the existing cover soil.

## 4. Direct Levels

Direct levels are those that would be run from one or more benchmarks located on stable ground. Elevation measurements would be taken to the nearest 0.01 foot. The three types of "monuments" experiencing settlement that could be measured are differential settlement plates, surface monuments, and the general ground surface.

Differential settlement plates consist of a 2-foot diameter (or square) plate buried beneath the trench surface with an attached shrouded vertical riser to the surface. The elevation of the top of the riser is periodically recorded and the accumulated data is analyzed for changes in the elevation of the riser. The advantage of this system is that elevation changes at various depths within the trench could be measured. Disadvantages are: grass mowing will interfere with anything projecting to the cap surface; economics preclude installing a large number of differential settlement plates; excavating in the trenches will have to be done carefully due to possible exposure of waste; small localized subsidences can easily tip the horizontal plate causing a lateral instead of vertical movement of the riser pipe; and piping may occur along the riser if the settlement plate tips. Althougn the establishment of buried settlement plates and the analysis of the settlement rate data generated may predict future subsidences, the plate would have to be located at a point of future subsidence, which is impossible to predict due to the causes of subsidences. The disadvantages of higher costs and limited usefulness of the data make buried differental settlement plates unfeasible.

Surface monuments are similar to buried settlement plates with the exception that they are located on the surface with a base extending one or two feet deep. Surface monuments are subject to frost heave, disturbances from operating equipment, and tilting from differential settlements. They are most commonly made by casting a bronze, or other metal disk, in the top of a concrete monument which is poured at the desired location. As with the buried settlement plates the surface monuments in our opinion are unfeasible.

Elevations of general ground surface appear to us to be the most feasible. Typically permanent reference points would be established at each end of each selected trench. These two reference points would then define a straight line along the longitudinal center of the top of each trench. Direct levels would then be taken every 25 feet by measuring with a steel tape between the two reference points. Elevations should be measured to 0.01 foot and referenced to previously established permanent benchmarks. Successive direct levels taken at six month intervals, say in May and November, should exhibit different elevations at each point if overall subsidence were still occurring. The data would be plotted on a graph as illustrated in Figure 26. When the rate of change of the surface elevations has decreased to a rate for which the final cap is designed to accomodate,the continuation of direct level measurements could be reviewed. This type of monitoring data will tell when most consolidation settlement has taken place and thereby give an indication when further consolidation will be negligible. It will not increase the accuracy of predicting sudden slumping.

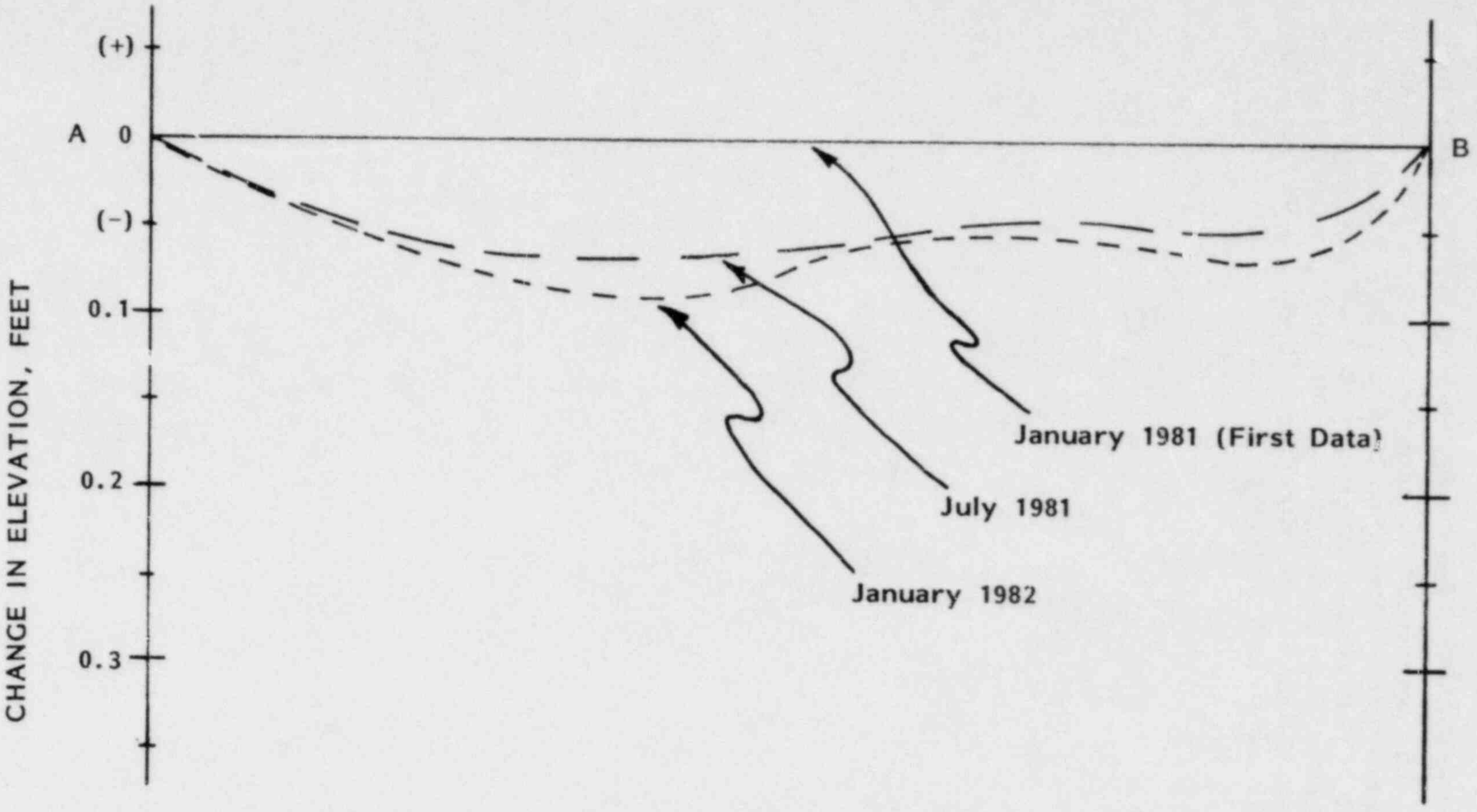


FIGURE 26 - PROPOSED PLOTTING OF DIRECT LEVEL DATA

# VI. CONCLUSIONS AND RECOMMENDATIONS

## A. CONCLUSIONS

### A.1. Data Base

The existing data on subsidence, waste characteristics and placement, and backfill soil placement and compaction in each trench was not sufficient enough to accurately predict future subsidence trends in specific trenches. Only potential subsidence scenarios could be identified.

### A.2. Subsidence Potential

Subsidence as it has occurred to date at the Sheffield site, is dependent on the amount of infiltration of surface water through the existing caps. Unusual climate conditions such as heavy rainfall following early snow that insulated the ground preventing freezing, which occurred from the winter of 1978 through the spring of 1979, can allow increased amounts of late winter and early spring snowmelt and rain to infiltrate the trenches. Heavy infiltration would not likely occur during periods of more normal climatic conditions where the ground was frozen. This extra amount of infiltration caused the piping of soil into voids in the trench backfill and waste with subsequent collapsing of trench surfaces. Eighty percent of the recorded subsidences were noted from November 7, 1978 to May 4 of 1979. Subsidences may have occurred after May of 1979 as a result of delayed reaction to a loss of support to the surface soils, or subsurface collapse of voids or a waste container.

All trenches have a potential for some future subsidence due to piping of soil, natural soil consolidation, and waste container deterioration. The location, sizes and extent of this subsidence is quantitatively indeterminant due to the unknown void sizes and their numbers and locations within the trenches. Subsidences due to piping will generally be characterized by local sudden collapsing, and those due to consolidation and container deterioration may be characterized by sudden collapsing or general area settlement.

Increased incidences of subsidence may occur from 10 to 14 years after waste disposal when metal drums, cardboard, and wood containers will have experienced some deterioration.

It is believed that future subsidence in Trenches 10, 8A and 8B should be small because the waste placed therein was reported to be solidified in Anafco tubs and the prospect for future deterioration and collapse of the containers is rated slight. The existing caps have no recent record of any subsidences on these three trenches.

Subsidences around sump pipes on Trenches 25C and 23 may indicate that backfill soils are piping through the gravel sumps and into the perforated drain pipes plugging them.

Each trench's potential for future subsidences is discussed below. All trenches should experience future subsidence due to the backfill soil consolidation mechanism alone.

### Trench 1

Trench 1 may have future subsidences due to piping and collapse of voids brought on by climatic extremes. As the only trench older than ten years it experienced two subsidences during the two year monitoring period, although one of them is attributed by NECO to a U.S.G.S. attempted monitoring well installation. It has a moderate potential for future subsidence due to waste and waste container deterioration. Its cap seems to be in relatively good condition.

### Trenches 2 and 8

Trench 2 has had no recorded subsidences and its cap seems to be in good condition. It has a moderate potential for future subsidences resulting from deterioration.

### Trench 3

Trench 3 had two subsidences in 1980 and may have more in the future if adverse climate conditions occur. It has a moderate potential for future subsidences resulting from deterioration.

### Trench 4

Trench 4 has had no recorded subsidences and its cap seems to be in good condition. It has a major potential for future deterioration subsidence.

### Trench 5

Trench 5 had one subsidence during the extreme climate condition periods and may have more under any future adverse climate conditions. It has a moderate potential for future subsidences resulting from deterioration.

### Trench 6

Trench 6 had five recorded subsidences during March to May, 1979 related to the extreme climate conditions and may have more under any future adverse climate conditions. It has a major potential for future deterioration subsidence.

### Trench 7

Trench 7 had many subsidences and may have more under any future adverse climate conditions. It has a major potential for future deterioration subsidence.

### Trench 9

Trench 9 had a number of subsidences during the winter and spring of 1978 to 1979 and may have more under any future adverse climate conditions. It has a moderate potential for future subsidences resulting from deterioration.

### Trench 10

The Trench 10 subsidences may have been primarily due to drainage over the trench which has now been corrected by redirecting it around the north end of the trench. The trench contains solidified waste and its deterioration potential is rated negligible.

### Trenches 11, 25, 8A and 8B

These trenches have had no recorded subsidences and their caps seem to be in good condition. Trenches 11 and 25 have a moderate potential for future subsidences from waste deterioration. Trenches 8A and 8B contain solidified waste and their deterioration potential is rated as negligible.

### Trenches 18 and 26

Trench 26 had a number of recorded subsidences and may have more under any adverse climate conditions. It has a moderate potential for future related subsidences resulting from deterioration.

### Trench 24

Trench 24 had two of the largest subsidences during the spring of 1979 and may have more under adverse climate conditions. It has a moderate potential for future subsidences resulting from deterioration.

### Trench 25C

Trench 25C had a number of subsidences during the winter and spring of 1978 and 1979 and continuing into April 1980 and may have more related to any adverse climate conditions. It has a moderate potential for future subsidences resulting from deterioration.

### Trench 23

Trench 23 had seven subsidences including 10 to 20-foot diameter ones between winter 1978 and winter 1979 and may have more related to any adverse weather conditions. It has a moderate potential for future subsidences resulting from deterioration.

### Trenches 14 and 14A

The wall between Trenches 14 and 14A is very susceptible to subsidences as evidenced by 12 subsidences recorded there from December 15, 1978 to March 1979. There have also been subsidences on the caps of Trench 14 and 14A. Additional subsidences may occur with adverse climatic conditions. It has a moderate potential for future subsidences resulting from deterioration.

### A.3. Trench Stabilization

All feasible techniques evaluated for stabilizing the trenches in the immediate future instead of waiting for natural deep compaction processes to occur have disadvantages. The primary disadvantage of dynamic consolidation are the probable destruction of numerous containers, increased exposure of radiological wastes to the backfill soil and the effects of strong vibration on adjacent trenches. These same disadvantages apply to using driven compaction piles with the additional drawback of exposing the driven and withdrawn reusable piles and thereby increasing worker exposure to low level radiation. Cost of the compaction pile technique is estimated to be a little less than double the estimated cost of dynamic consolidation. The most expensive techniques appear to be compaction grouting alone and in combination with chemical grouting at estimated costs of three to eight times that for driven compaction piles. The grouting pipes may also puncture waste containers and withdrawn grout pipes would expose workers to the possibly contaminated equipment.

The least hazardous technique from the standpoint of exposing waste, and workers and equipment to waste, is surcharging. It is estimated to be the least cost also. A disadvantage to surcharging is the extended time period for subsidence to occur under the increased overburden loads. Installed settlement plates would be required to monitor the trench cover surface movement beneath the surcharging mounds of soil. Surcharging should have less of an effect on collapsing waste containers then the other techniques. Therefore potential settlements from future container deterioration and collapse may remain a continuing problem with this technique.

## B. RECOMMENDATIONS

### B.1. Future Monitoring

Continue visual trench cap monitoring on a minimum monthly basis and more often as climate conditions may dictate to identify future subsidences for repair and areas requiring other attention.

### B.2. Surface Stabilization

Use sod in places where it is difficult or there is not sufficient time to seed grass to protect the surface from erosion, rilling and gullying which can be contributory to subsidences.

Excelsior blankets may be used on sloping ground to reduce and control erosion. They are used by the Illinois State Department of Transportation. The blankets could be particularly helpful on the south side of Trench 11, the west end of Trenches 23 and 24, on the north half of Trench 14A, and along the side slopes of the developed drainage channel which runs through the middle of the site. These side slopes could alternatively be sodded.

### B.3. General Site

Vehicular access to the site and particularly the trench surfaces should be eliminated except for well defined necessary routes not crossing any trench surfaces.

Allow maintenance and contractor vehicular access only over rigidly planned and controlled routes to mitigate damage to the soil surface.

The judicious use of large tarpaulins, or membranes, to cover problem trench areas prior to adverse weather conditions may reduce water infiltration.

### B.4. Impermeable Trench Caps

#### Trenches 8A, 8B, and 10

Trenches 8A, 8B and 10 have a low potential for future waste and container deterioration and therefore future subsidences will be primarily related to moisture infiltration and piping. Therefore it is recommended to mitigate against future subsidences due to moisture infiltration and low permeability caps be constructed on Trenches 8A, 8B and 10. This should eliminate future maintenance problems on these three trenches.

#### Trenches 2, 4, 11, and 25

Trenches 2, 4, 11, and 25 did not experience subsidences during the period of recorded data. They are however, subject to future subsidence from container and waste deterioration. Low permeability caps should be constructed on these trenches to reduce infiltration and thus the potential for subsidence from piping. The resulting reduced moisture content in the trenches will decrease the rate of container and waste deterioration. The reduced deterioration rate will extend the time until containers collapse. The radioactivity levels of the contained waste will also have decreased over the extended time period.

The low permeability caps will also reduce trench maintenance until the containers collapse.

### Trenches 1, 3, 5, 6, 7, 8, 9, 26, 24, 18, 25C, 23, 14, 14A

The trenches experienced subsidence during the period of recorded data. They may still be susceptible to subsidence from settlement and piping due to infiltration of water during and following unusual climate conditions. Low permeability caps should be constructed on these trenches to reduce infiltration for the same reasons as stated for Trenches 2, 4, 11 and 25.

# REFERENCES

1. General Soils Map of Bureau County, Illinois. USDA, Soil Conservation Service, May, 1969.

2. J.B. Foster, J.R. Erickson, USGS - "Preliminary Report on the Hydrogeology of a Low-Level Radioactive Waste Disposal Site Near Sheffield, Illinois" January, 1980. Open File Report 79-1545.

3. Illinois Department of Agricultural Statistics, Bureau County, Illinois Bulletin C-48, October, 1970.

4. K. Dragonette, J. Blackburn, K. Cartwright, "Interagency Task Force Report on the Proposed Decommissioning of the Sheffield Nuclear Waste Disposal Site". September, 1979.

5. Environmental Report for the Sheffield Low-Level Radioactive Waste Disposal Facility, by NECO.

6. D'Appolonia Consulting Engineers "Investigation of Trench 18, Nuclear Waste Disposal Site" Project No. 76-219A, July, 1976.

7. H.F. Winterkorn, H.Y. Fang, "Foundation Engineering Handbook", pages 148-194. Van Nostrand Reinhold Company, 1975.

8. M.F. Schiff, "What is Corrosive Soil?" Western States Corrosion Seminar, California State Polytechnical University, Pomona, California. May 3 - 5, 1978, page 15/3-4.

9. "Soil Improvement History, Capabilities and Outlook." Report by the Committee on Placement and Improvement of Soils by the Geotechnical Engineering Division of the American Society of Civil Engineers. February 1978.

10. J.K. Mitchell, "In-Place Treatment of Foundation Soils", pages 73-93 in Journal of the Soil Mechanics and Foundation Division, Proceedings of the American Society of Civil Engineers, Volume 96 No. SMI, January 1970. Published by American Society of Civil Engineers, 345 East 47th Street, New York, N.Y. 10017.

11. J. Warner, D.R. Brown, "Planning and Performing Compaction Grouting", page 653 in Journal of the Geotechnical Engineering Division, Proceedings of the American Society of Civil Engineers. Volume 100, No. GT6. June 1974.

12. S.S. Rathburn, Grouting Information from Hunt Contracting Company, 1627 Chico Avenue, South El Monte, California. 91733.

13. R. Stone, "Aerobic Landfill Stabilization", Page 153 in "Solid Wastes: Origin, Collection, Processing and Disposal," edited by C.L. Mantell. A. Wiley - Interscience Publication, John Wiley and Sons, Inc., 1975.

14. C.G. Golucke, "Biological Processing: Composting and Hydrolysis", page 197 in "Handbook of Solid Waste Management," edited by D.G. Wilson. Van Nostrand Reinhold Company, 1977.

# APPENDIX A

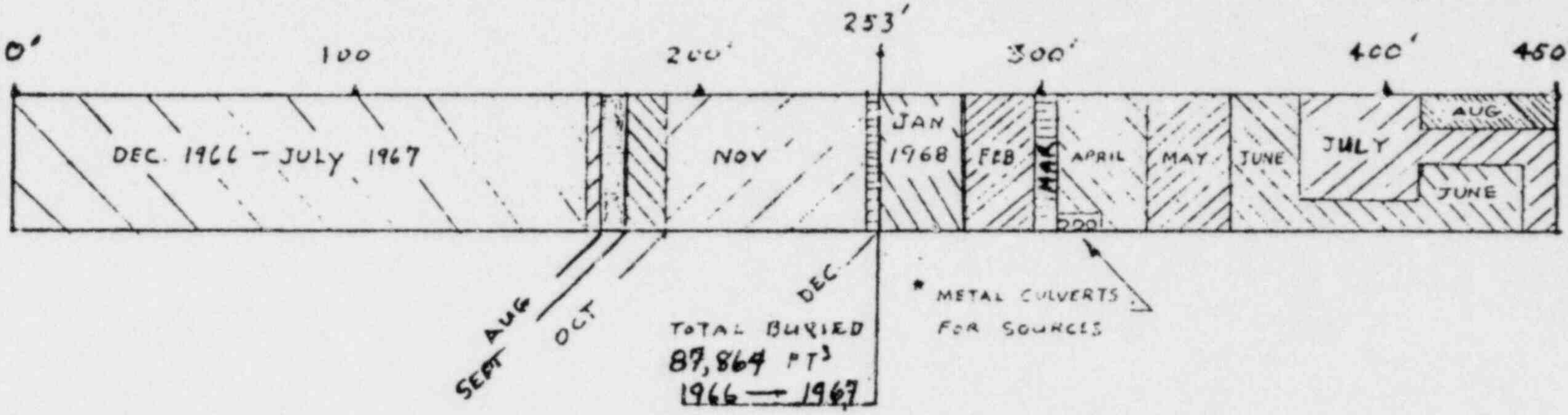
# TRENCH STATUS REPORTS

Source: Nuclear Engineering Company, Inc.

# WASTE ACCUMULATION [illegible]aph

TRENCH: NO. ONE
STARTED – AUG 1967
COMPLETED – AUG. 16, 1968
LENGTH – 450 FEET
WIDTH – 40 FEET

ACCOUNTABILITY OF MATERIAL:
BYPRODUCT = 4,977,531.01 MC.
SPECIAL NUCLEAR = 2929.50 GRAMS
SOURCE = 14,995.67 LBS.
CUBIC FEET = 144,817.00



NOTES.
- * THREE 12" METAL [illegible] 4' LONG. THE TOP 4' SECTION CAN BE [illegible]

SHEFFIELD NUCLEAR CNTR
NUCLEAR ENGINEERING CO.
SHEFFIELD, ILLINOIS

# NUCLEAR ENGINEERING COMPANY, INC.

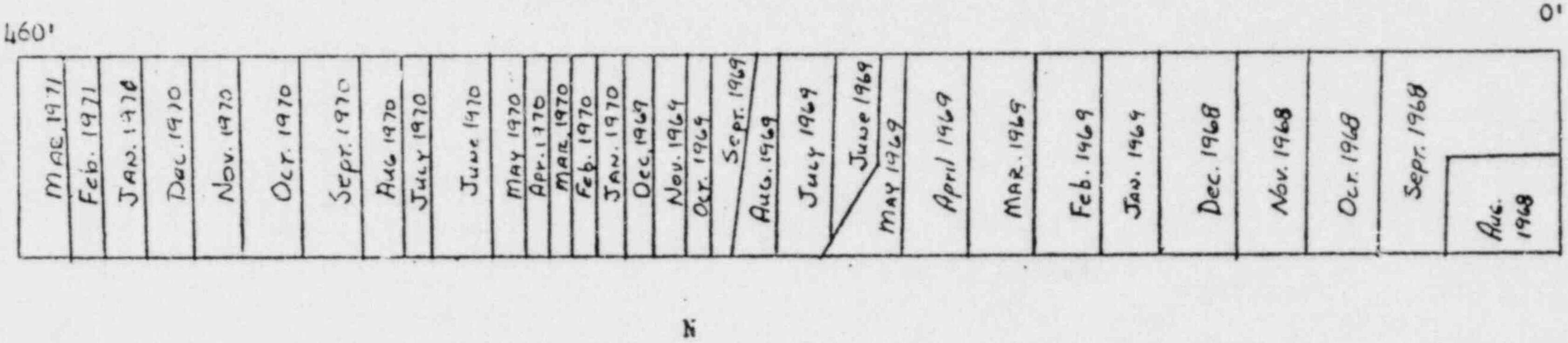
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

Facility : ILLINOIS
Trench No. : 2
Current Month : March, 1971
Date Opened : August 16, 1968
Date Closed : March 31, 1971
Length : 460 Feet
Width : 60 Feet
Depth : 25 Feet

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu. Ft.) | 9,002.84 | 231,235.67 |
| By-Product (Curies) | 1,479.92 | 10,451.15 |
| Plutonium | 40.80 | 4,970.40 |
| Uranium 233 | 0.00 | 0.00 |
| Uranium 235 | 400.60 | 7,725.46 |
| Total SNM (grams) | 441.40 | 12,695.86 |
| Source (Lbs.) | 0.00 | 37,736.06 |



## NUCLEAR ENGINEERING COMPANY, INC.

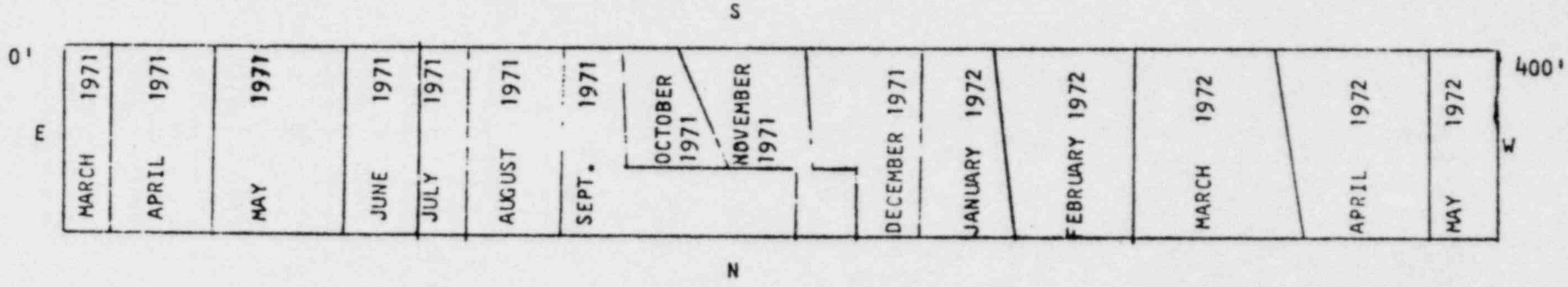
### TRENCH STATUS
### (RADIOACTIVE WASTE MATERIAL)

INFORMATION

| | |
|---|---|
| Facility | : ILLINOIS |
| Trench No. | : 3 |
| Current Month | : May 1972 |
| Date Opened | : March 1972/ |
| Date Closed | : May 15, 1972 |
| Length | : 400' |
| Width | : 55' |
| Depth | : 25' |

BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu. Ft.) | : 8,516.34 | 191,201.44 |
| By-Product (Curies) | : 17.50 | 7,758.19 |
| Plutonium | : -0- | 5,625.65 |
| Uranium 233 | : -0- | -0- |
| Uranium 235 | : -0- | 2,714.26 |
| Total SNM (grams) | : -0- | 8,339.91 |
| Source (Lbs.) | : -0- | 4,310.80 |



## NUCLEAR ENGINEERING COMPANY, INC.

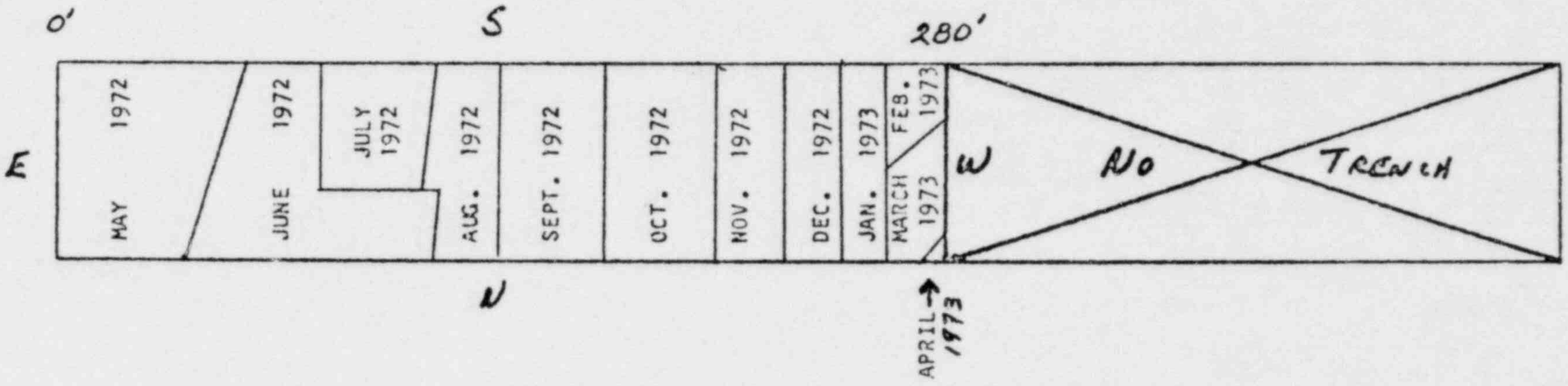
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

INFORMATION

Facility : ILLINOIS
Trench No. : #4
Current Month : APRIL 1973
Date Opened : MAY 1972
Date Closed : APRIL 6, 1973
Length : 280'
Width : 60'
Depth : 20'

BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu. Ft.) | 1,995.70 | 197,898.39 |
| By-Product (Curies) | 5.01 | 4,443.43 |
| Plutonium | -0- | 1,698.60 |
| Uranium 233 | -0- | -0- |
| Uranium 235 | -0- | 3,165.05 |
| Total SNM (grams) | -0- | 4,863.65 |
| Source (Lbs.) | -0- | 3,980.75 |



# NUCLEAR ENGINEERING COMPANY, INC.

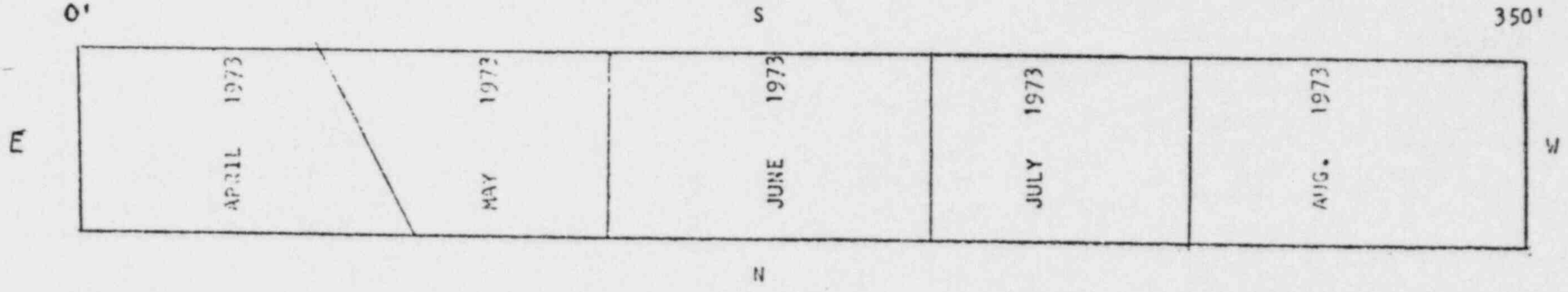
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

Facility : ILLINOIS
Trench No. : 5
Current Month : AUGUST 1973
Date Opened : APRIL 1973
Date Closed : AUGUST 31, 1973
Length : 350'
Width : 50'
Depth : 20'

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) : | 15,420.11 | 136,419.24 |
| By-Product (Curies) : | 112.52 | 1,167.66 |
| Plutonium : | 48.00 | 1,257.28 |
| Uranium 233 : | -0- | -0- |
| Uranium 235 : | -0- | 1,930.05 |
| Total SNM (grams) : | 48.00 | 3,187.33 |
| Source (Lbs.) : | -0- | 5,163.95 |



# NUCLEAR ENGINEERING COMPANY, INC.

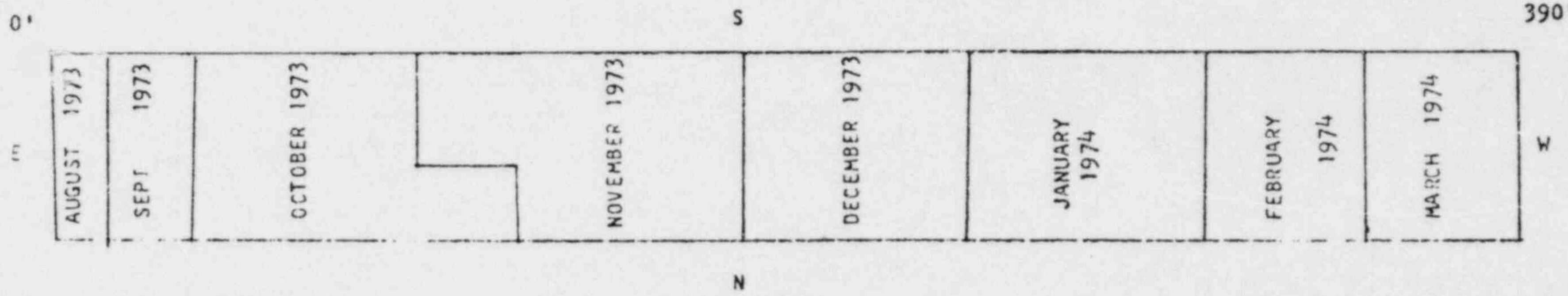
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

| | |
|---|---|
| Facility | : ILLINOIS |
| Trench No. | : 6 |
| Current Month | : MARCH 1974 |
| Date Opened | : AUGUST 1973 |
| Date Closed | : MARCH 22, 1974 |
| Length | : 390' |
| Width | : 45' |
| Depth | : 20' |

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) | : 30,640.93 | 211,677.27 |
| By-Product (Curies) | . 228.00 | 1,327.49 |
| Plutonium | : 86.75 | 1,131.86 |
| Uranium 233 | : -0- | .014 |
| Uranium 235 | : 22.00 | 5,908.30 |
| Total SNM (grams) | : 108.75 | 7,040.174 |
| Source (Lbs.) | : -0- | 475.32 |



# NUCLEAR ENGIN ING COMPANY, INC.

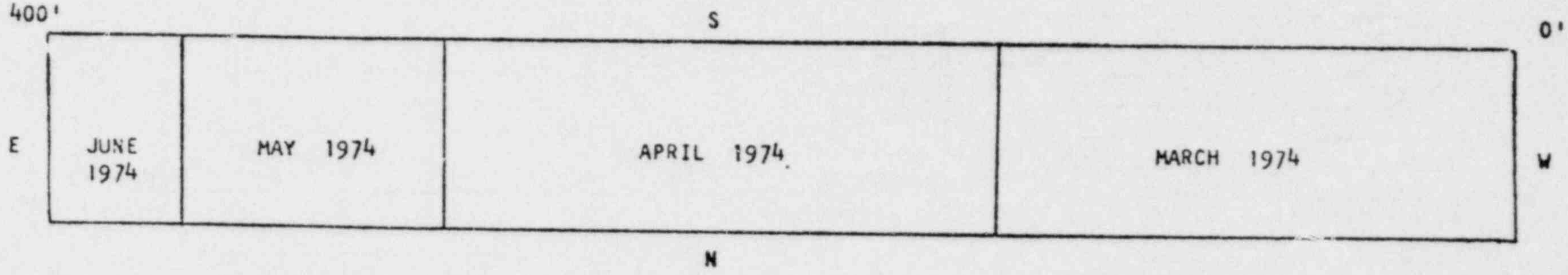
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

Facility : ILLINOIS
Trench No. : #7
Current Month : JUNE 1974
Date Opened : MARCH 22, 1974
Date Closed : JUNE 24, 1974
Length : 400'
Width : 19' to 41'
Depth : 17' to 23'

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) | 10,031.32 | 133,709.37 |
| By-Product (Curies) | 326.81 | 635.76 |
| Plutonium | 118.96 | 450.83 |
| Uranium 233 | -0- | -0- |
| Uranium 235 | -0- | 1,189.90 |
| Total SNM (grams) | 118.96 | 1,640.73 |
| Source (Lbs.) | -0- | 1,356.00 |



# NUCLEAR ENGINEERING COMPANY, INC.

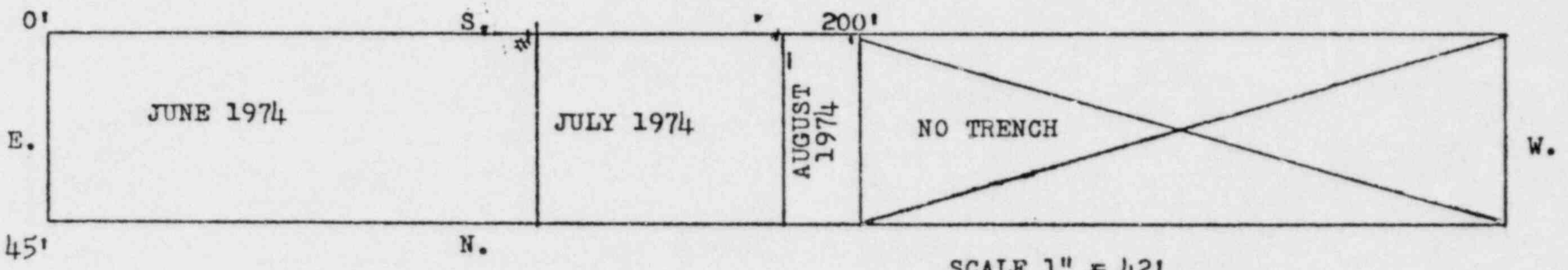
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

INFORMATION

Facility : ILLINOIS
Trench No. : #8
Current Month : AUGUST 1974
Date Opened : JULY 3, 1974
Date Closed : AUGUST 9, 1974
Length : 200 ft
Width : 45 ft
Depth : 8 ft to 15 ft

BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu. Ft.) | : 3,206.48 | 49,364.70 |
| By-Product (Curies) | : 8.21 | 354.96 |
| Plutonium | : 0.00 | 0.00 |
| Uranium 233 | : 0.00 | 0.00 |
| Uranium 235 | : 0.00 | 0.00 |
| Total SNM (grams) | : 0.00 | 0.00 |
| Source (Lbs.) | : 0.00 | 0.00 |



SCALE 1" = 42'

## NUCLEAR ENGINEERING COMPANY, INC.

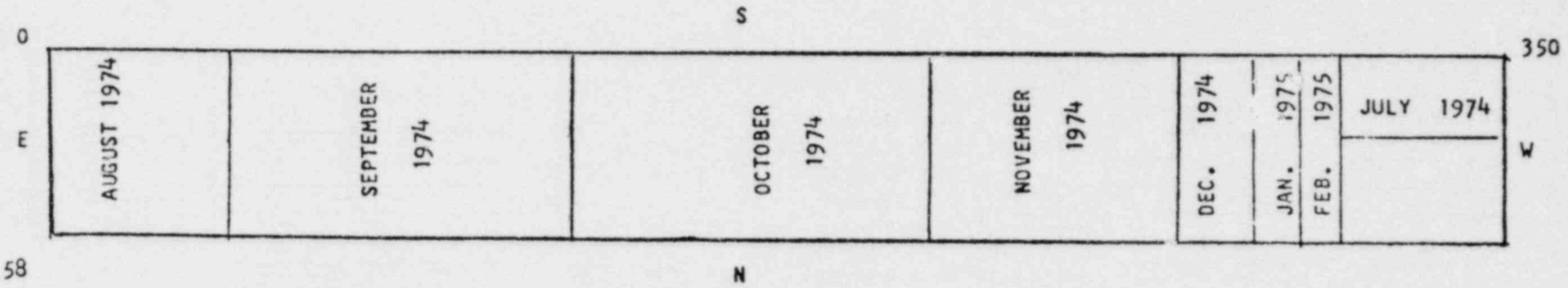
### TRENCH STATUS
### (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

Facility : ILLINOIS
Trench No. : 9
Current Month : FEB. 1975
Date Opened : JULY 18, 1974
Date Closed : FEB. 18, 1975
Length : 350'
Width : 58'
Depth : 22'

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) : | 2,828.10 | 185,237.52 |
| By-Product (Curies) : | 88.77 | 1,385.02 |
| Plutonium : | 4.73 | 75.76 |
| Uranium 233 : | -0- | 1.00 |
| Uranium 235 : | -0- | 836.18 |
| Total SNM (grams) : | 4.73 | 912.94 |
| Source (Lbs.) : | -0- | 29,613.79 |



## NUCLEAR ENGINEERING COMPANY, INC.

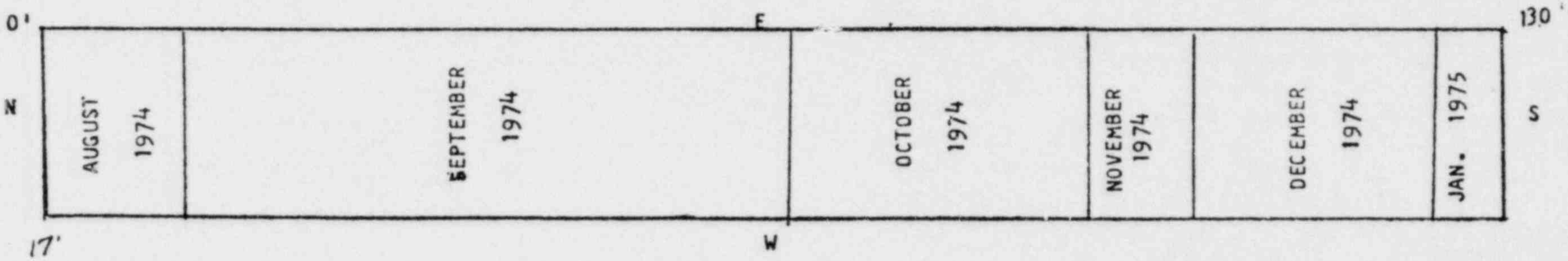
### TRENCH STATUS
### (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

Facility : ILLINOIS
Trench No. : #10
Current Month : JANUARY 1975
Date Opened : AUGUST 21, 1974
Date Closed : JANUARY 2, 1975
Length : 130'
Width : 17'
Depth : 15'

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) : | 213.15 | 13,945.10 |
| By-Product (Curies) : | 6.57 | 381.93 |
| Plutonium : | -0- | -0- |
| Uranium 233 : | -0- | -0- |
| Uranium 235 : | -0- | -0- |
| Total SNM (grams) : | -0- | -0- |
| Source (Lbs.) : | -0 | -0- |



## NUCLEAR ENGINEERING COMPANY, INC.

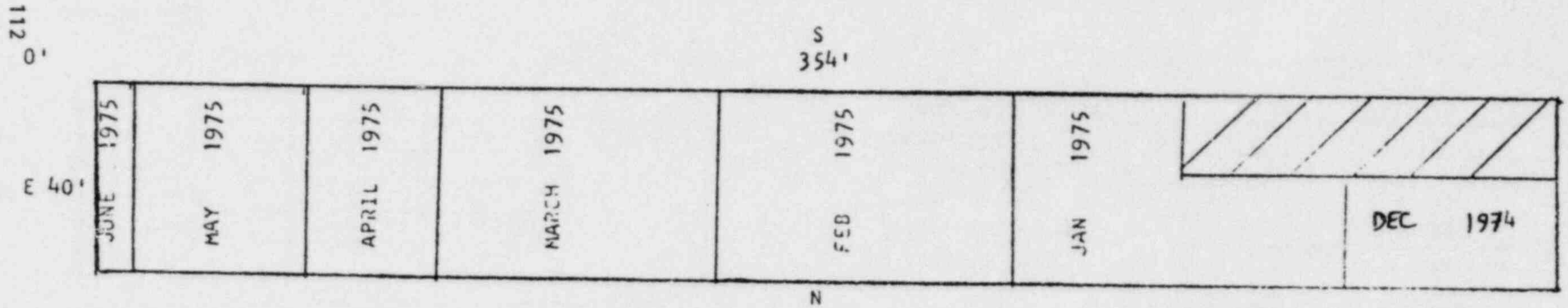
### TRENCH STATUS
### (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

Facility : ILLINOIS
Trench No. : 11
Current Month : JUNE 1975
Date Opened : DEC. 18, 1974
Date Closed : JUNE 4, 1975
Length : 354'
Width : 40'
Depth : 20'

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) : | 2743.91 | 92,409.94 |
| By-Product (Curies) : | 110.35 | 1446.94 |
| Plutonium : | -0- | 199.33 |
| Uranium 233 : | -0- | -0- |
| Uranium 235 : | -0- | ~~-0-~~ 484.00 |
| Total SNM (grams) : | -0- | 683.33 |
| Source (Lbs.) : | | 32,947.73 |



SCALE = 1/4" = 10'

## NUCLEAR ENGINEERING COMPANY, INC.

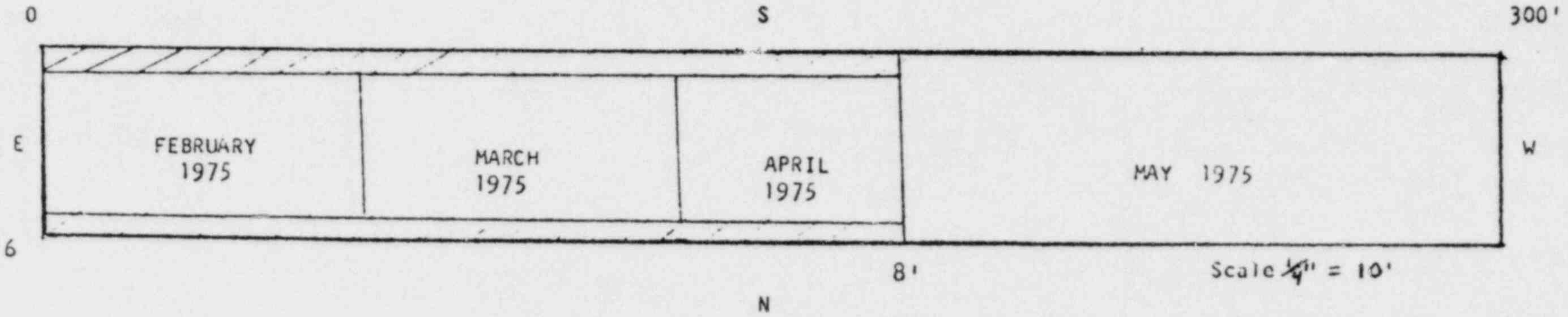
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

Facility : ILLINOIS
Trench No. : #25
Current Month : MAY 1975
Date Opened : FEB. 20, 1975
Date Closed : MAY 15, 1975
Length : 300'
Width : 8'
Depth : 18'

### BURIAL INVENTORY

| | | Current Month | To Date |
|---|---|---|---|
| Volume (Cu.Ft.) | : | 7676.05 | 14,525.30 |
| By-Product (Curies) | : | 110.07 | 195.89 |
| Plutonium | : | -0- | -0- |
| Uranium 233 | : | -0- | -0- |
| Uranium 235 | : | -0- | -0- |
| Total SNM (grams) | : | -0- | -0- |
| Source (Lbs.) | : | -0- | -0- |



# NUCLEAR ENGINEERING COMPANY, INC.

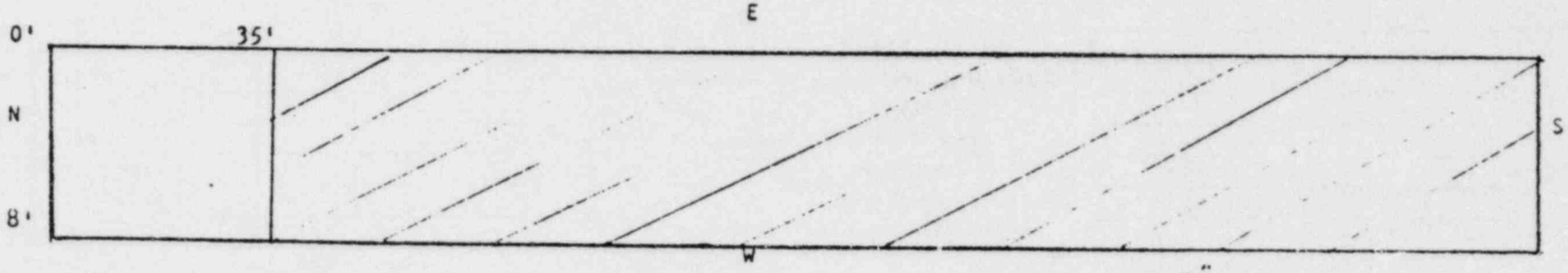
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

Facility : ILLINOIS
Trench No. : 8-A
Current Month : MAY 1975
Date Opened : MAY 16, 1975
Date Closed : MAY 28, 1975
Length : 35'
Width : 8'
Depth : 18'

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) : | 3,178.30 | 3,178.30 |
| By-Product (Curies) : | 237.99 | 237.99 |
| Plutonium : | -0- | -0- |
| Uranium 233 : | -0- | -0- |
| Uranium 235 : | -0- | -0- |
| Total SNM (grams) : | -0- | -0- |
| Source (Lbs.) : | -0- | -0- |



Scale ¼" = 10'

# NUCLEAR ENGINEERING COMPANY, INC.

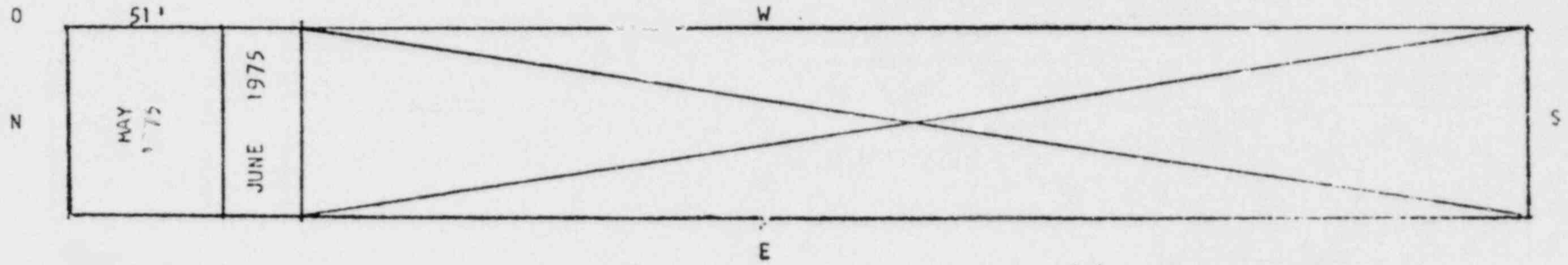
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

Facility : ILLINOIS
Trench No. : 88
Current Month : JUNE 1975
Date Opened : MAY 28, 197
Date Closed : JUNE 6, 1975
Length : 51'
Width : 8'
Depth : 18'

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) : | 1578.25 | 2653.25 |
| By-Product (Curies) : | 49.37 | 250.67 |
| Plutonium : | -0- | -0- |
| Uranium 233 : | -0- | -0- |
| Uranium 235 : | -0- | -0- |
| Total SNM (grams) : | -0- | -0- |
| Source (Lbs.) : | -0- | |



SCALE 1/4" = 10'

# NUCLEAR ENGINEERING COMPANY, INC.

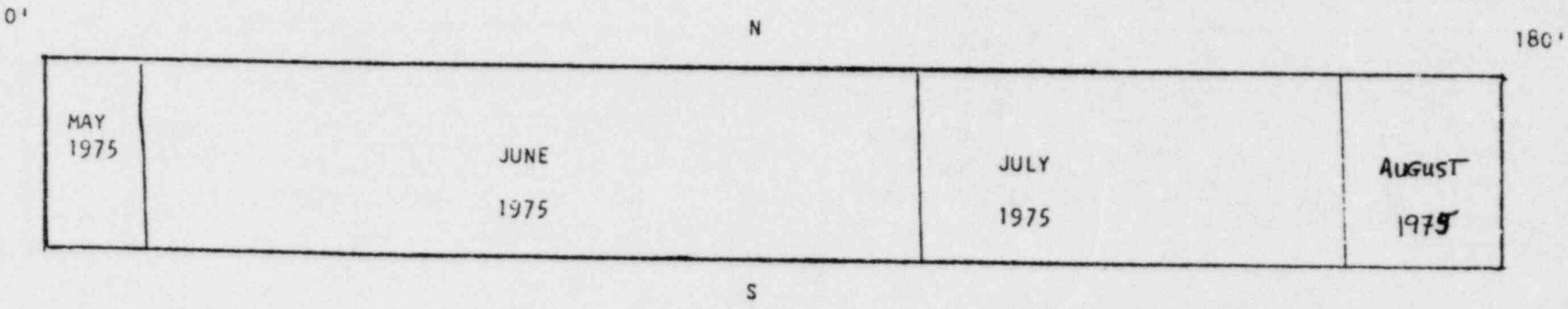
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

Facility : ILLINOIS
Trench No. : 26
Current Month : AUGUST 1975
Date Opened : MAY 30, 1975
Date Closed : AUGUST 27, 1975
Length : 180'
Width : 64'
Depth : 23'

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) : | 28,340.34 | 166,137.91 |
| By-Product (Curies) : | 277.35 | 991.20 |
| Plutonium : | -0- | 5.0 |
| Uranium 233 : | -0- | -0- |
| Uranium 235 : | 853.80 | 1,082.80 |
| Total SNM (grams) : | 853.80 | 1,087.80 |
| Source (Lbs.) : | 16,378.79 | 29,611.79 |



SCALE 1/4" = 10'

# NUCLEAR ENGINEERING COMPANY, INC.

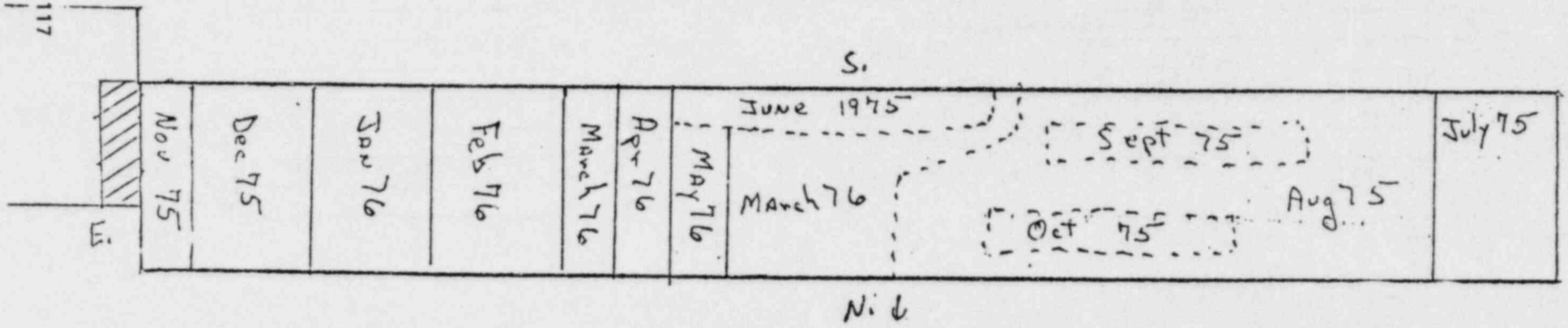
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

Facility : ILLINOIS
Trench No. : 24
Current Month : MAY, 1976
Date Opened : JUNE 27, 1975
Date Closed : MAY 24, 1976
Length : ~~[illegible]~~ 455'
Width : 62'
Depth : 17'

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) : | 8,243.83 | 227,695.83 |
| By-Product (Curies) : | 154.52 | 5,100.38 |
| Plutonium : | -0- | 1.71 |
| Uranium 233 : | -0- | -0- |
| Uranium 235 : | -0- | 4,283.90 |
| Total SNM (grams) : | -0- | 4,285.61 |
| Source (Lbs.) : | -0- | 24,123.72 |



# NUCLEAR ENGINEERING COMPANY, INC.

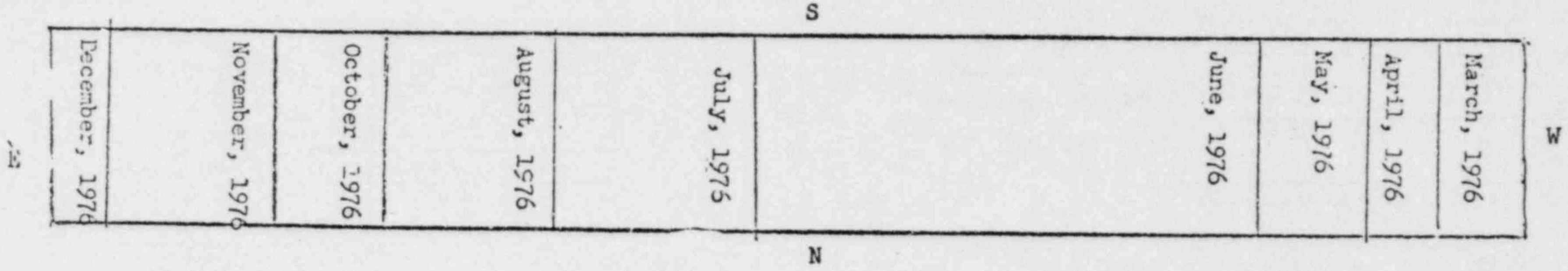
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

Facility : ILLINOIS
Trench No. : 18
Current Month : DECEMBER, 1976
Date Opened : MARCH 29, 1976
Date Closed : DECEMBER 6, 1976
Length : 320'
Width* : 70' 80' at slump
Depth : 15'

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) | 4,849.65 | 120,655.69 |
| By-Product (Curies) | 12.72 | 131.30 |
| Plutonium | -0- | -0- |
| Uranium 233 | -0- | -0- |
| Uranium 235 | 13.50 | 99.00 |
| Total SNM (grams) | 13.50 | 99.00 |
| Source (Lbs.) | 27.00 | 198.00 |



# NUCLEAR ENGINEERING COMPANY, INC.

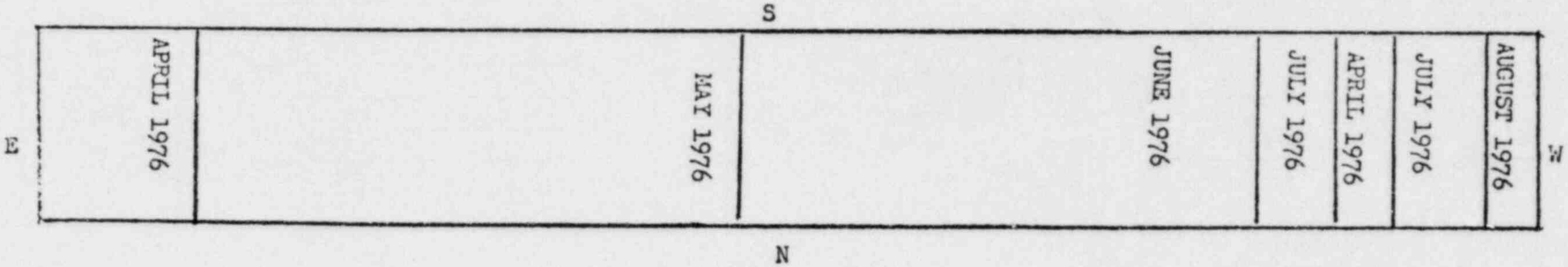
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

Facility : ILLINOIS
Trench No. : 25C
Current Month : AUGUST
Date Opened : APRIL 13, 1976
Date Closed : AUGUST 6, 1976
Length : 218'
Width : 35'
Depth : 18'

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) | 1,911.89 | 65,579.83 |
| By-Product (Curies) | 14.07 | 863.86 |
| Plutonium | -0- | -0- |
| Uranium 233 | -0- | -0- |
| Uranium 235 | -0- | 177.58 |
| Total SNM (grams) | -0- | 177.58 |
| Source (Lbs.) | -0- | 622.25 |



# NUCLEAR ENGINEERING COMPANY, INC.

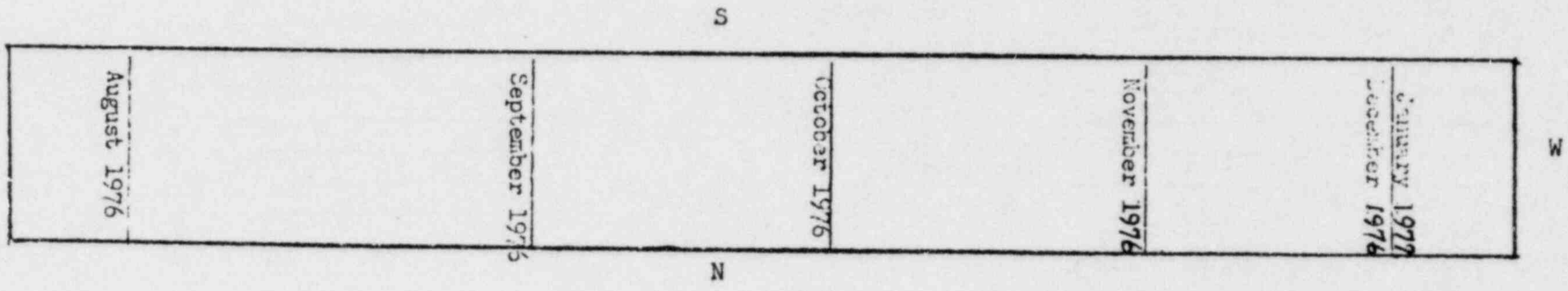
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

Facility : Illinois
Trench No. : 23
Current Month : January 1977
Date Opened : August 16, 1976
Date Closed : January 13, 1977
Length : 440'
Width : 54'
Depth : 18'

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) : | 4,288.80 | 184,450.75 |
| By-Product (Curies) : | 175.50 | 4,565.03 |
| Plutonium : | -0- | -0- |
| Uranium 233 : | -0- | -0- |
| Uranium 235 : | -0- | 211.27 |
| Total SNM (grams) : | -0- | 211.27 |
| Source (Lbs.) : | 45.00 | **6,622.66** |



# NUCLEAR ENGINEERING COMPANY, INC.

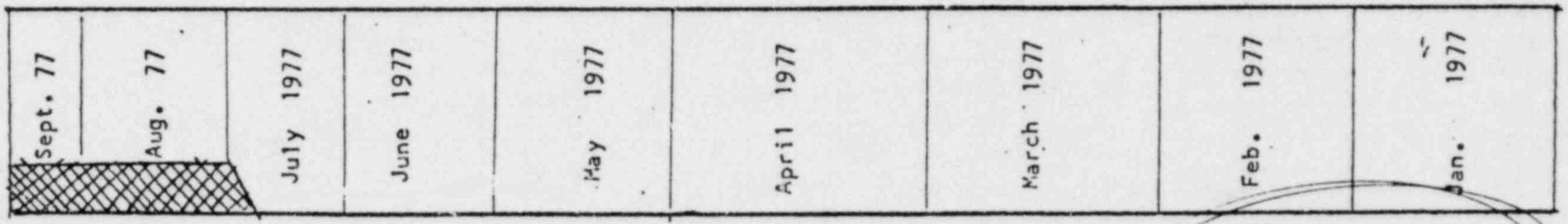
## TRENCH STATUS
## (RADIOACTIVE WASTE MATERIAL)

### INFORMATION

| | |
|---|---|
| Facility | ILLINOIS |
| Trench No. | 14 |
| Current Month | September 1977 |
| Date Opened | January 6, 1977 |
| Date Closed | September 12, 1977 |
| Length | 580' |
| Width | 54' |
| Depth | 25' |

### BURIAL INVENTORY

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) | 14,832.83 | 394,399.80 |
| By-Product (Curies) | 150.74 | 7,197.06 |
| Plutonium | -0- | -0- |
| Uranium 233 | -0- | -0- |
| Uranium 235 | 4.01 | 2,346.39 |
| Total SNM (grams) | 4.01 | 2,346.39 |
| Source (~~lbs.~~) Kgms. | 33,001.69 | 133,139.70 |



CORRECTED COPY

CHECKED FEB 10 1978

## NUCLEAR ENGINEERING COMPANY, INC.

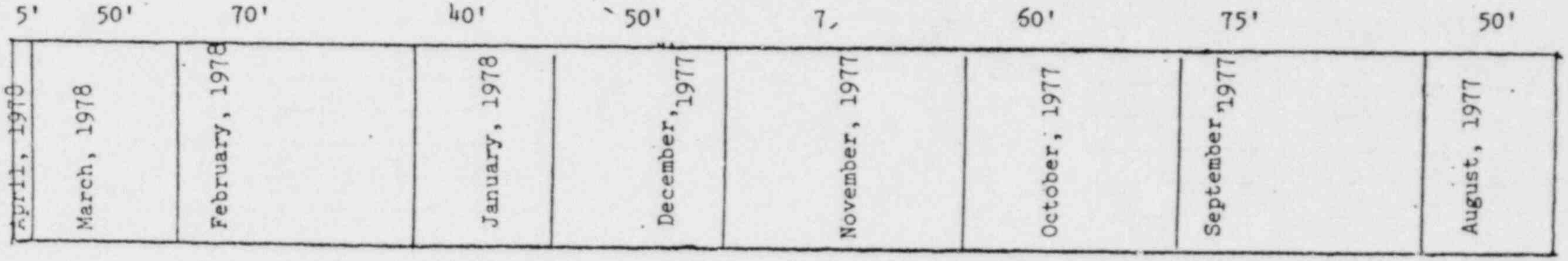
### TRENCH STATUS
### (RADIOACTIVE WASTE MATERIAL)

**INFORMATION**

Facility : Sheffield, Illinois
Trench No. : 14-A
Current Month : April, 1978
Date Opened : August 12, 197~~8~~ 7
Date Closed : April 8, 1978
Length : 475'
Width : 58'
Depth : 26'

**BURIAL INVENTORY**

| | Current Month | To Date |
|---|---|---|
| Volume (Cu.Ft.) | 5,198.01 | 351,877.34 |
| By-Product (Curies) | 142.11 | 6,321.50 |
| Plutonium | -0- | -0- |
| Uranium 233 | -0- | -0- |
| Uranium 235 | -0- | 5,097.63 |
| Total SNM (grams) | -0- | 5,097.63 |
| Source (kilograms) | -0- | 272,150.87 |



# APPENDIX B

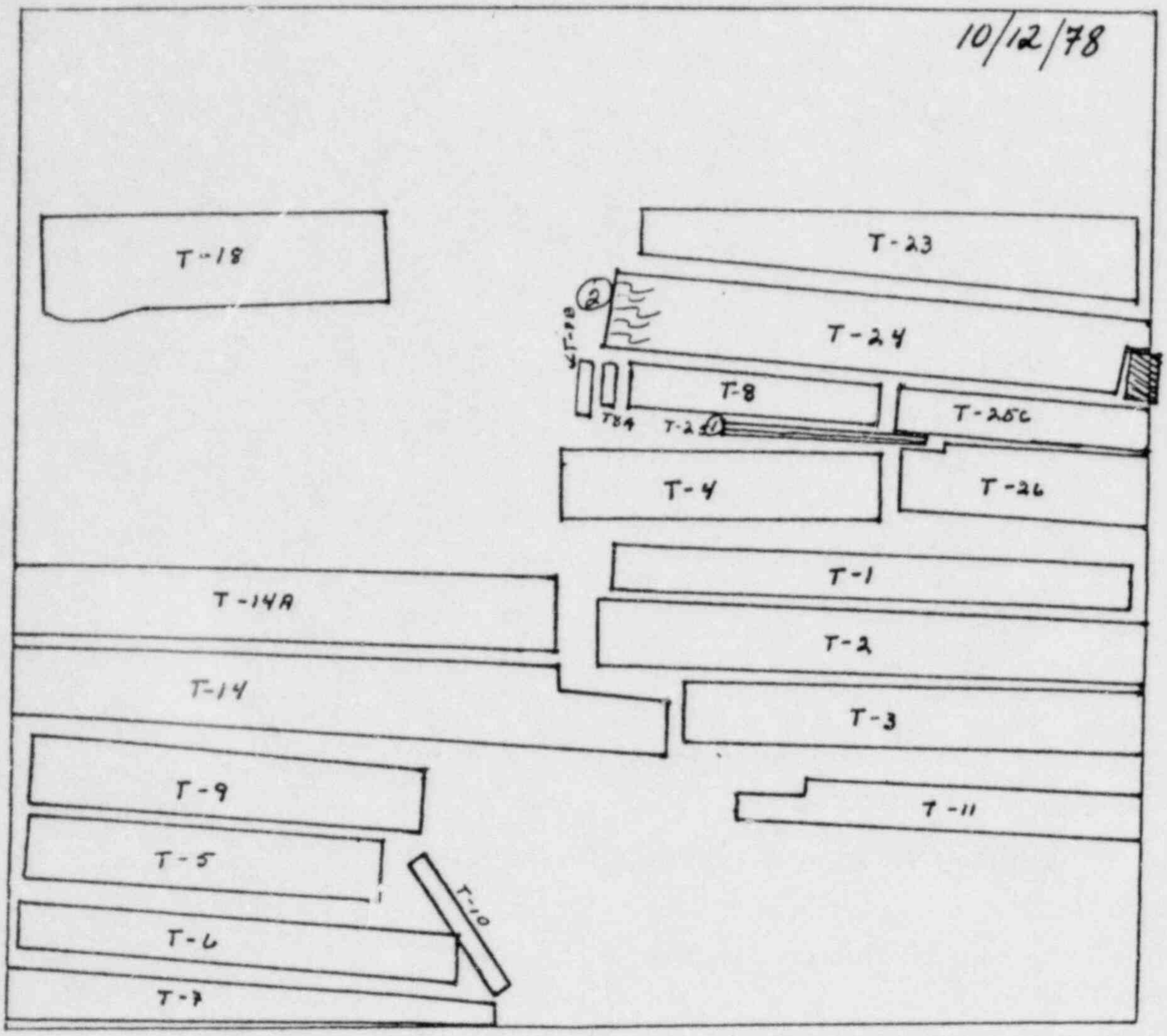
## MONTHLY TRENCH INSPECTION REPORTS

Source: Nuclear Engineering Company, Inc

Note: Writing on Reports has been enhanced for reproduction.

10/12/78

# MONTHLY TRENCH INSPECTION



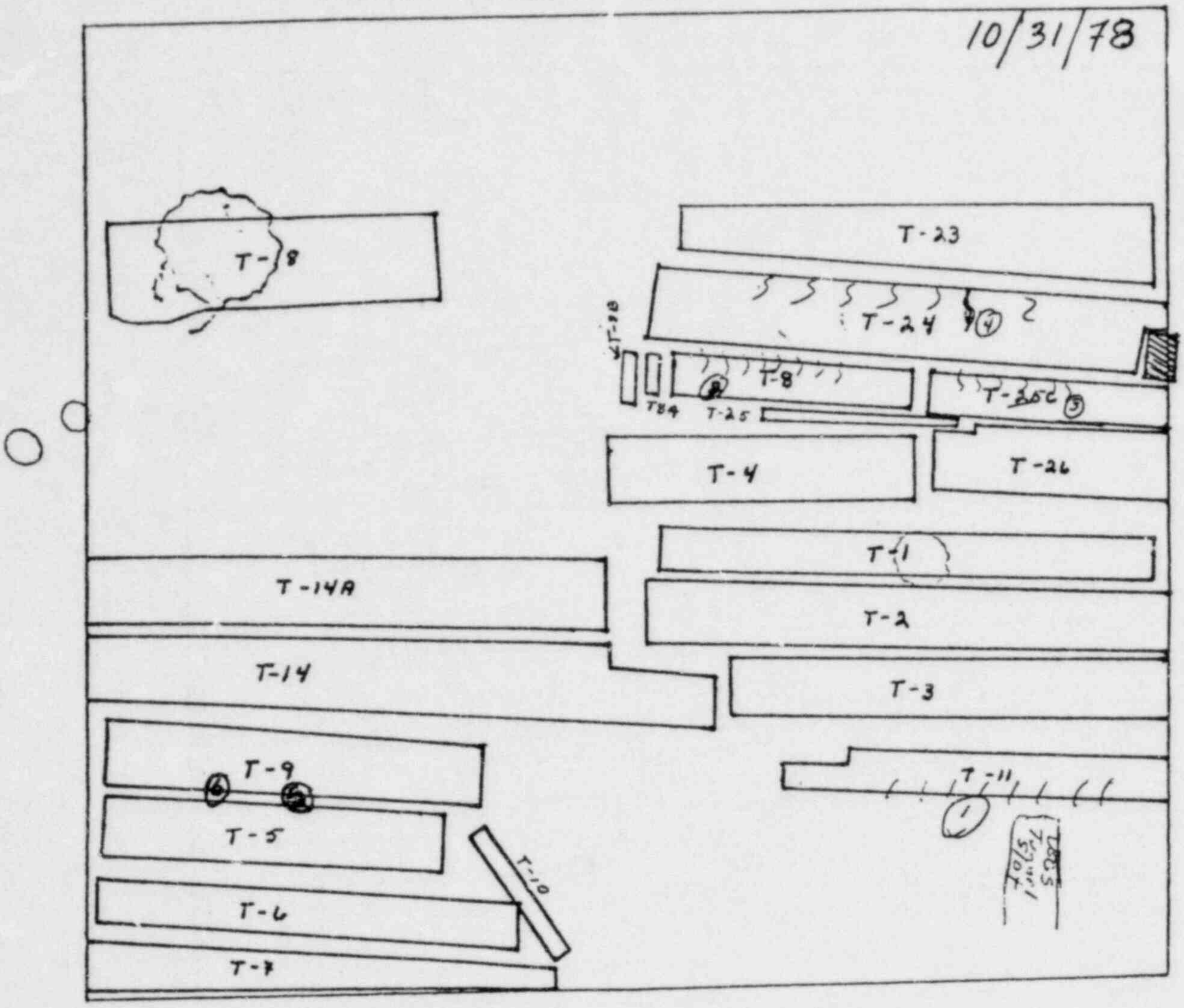
1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① Erosion 2' deep 2' wide down center of T-25
Placed a new cap on T-25 redirected the runoff to the south of T-25 off the cap. re seeded trench

② Filled & seeded minor erosion on west end of T-24 6" deep

10/31/78

# MONTHLY TRENCH INSPECTION



1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① erosion along the south side of T-11 about 1'wide and 6" to 1'deep

② erosion along the north side of T-8 about 6" wide 6" deep

③ erosion along north side of T-25C about 6" wide 6" deep

④ erosion T-24 6" wide 1'deep - other minor erosion along north side of tren

⑤ hole south side of T-9 1'diameter 1'deep

⑥ Lowspot south side of T-9 holds water

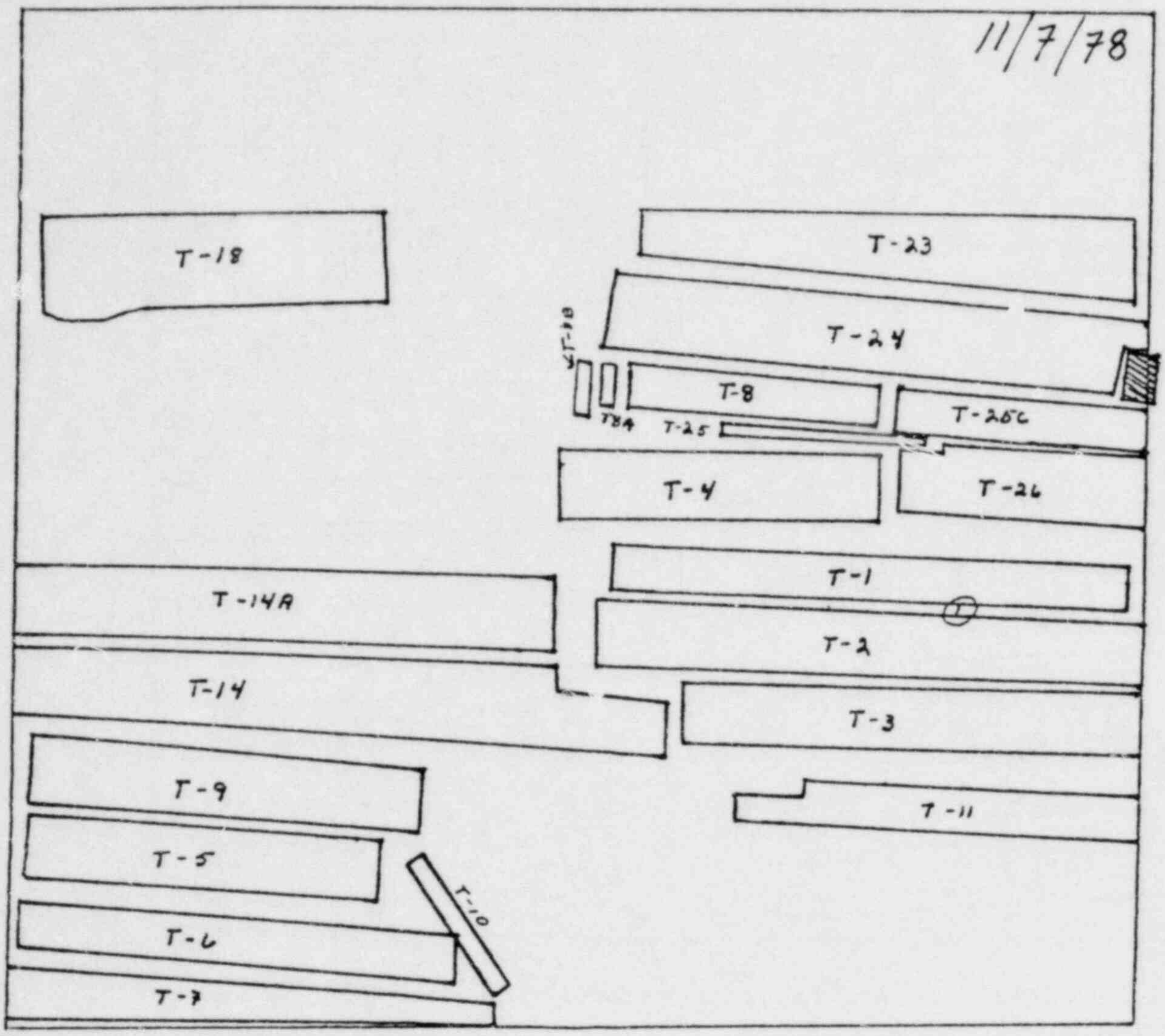
⑦ 11/3/78 Completed capping T-11

⑤ hole filled 11/1/78

Items 2, 3, 4 minor will be repaired in spring when they can be reseeded.

11/7/78

MONTHLY TRENCH INSPECTION



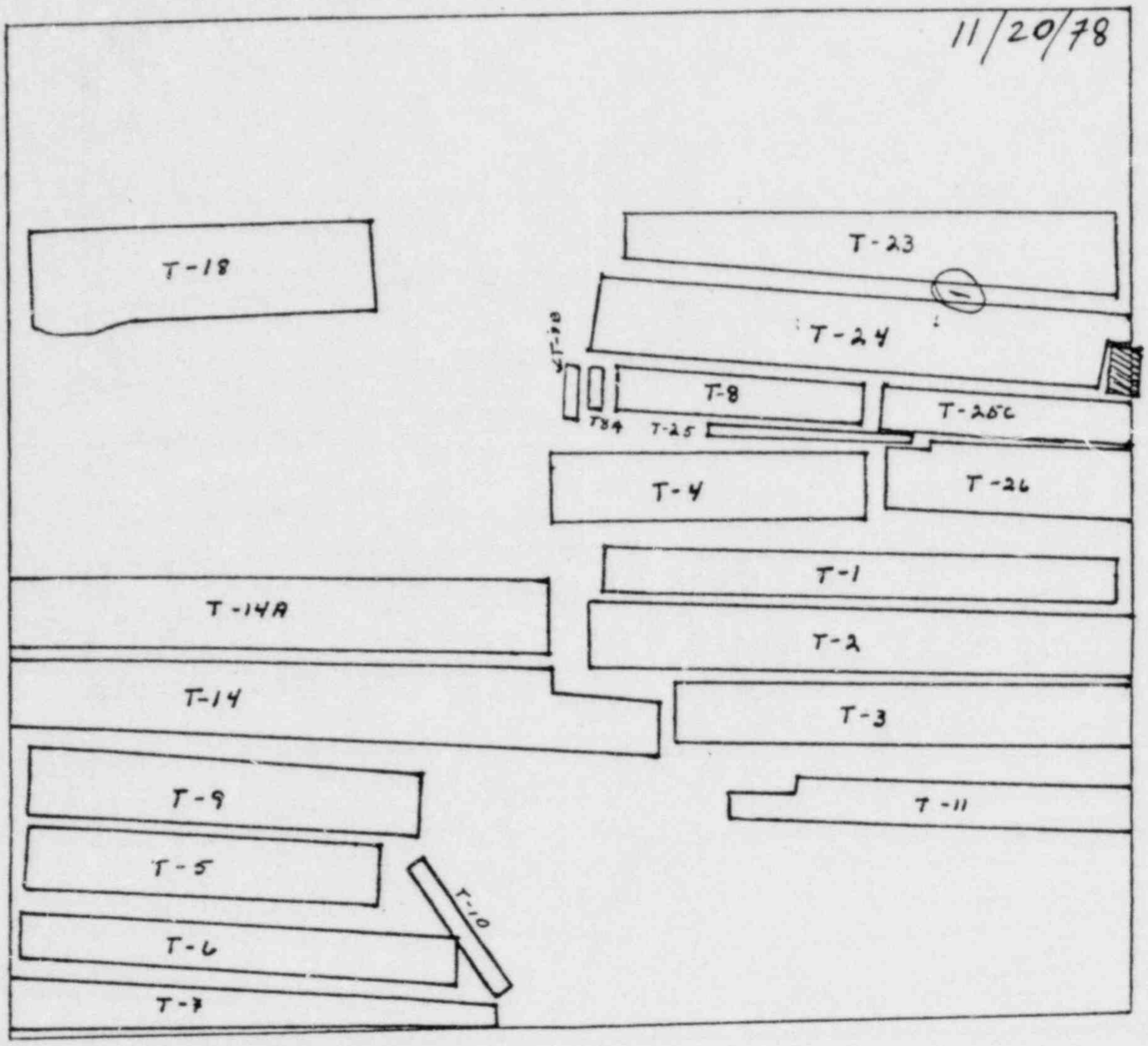
1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① USGS while drilling a well drilled into a drum of hospital or lab waste
Hole ≈ 4" wide 10' deep
filled with cement & bentonite

AJA

11/20/78

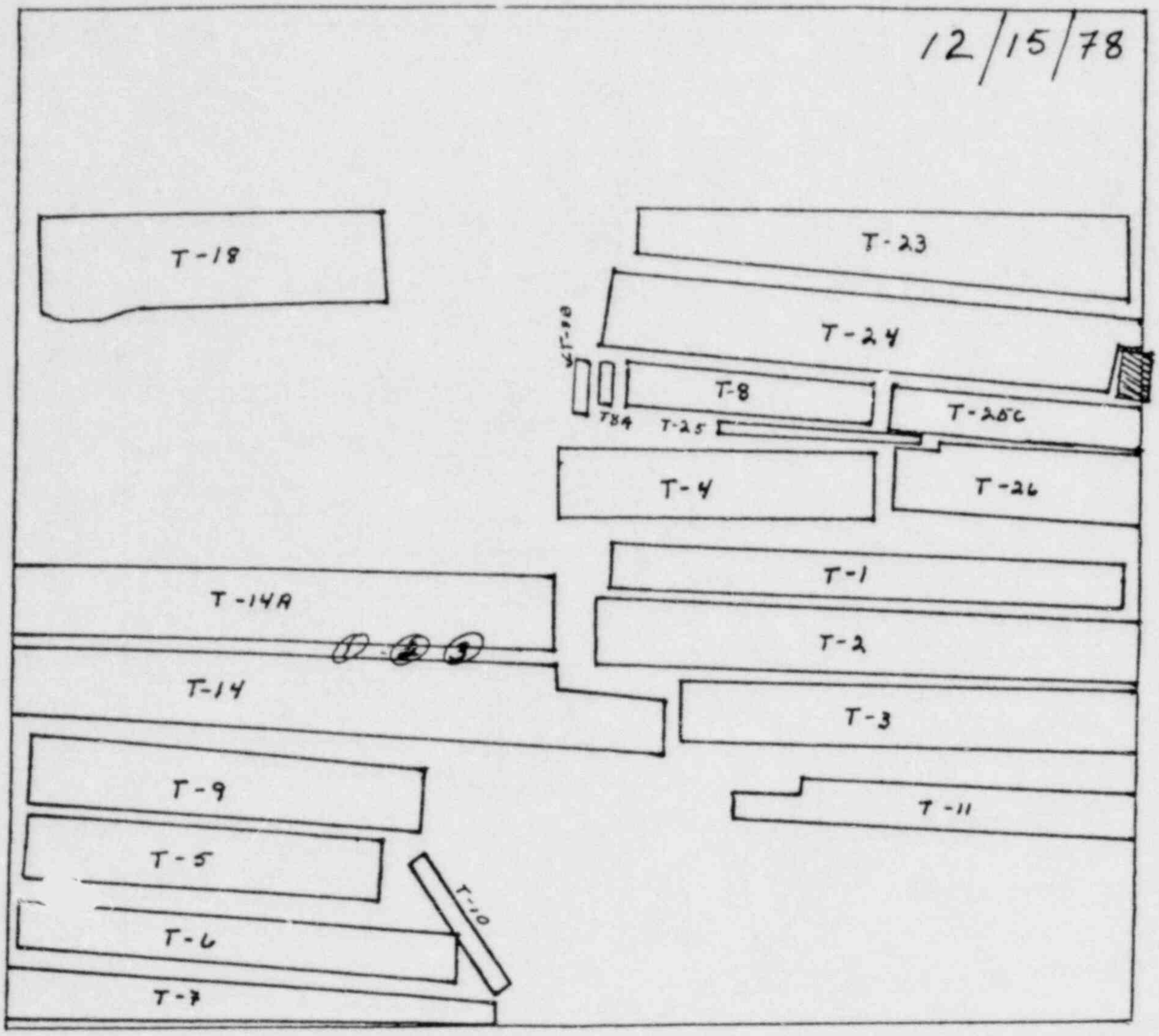
MONTHLY TRENCH INSPECTION



1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① Hole 3' diameter ~ 6' deep caused by heavy rains
hole filled 11/20/78

MONTHLY TRENCH INSPECTION 12/15/78

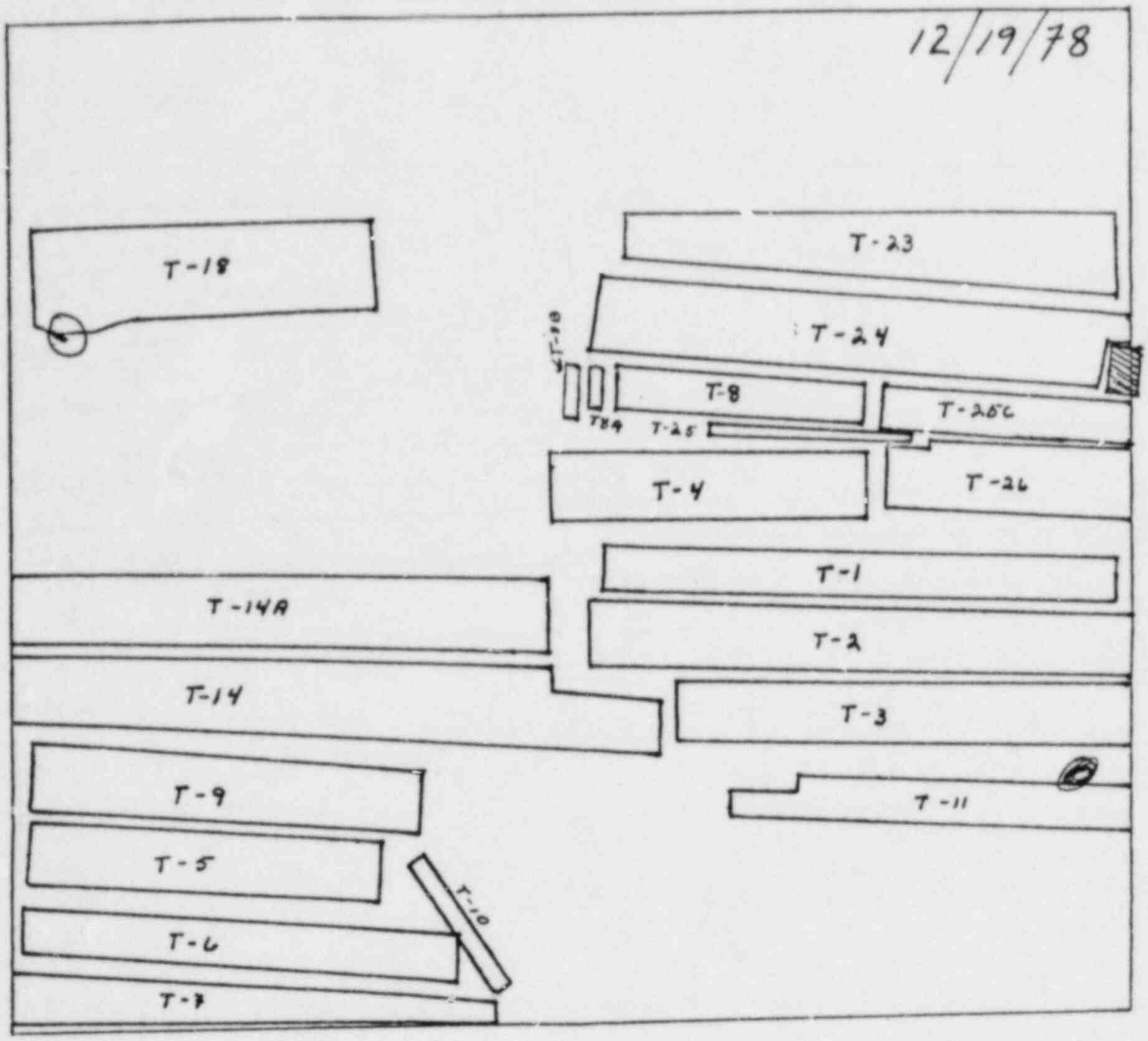

12/15/78

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① ② ③ holes 3' diameter 4' deep caused by settling filled 12/15/78

12/19/78

MONTHLY TRENCH INSPECTION

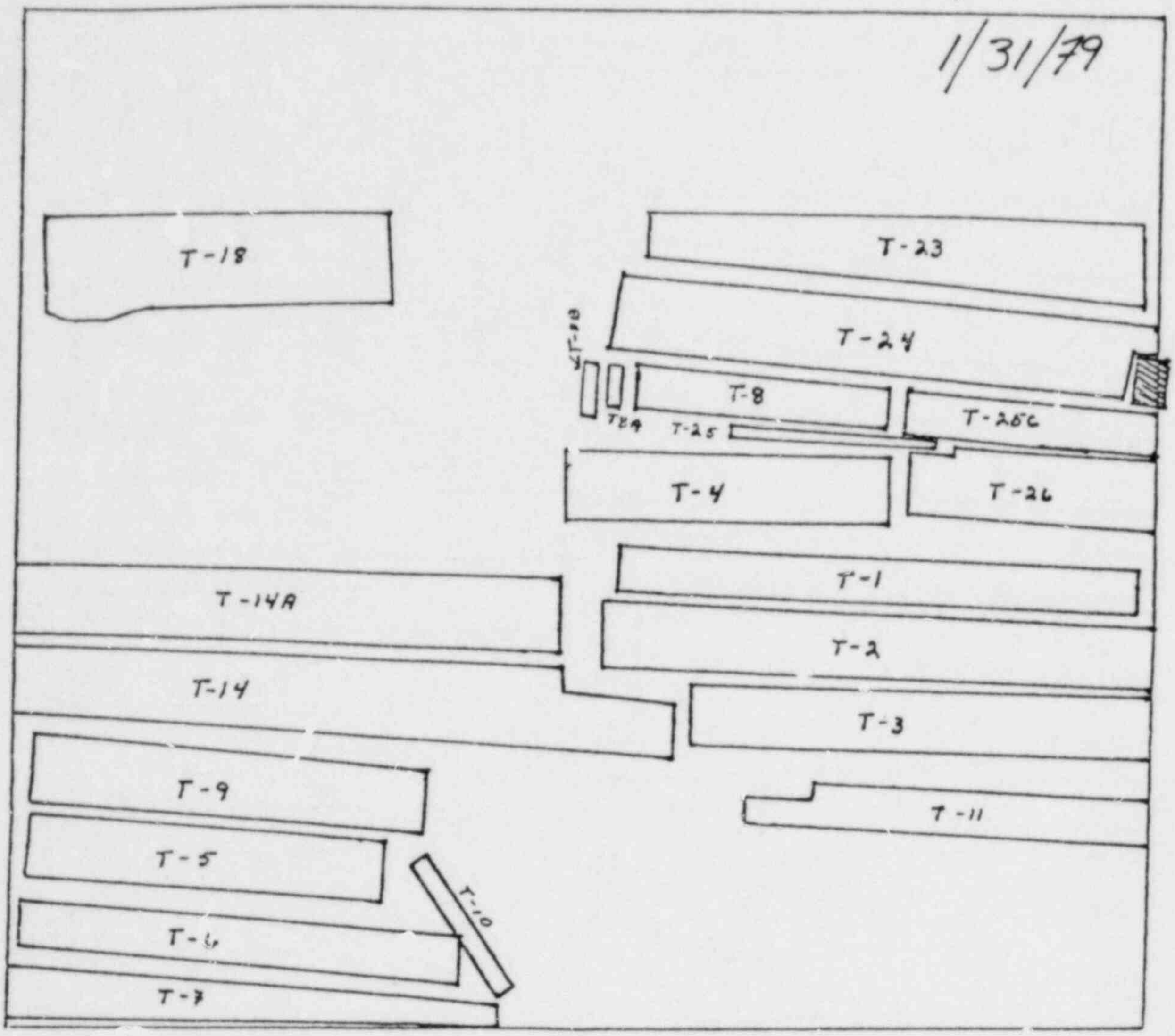


12/19/78

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① hole 2' diameter 4' deep. settling
filled 12/19/78

MONTHLY TRENCH INSPECTION 1/31/79

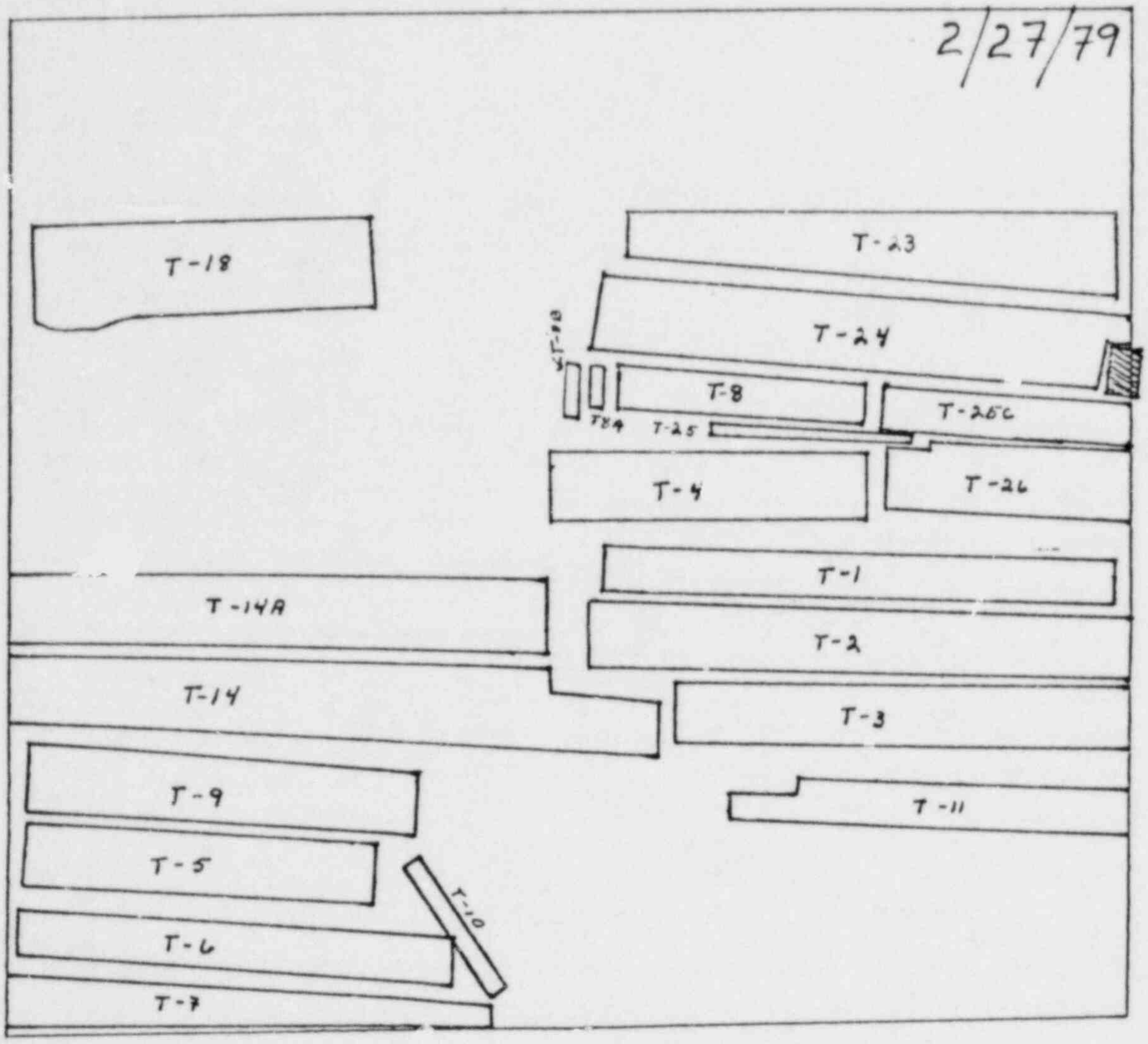


1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

Trenches covered with ~ 3' of snow

2/27/79

MONTHLY TRENCH INSPECTION

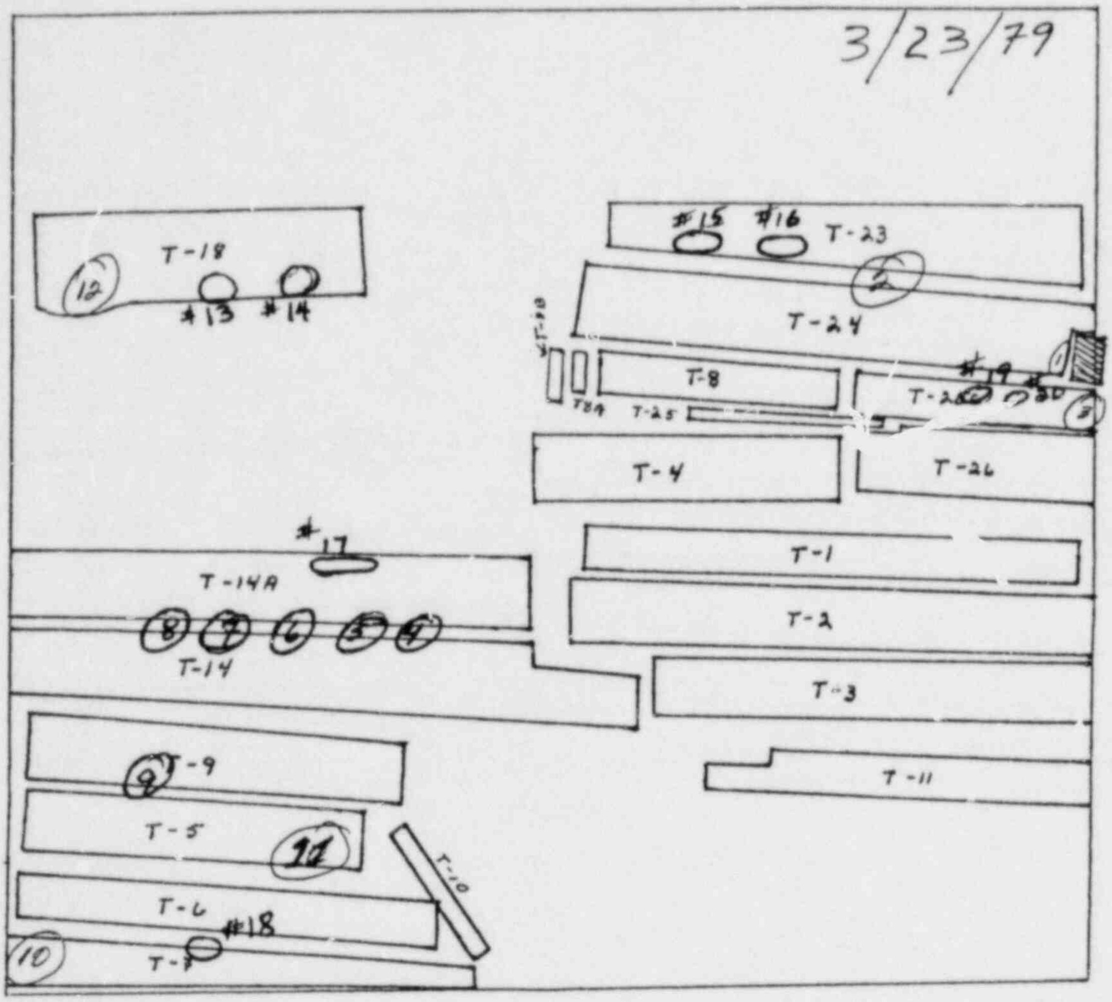


1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

Trenches all covered with snow.
Found no indications of holes.

3/23/77

MONTHLY TRENCH INSPECTION


3/23/79

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① hole 10' diameter 4' deep — filled 3-23-79
② hole 20' diameter 6' deep — filled 3-23-79
③ hole 4' diameter 5' deep — filled 3-23-79
④ hole 4' diameter 3' deep
⑤ hole 4' diameter 3' deep
⑥ hole 8' diameter 6' deep
⑦ hole 10' diameter 6' deep exposed waste
⑧ hole 10' diameter 5' deep
all filled 3-23-79
⑨ hole 3' diameter 2' deep — filled 3-23-79
⑩ hole 15' diameter 10' deep exposed waste filled 3-23-79

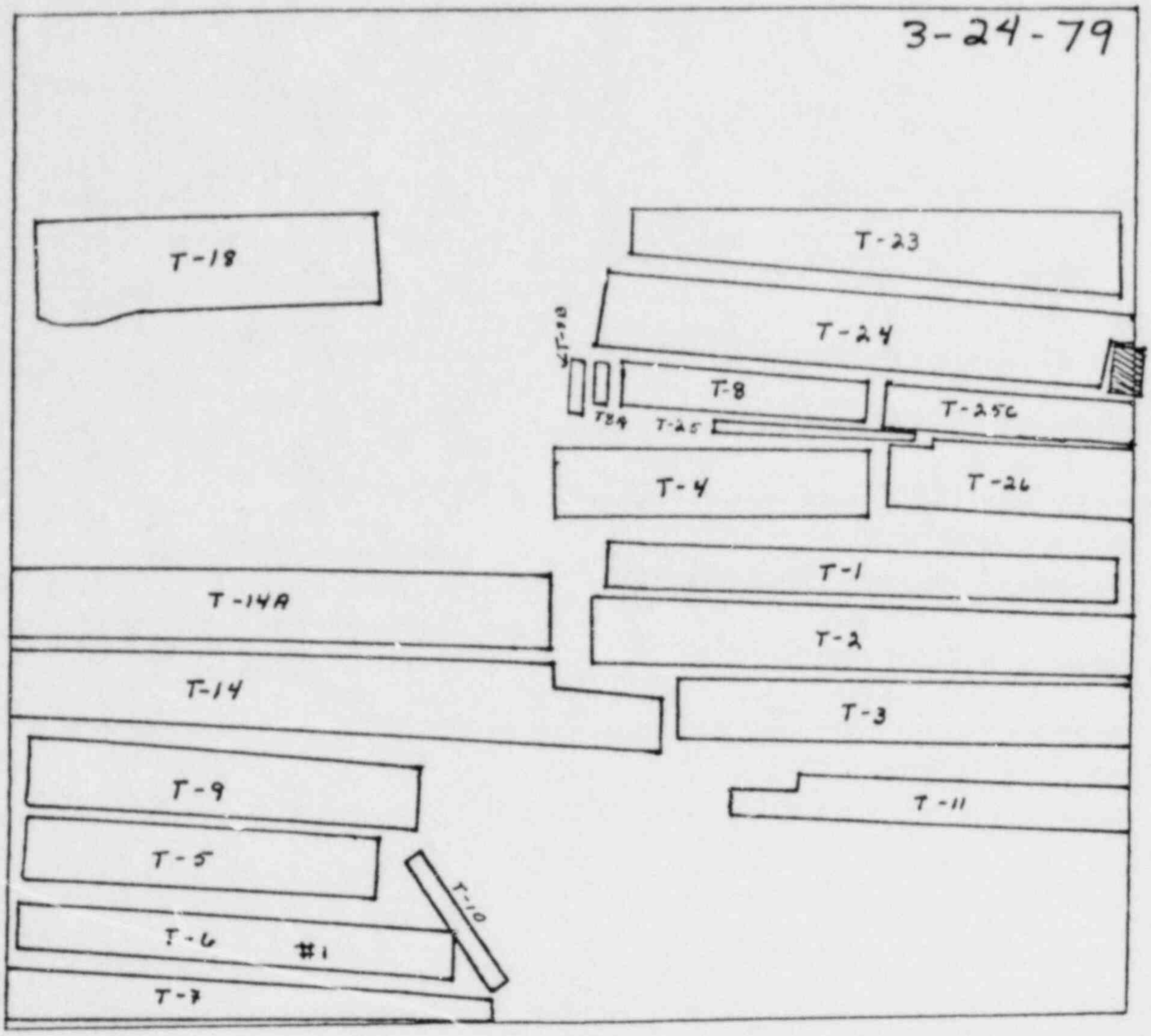
(OVER) Note - see attachment

| | | | | | | |
|---|---|---|---|---|---|---|
| ⑪ | hole | 3' diameter | 2' deep | — | filled | 3-23-79 |
| ⑫ | hole | 3' diameter | 4' deep | — | filled | 3-23-79 |
| #13 | hole | 10' diameter | 2' deep | — | filled | 3-23-79 |
| 14 | hole | 4' diameter | 1' deep | — | filled | 3-23-79 |
| 15 | hole | 4' diameter | 1½' deep | — | filled | 3-23-79 |
| 16 | hole | 5' diameter | 1' deep | — | filled | 3-23-79 |
| 17 | hole | 6' long 1 foot wide | 6" deep | — | filled | 3-23-79 |
| 18 | hole | 3' diameter | 1 ft deep | — | filled | 3-23-79 |
| 19 | hole | 1' diameter | 1 ft deep | — | filled | 3-23-79 |
| 20 | hole | 1' diameter | 1 ft deep | — | filled | 3-23-79 |

Rtm

3-24-79

MONTHLY TRENCH INSPECTION



3-24-79

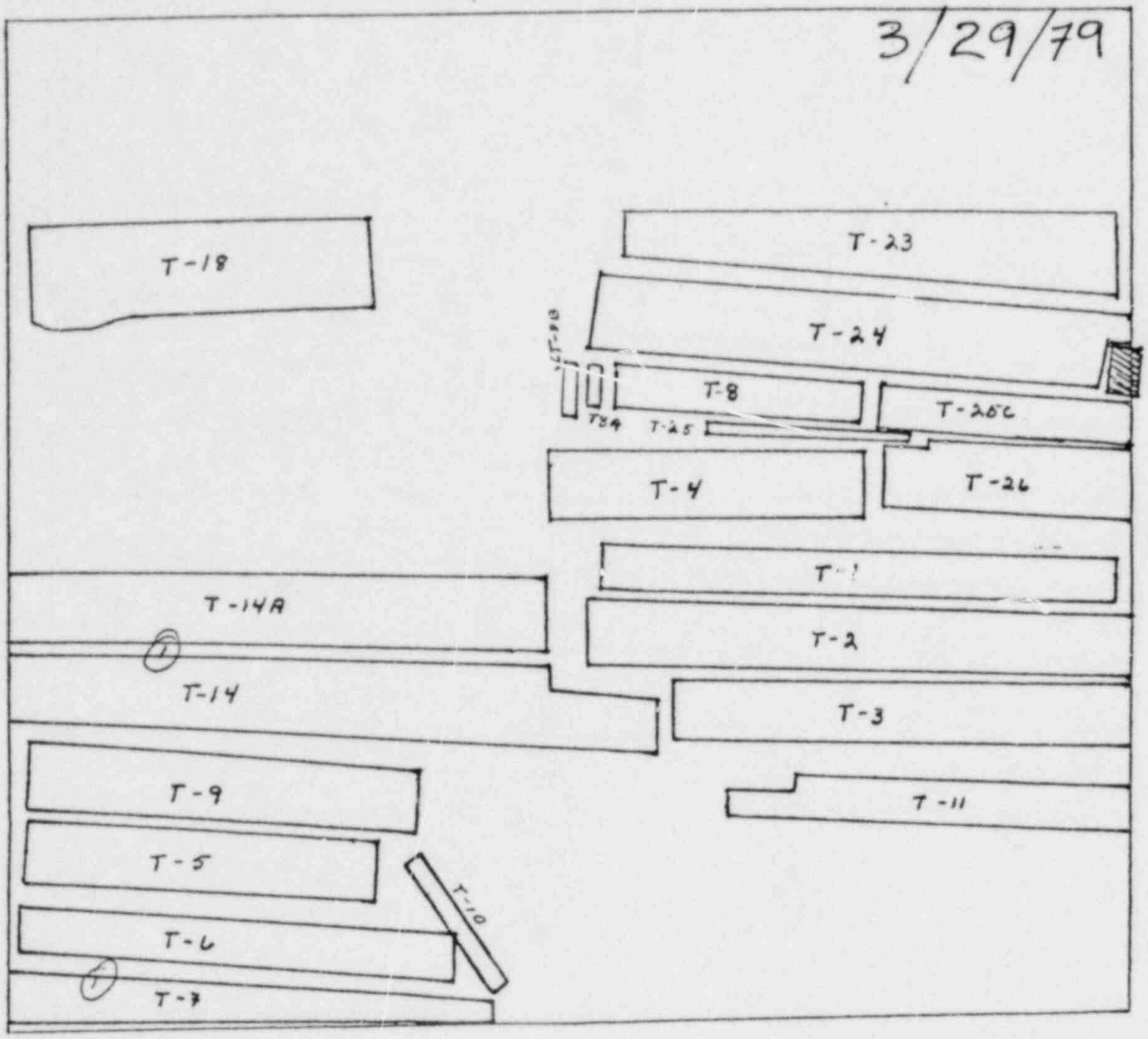
1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

#1 Hole 2' Diameter 6 to 12" deep - filled Depression 3-24-79 KPM

inspected all 20 acres - OK 3-24-79 KPM

3/29/79 T7

MONTHLY TRENCH INSPECTION



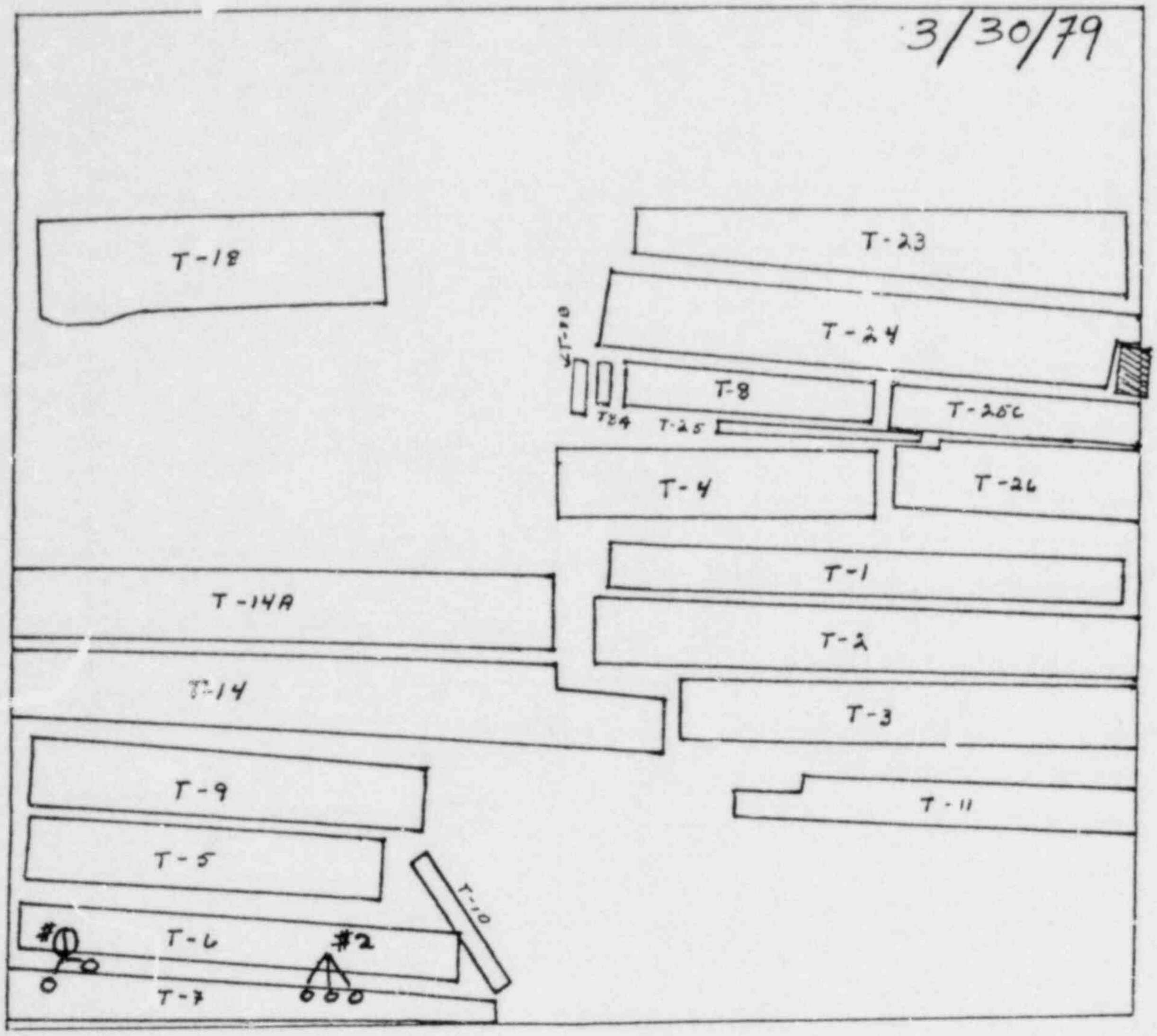
1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of hole .

① hole 2' diameter 4' deep } found & filled within the same hour.
② hole 1' diameter 2' deep }

AJA

MONTHLY TRENCH INSPECTION 3-30-79

3/30/79



1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

#1 refilled two small areas approximately (2'x6" each day)
which earlier in the day were OK.

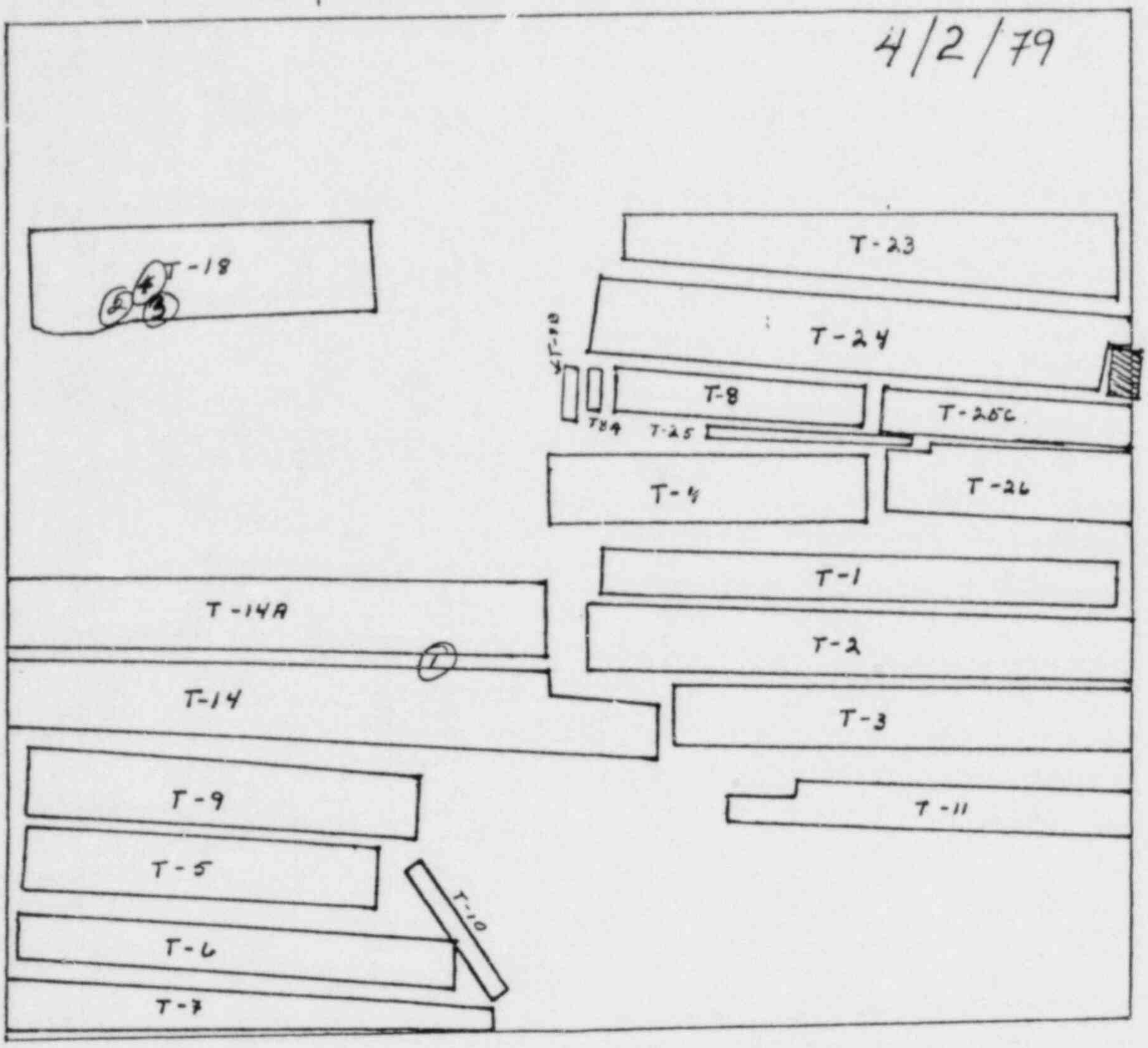
#2 3 small holes were filled that appeared during the
day (1' to 2' by 6" ~~deep~~

note- heavy rains during the day

RPM

4/3/79

MONTHLY TRENCH INSPECTION


4/2/79

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

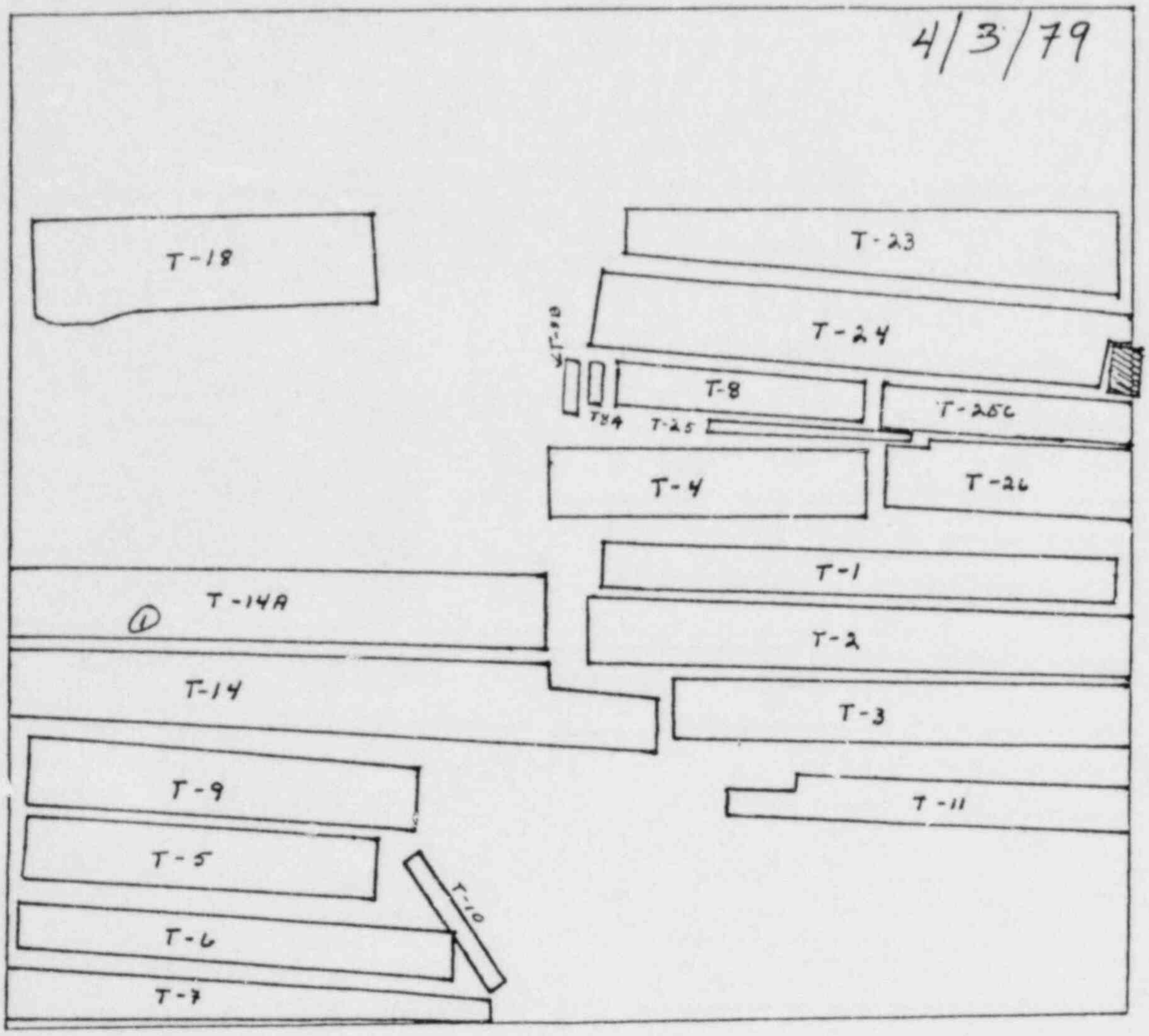
① Filled hole 1' diameter 3' deep

② Filled hole 2' diameter 3' deep
③ Filled hole 1' diameter 1' deep
4 Filled hole 3' diameter 2' deep

## MONTHLY TRENCH INSPECTION

4/3/79

4/3/79

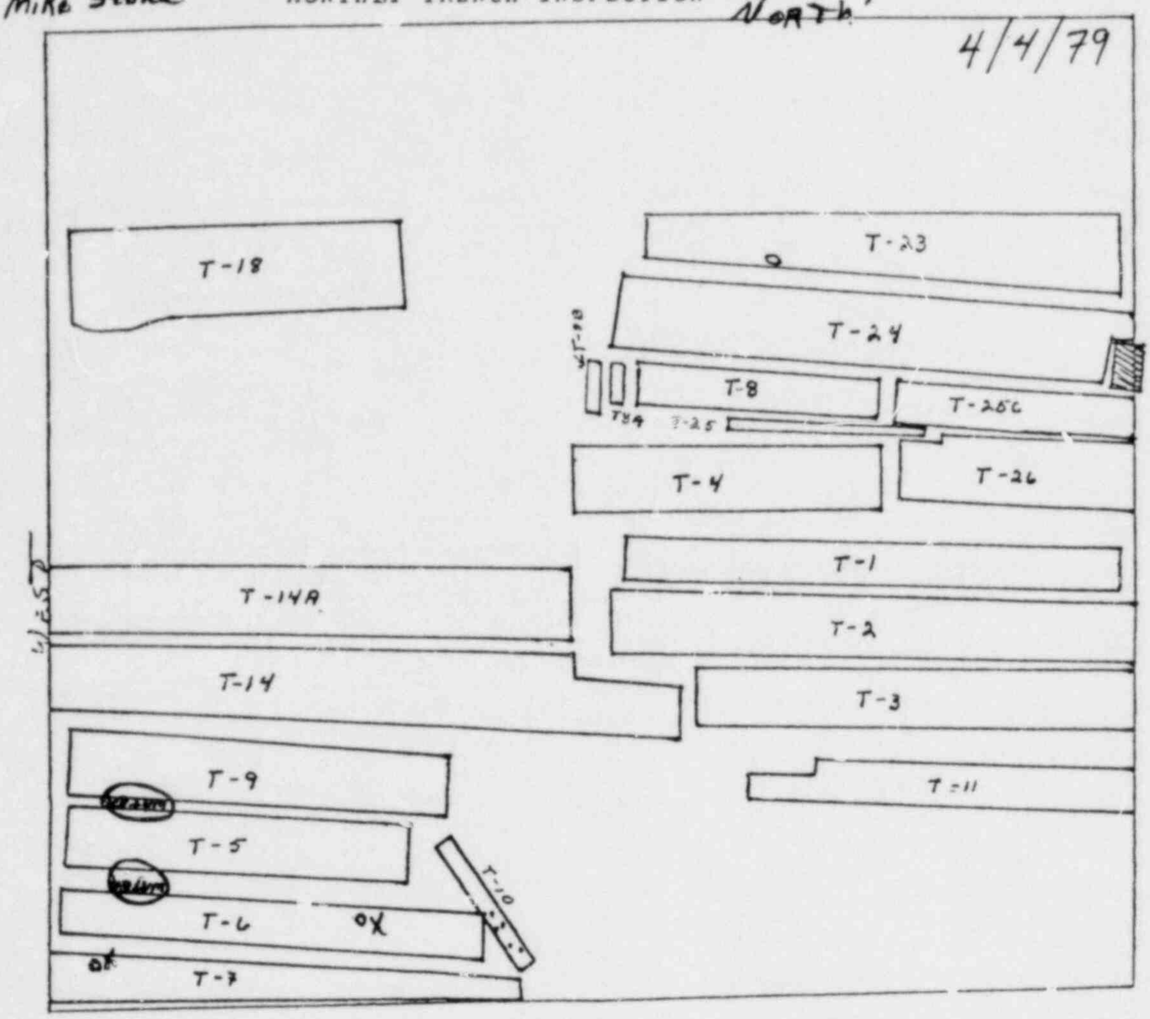


1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① Filled hole 2' diameter 4' deep

4/4/79

Mike Stone MONTHLY TRENCH INSPECTION



1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

T-10 : 3'x2' ⑤
T-7 : 3'x2' ①
T-6 : 5'x2' ①
→T-5 : OK Except for pockets of water between T5 + T6
Also between T5 + T9 on west end.

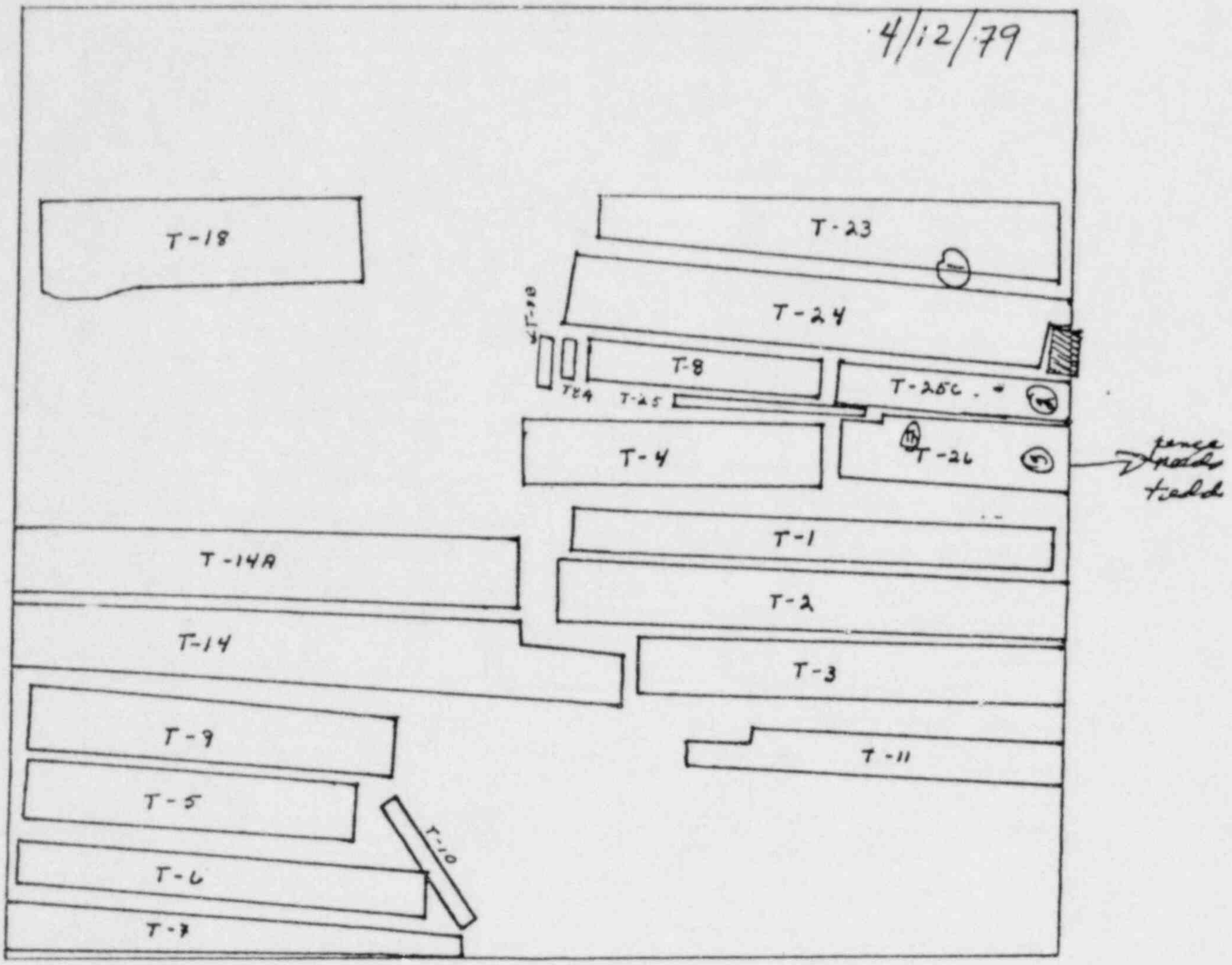
T-9 : OK
T-14 : OK
T-14A : OK
T-18 = OK
T-8B : OK
T-8A : OK
T-23 : 3'x2' ①
T-24 : OK
T-25 : OK
T-25C - OK

T-8 : OK
T-1 : OK
T-2 : OK
T-3 : OK
T-11 = OK
T-4 = OK
T-26 = OK

Filled 4/4/79

4/12/79

## MONTHLY TRENCH INSPECTION



1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① T-23 depression ~6" deep 10' diameter

② T-25C depression ~ 1' deep 2' diameter

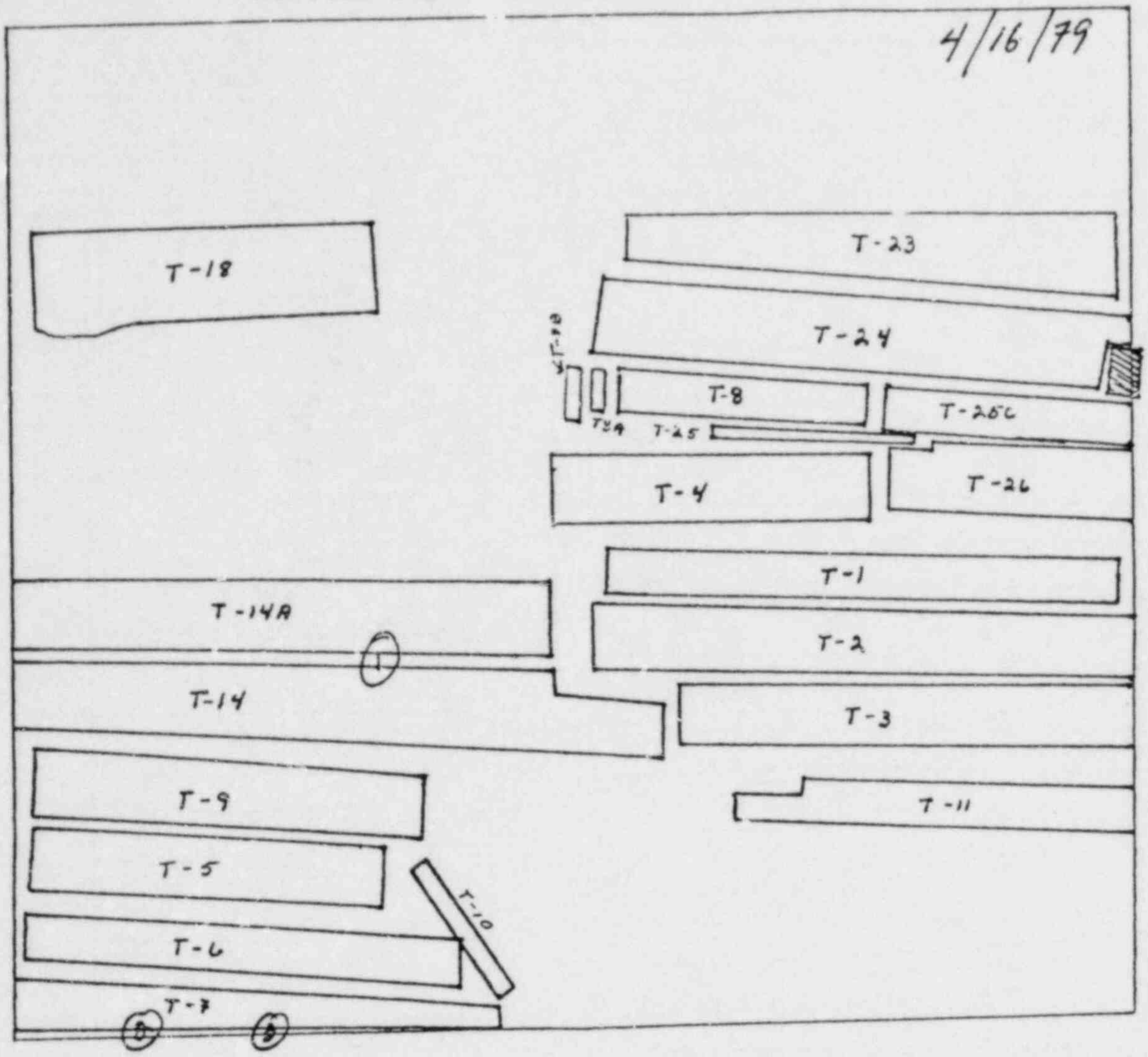
③ T-26 Hole ~ 1' deep. 2' diameter
Fence behind pol: steel needs tied down

④ T-26 Hole ~ 1' diameter 2' deep

All holes filled same day. Got end Loader stuck filling T-23 had to pull out with TD-15.

4/16/79

MONTHLY TRENCH INSPECTION



4/16/79

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

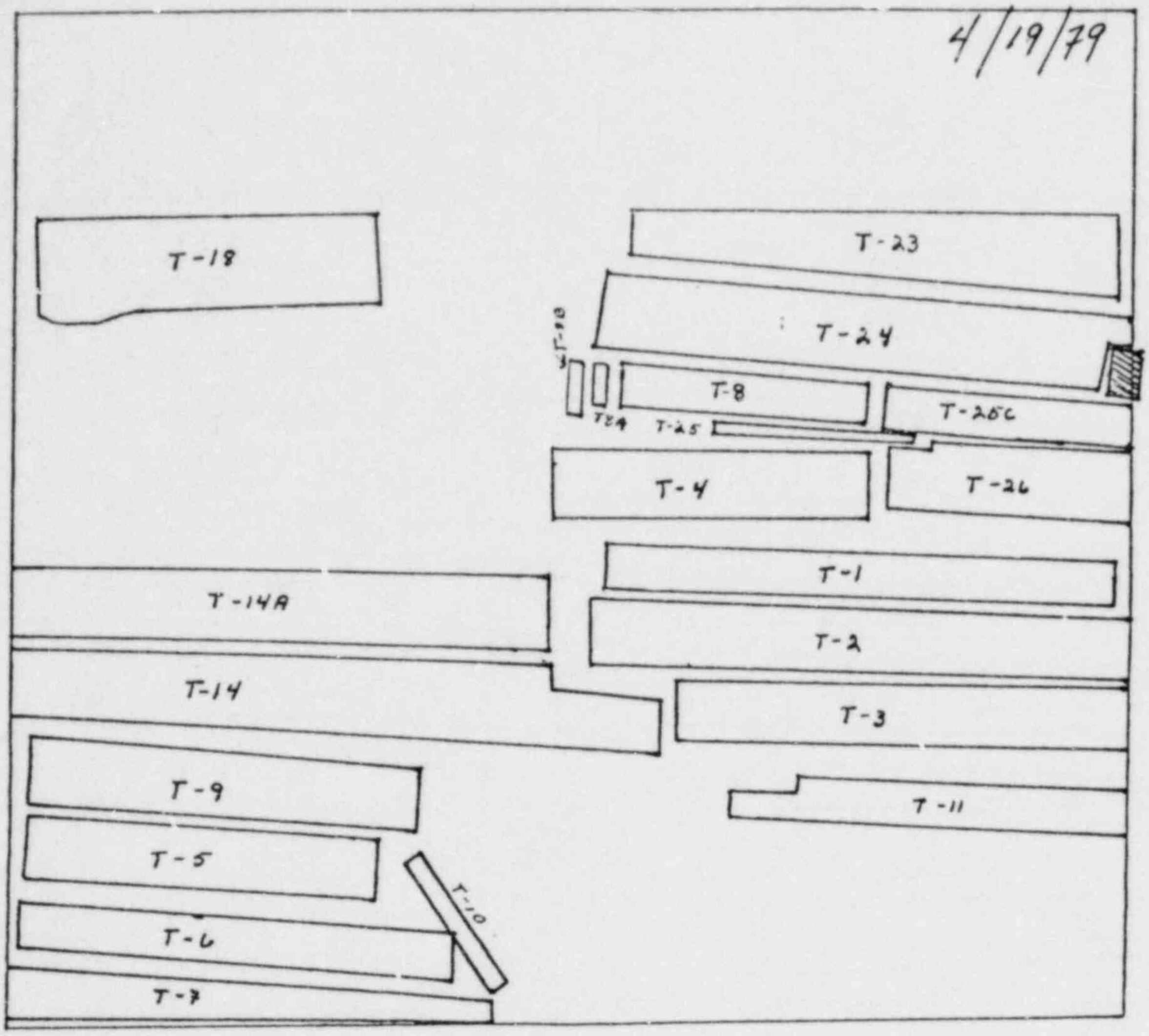
① depression 3' diameter 1' deep
② hole 2' diameter 5' deep
③ hole 3' deameter 3' deep

} found & filled same da.

staked down the fence behind pole shed & south fence about midway

4/19/79

## MONTHLY TRENCH INSPECTION

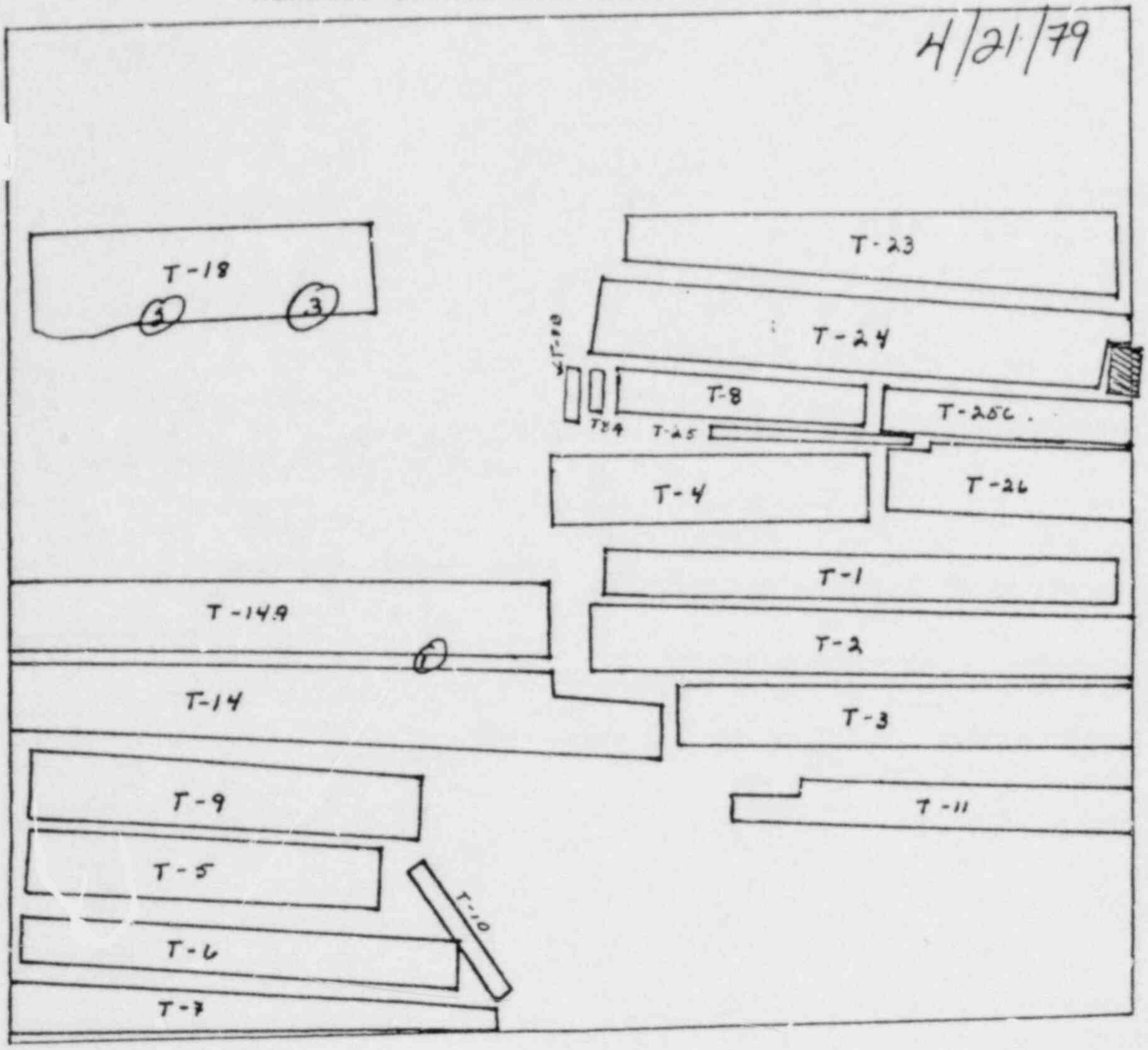

4/19/79

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

Walked trenches found no holes

4/21/79

## MONTHLY TRENCH INSPECTION



1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

(1) depression 3' diameter 1' deep

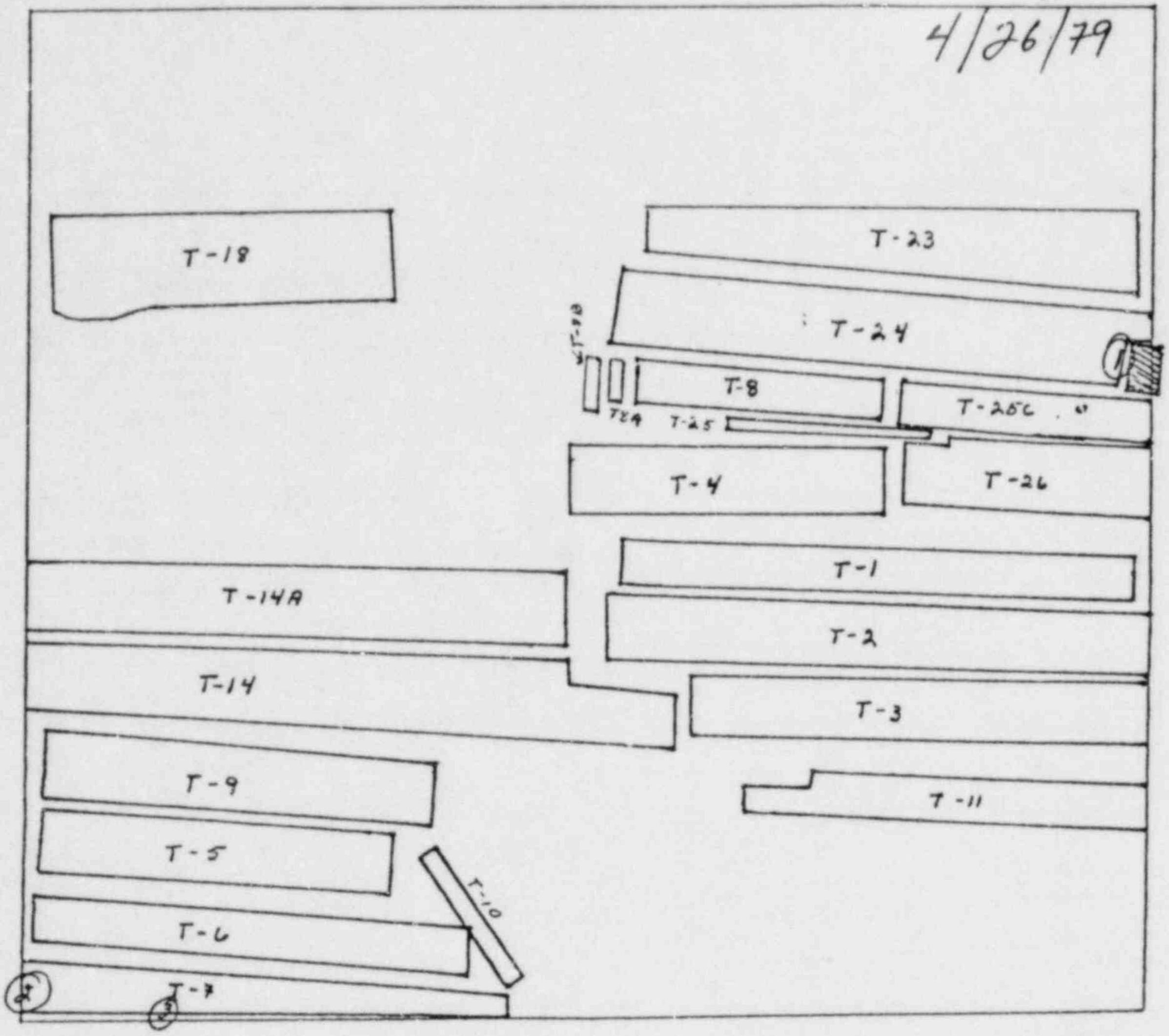
(2) hole 1' diameter 4' deep

(3) depression 4' diameter 1' deep

Filled the ~~one~~ day

4/26/79

## MONTHLY TRENCH INSPECTION


4/26/79

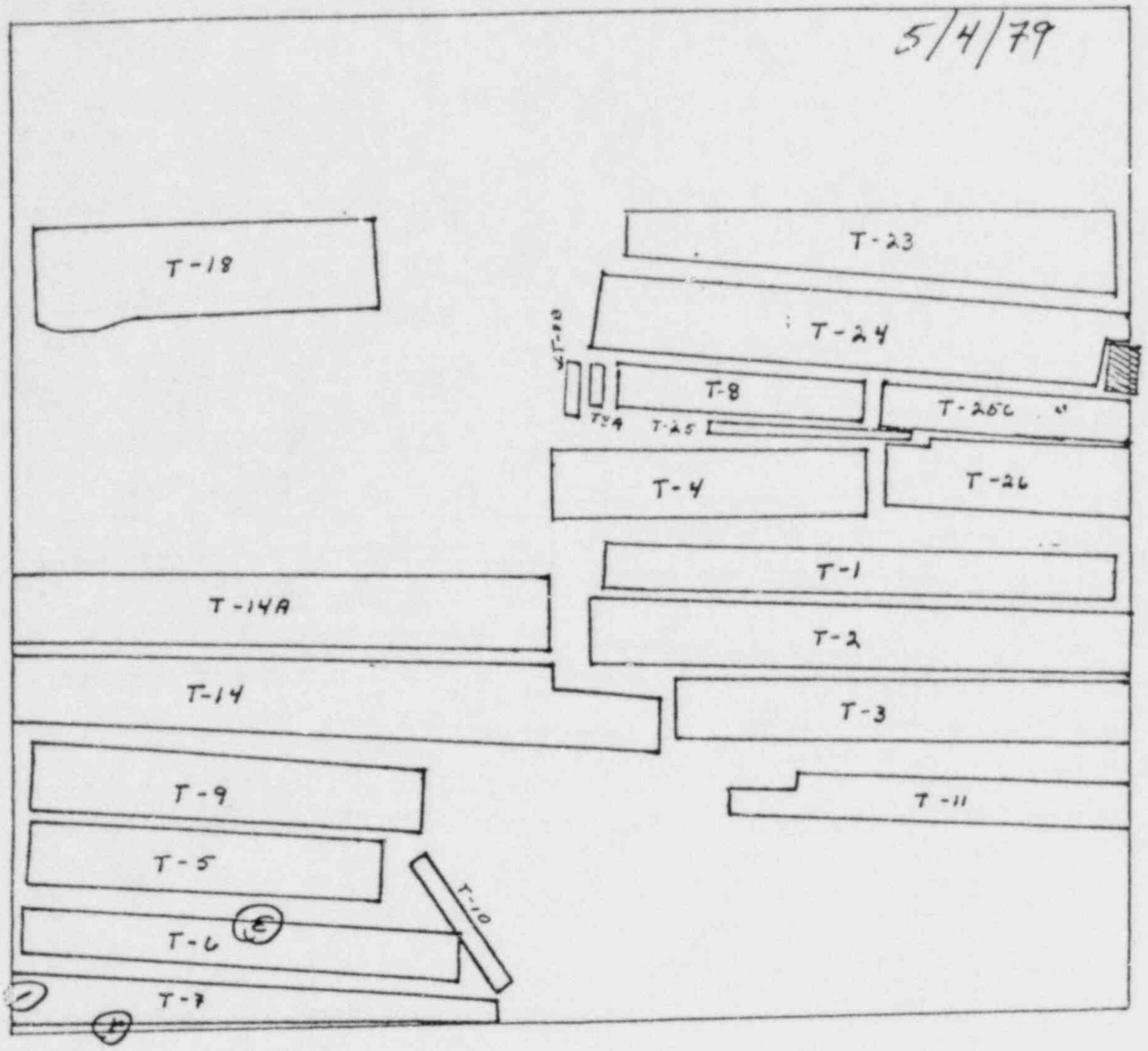
1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① Hole 20' diameter x 5' deep exposed waste
② Hole 5' diameter x 10' deep exposed waste
③ Hole 1' diameter x 10' deep

filled same day after 1 7/10" rainfall

5/14/79

MONTHLY TRENCH INSPECTION



5/4/79

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

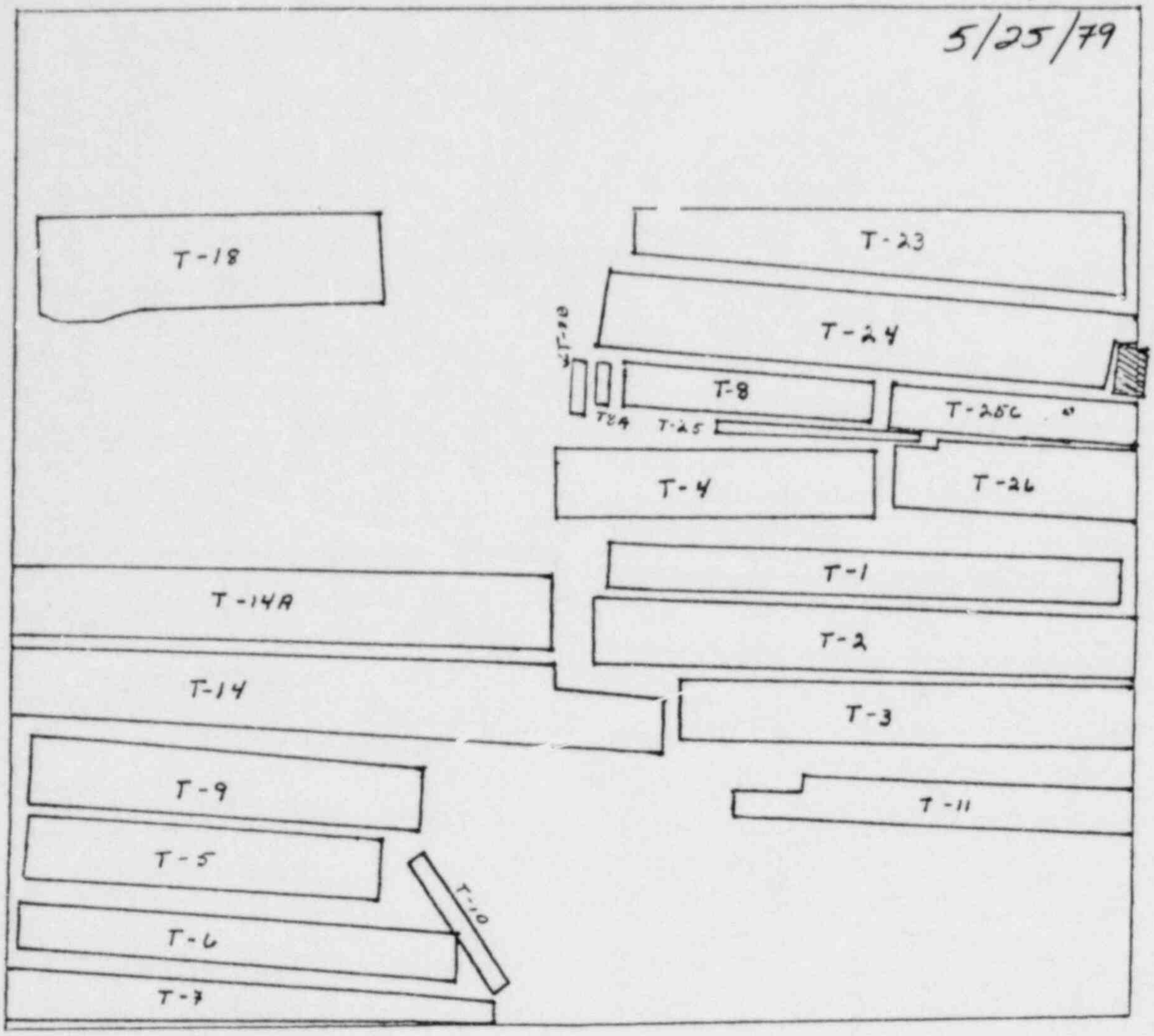
① Depression 1' deep 5' diameter
② Hole 2' diameter 4' deep
③ Depression 3' diameter 1' deep

filled same day

AJA

# MONTHLY TRENCH INSPECTION

5/25/79

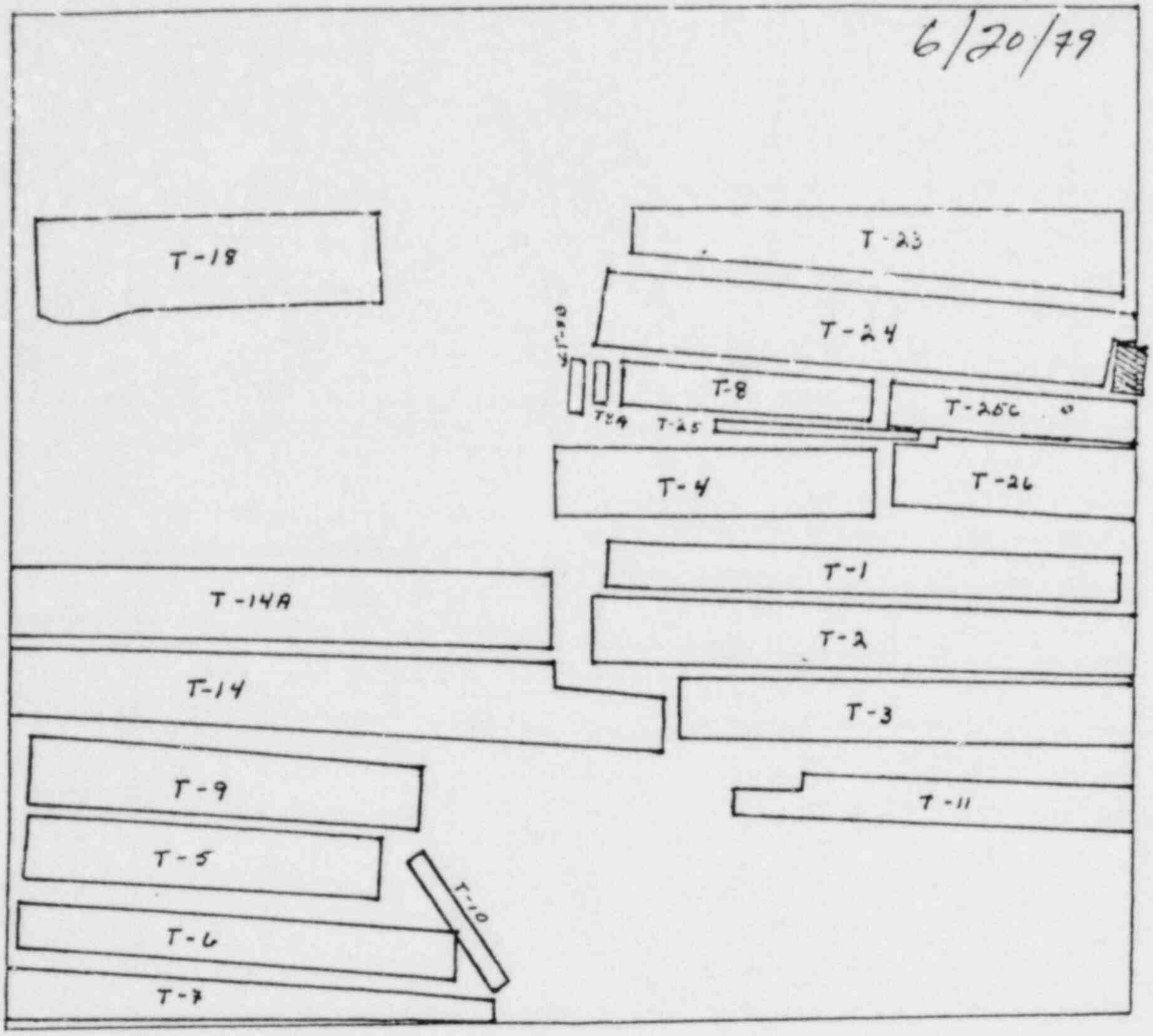


1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

Walked Trench tops found no holes

6/20/79

MONTHLY TRENCH INSPECTION



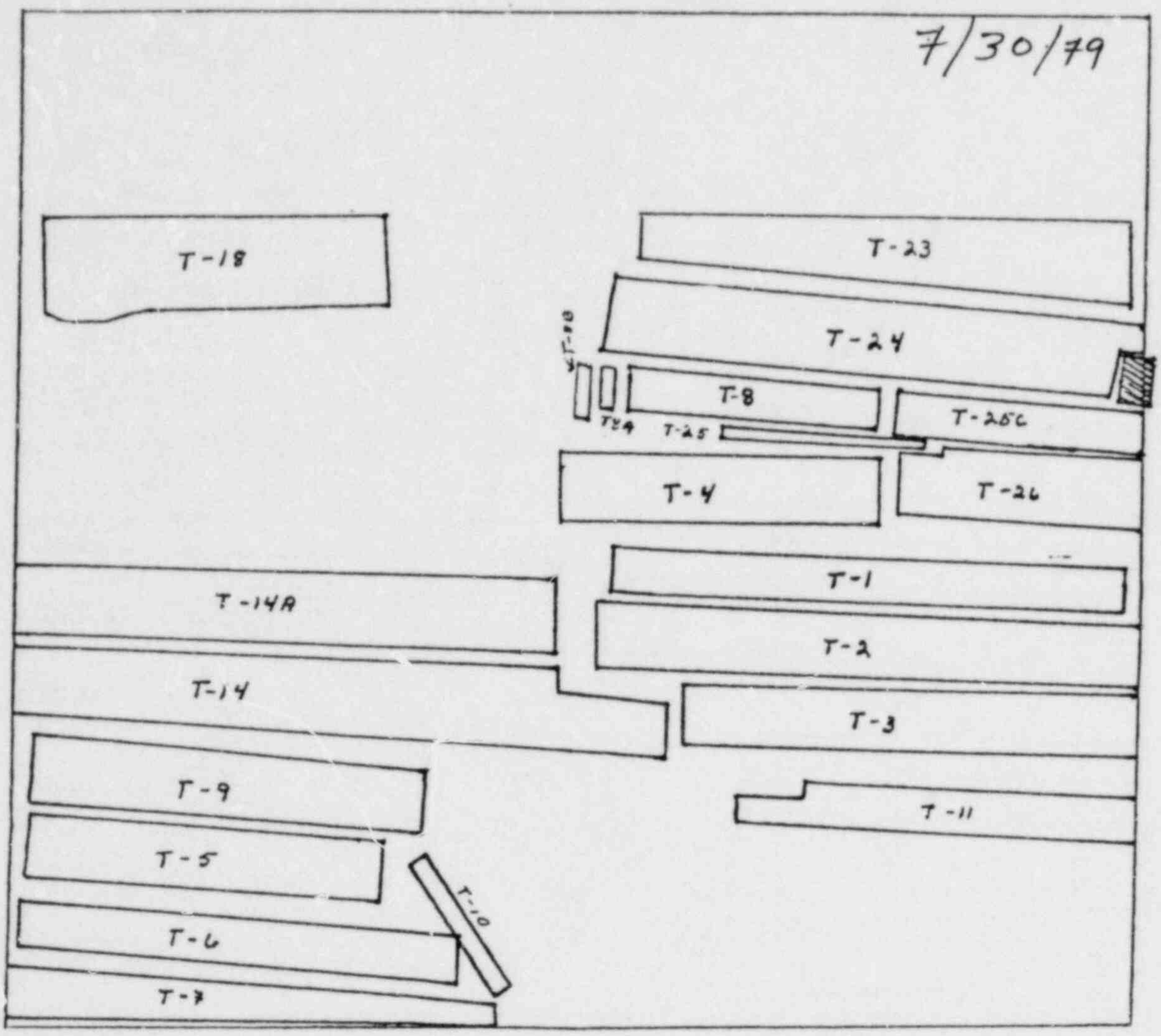
6/20/79

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

Walked all trench tops found no hole

7/30/79

# MONTHLY TRENCH INSPECTION

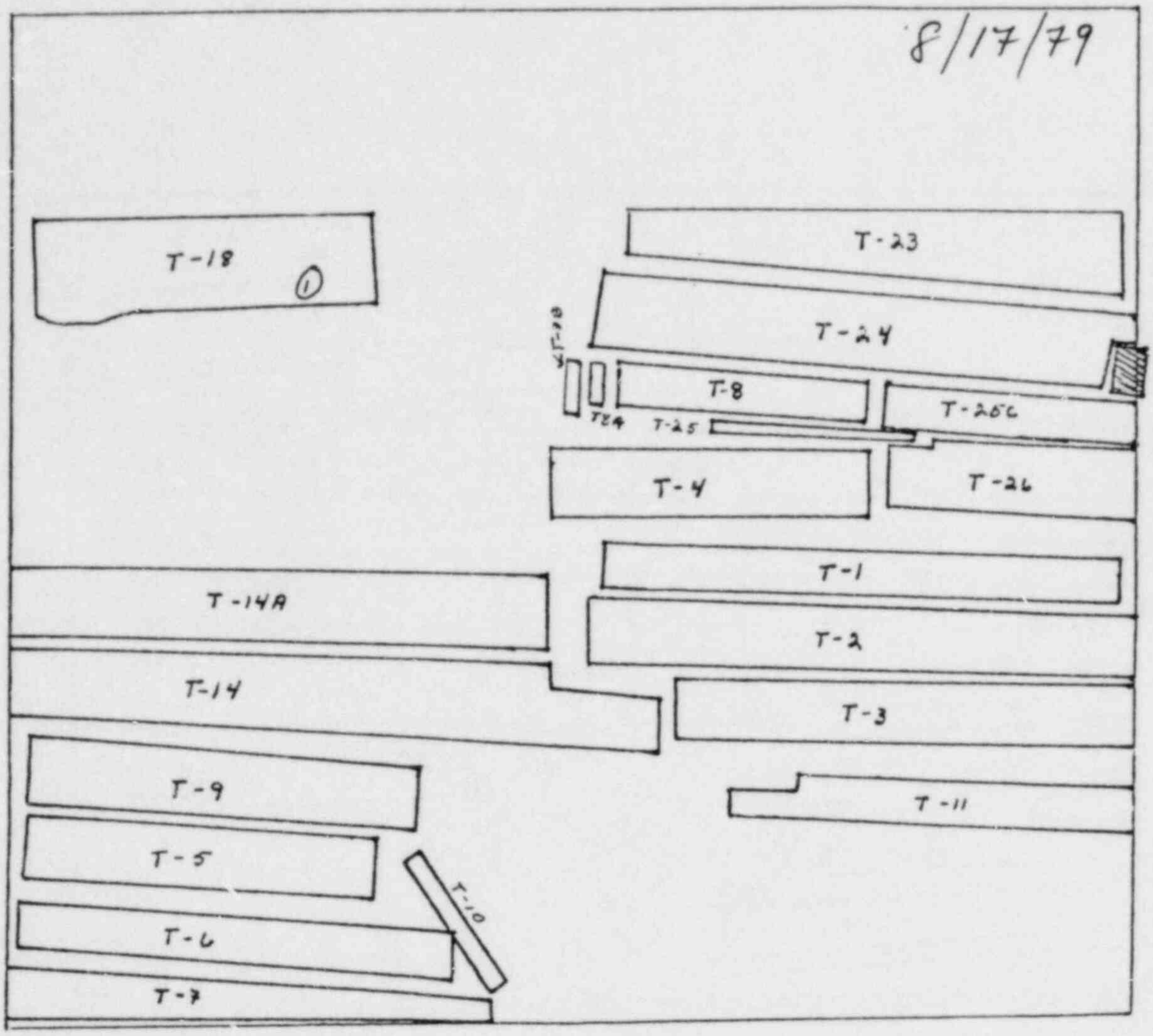


1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

Walked all trenches found no holes.
Fence intact

8/17/7>

MONTHLY TRENCH INSPECTION



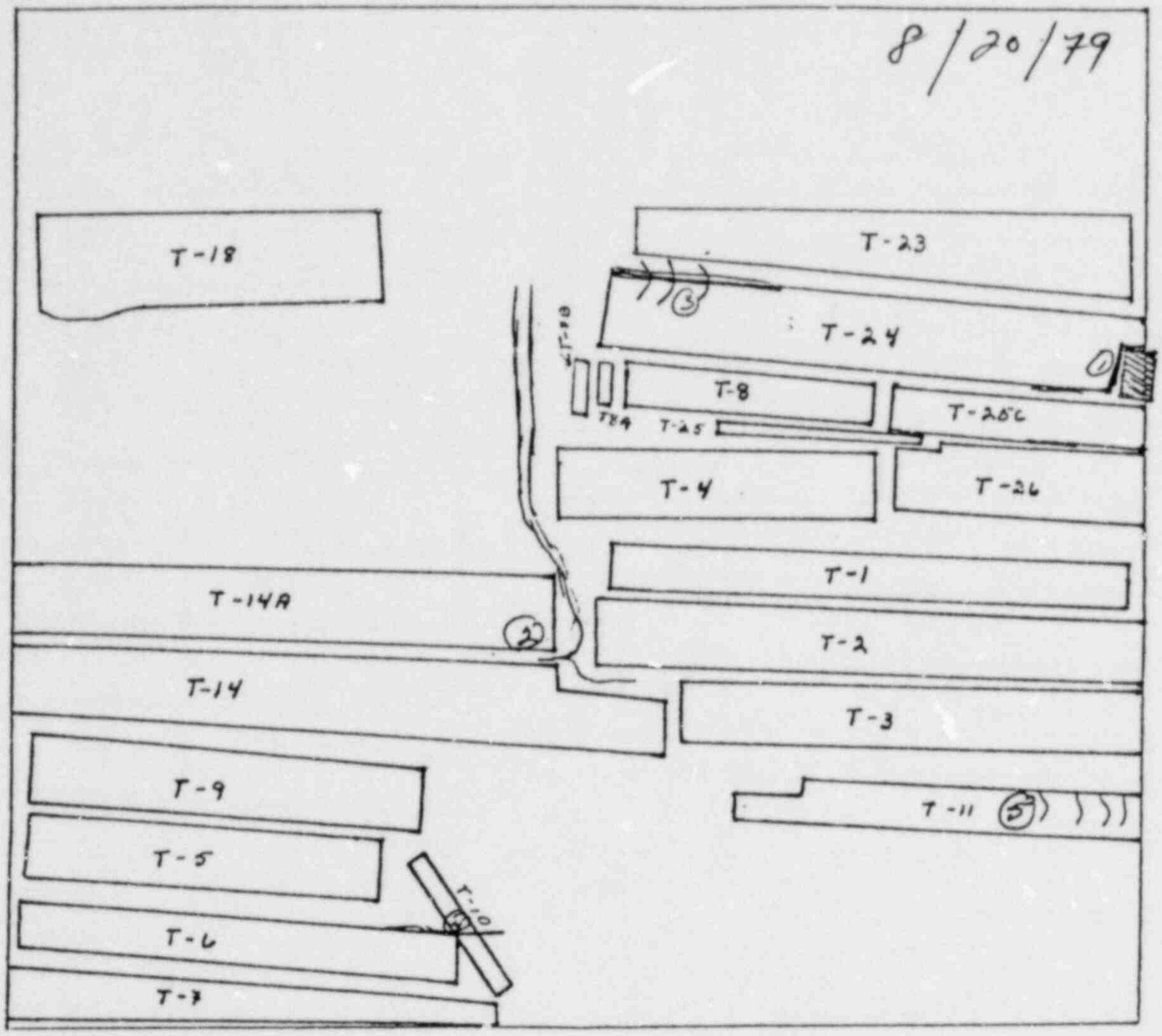
8/17/79

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① 1 hole 1' diameter ≈ 2' deep settling around side sump. hole filled same day as found

8/20/79

## MONTHLY TRENCH INSPECTION


8/20/79

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① Erosion 3' wide ~ 3' deep

② Erosion 3' deep by 14A

③ Erosion various sizes

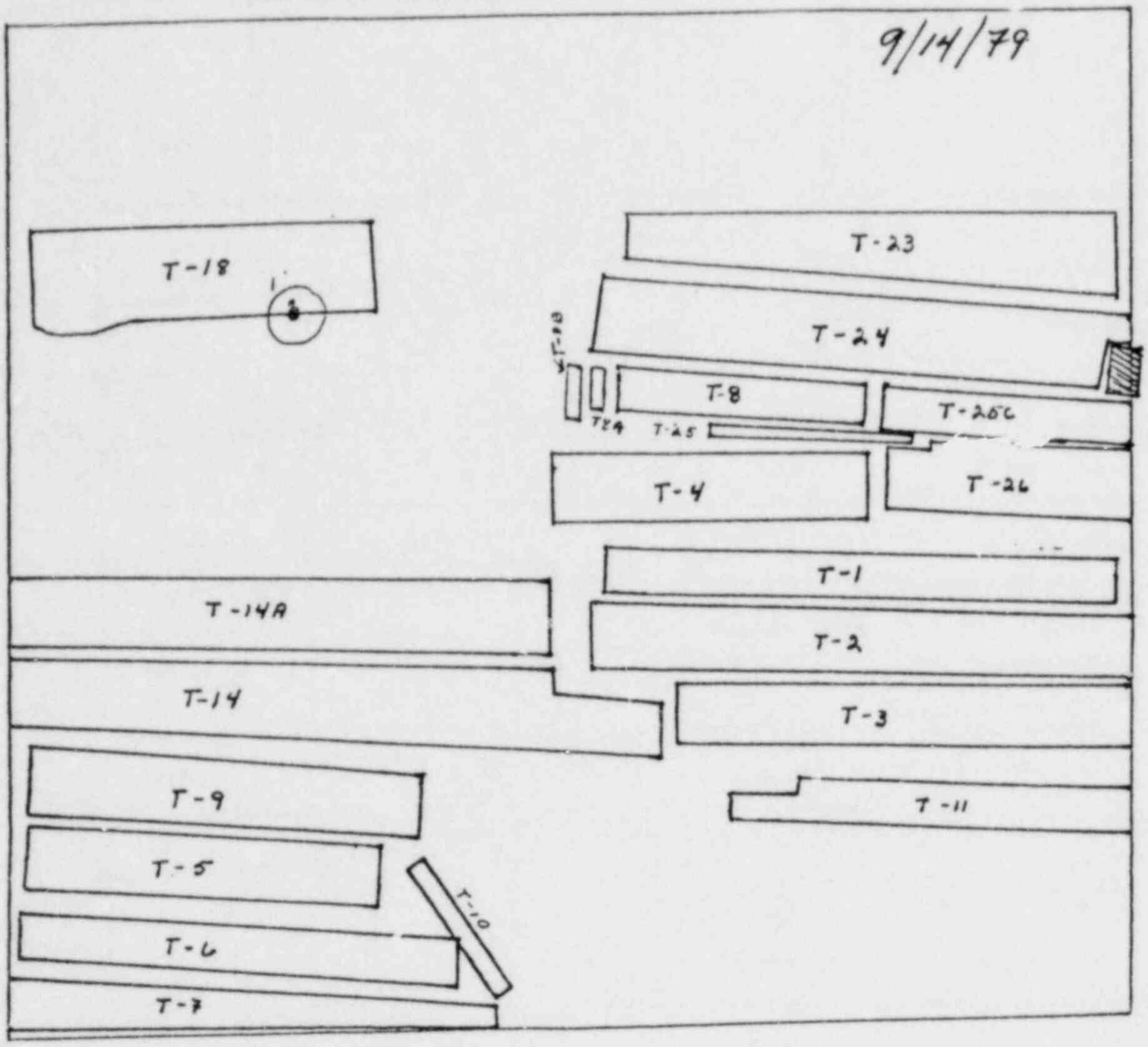
④ Erosion 3' deep

⑥ Erosion 2' deep

After 9" of rain in one weekend.

7/14/79

# MONTHLY TRENCH INSPECTION

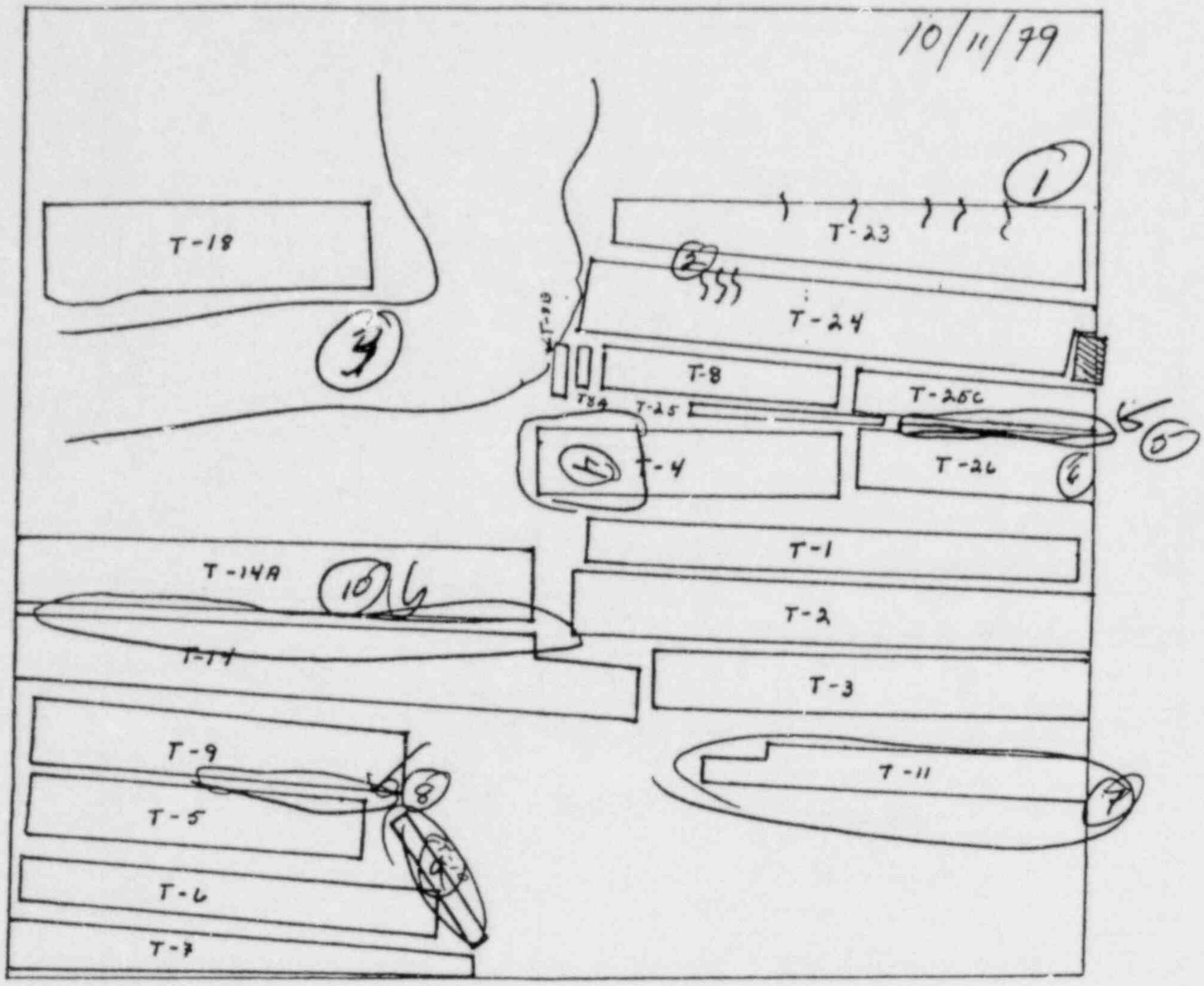

9/14/79

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① Depression 6' diameter 3' deep
filled same day.

10/11/79

# MONTHLY TRENCH INSPECTION


10/11/79

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① Filled erosion on N side of T-23

② Filled erosion on N side of T-24

③ Graded drainage areas filled erosion

④ Graded erosion old Lagoon area

⑤ Repaired drainage path between T-26 & T-24

⑥ Filled depression end of T-26.

⑦ Graded erosion T-11.

⑧ Repaired drainage between T-9 & T-5.

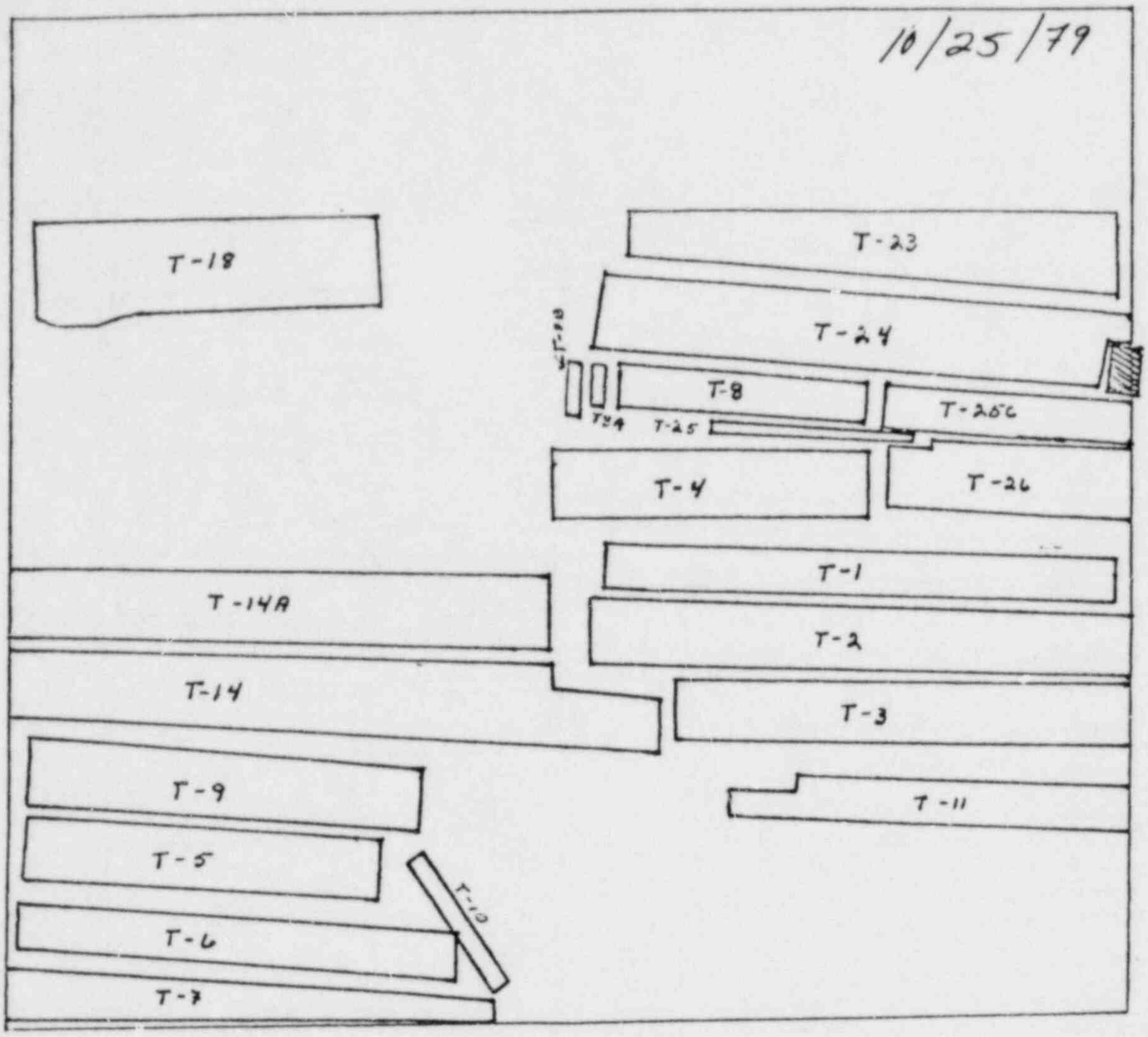
Repaired erosion on T-10

⑩ Repaired Drainage between T-14 & 14A

10/25/79

MONTHLY TRENCH INSPECTION

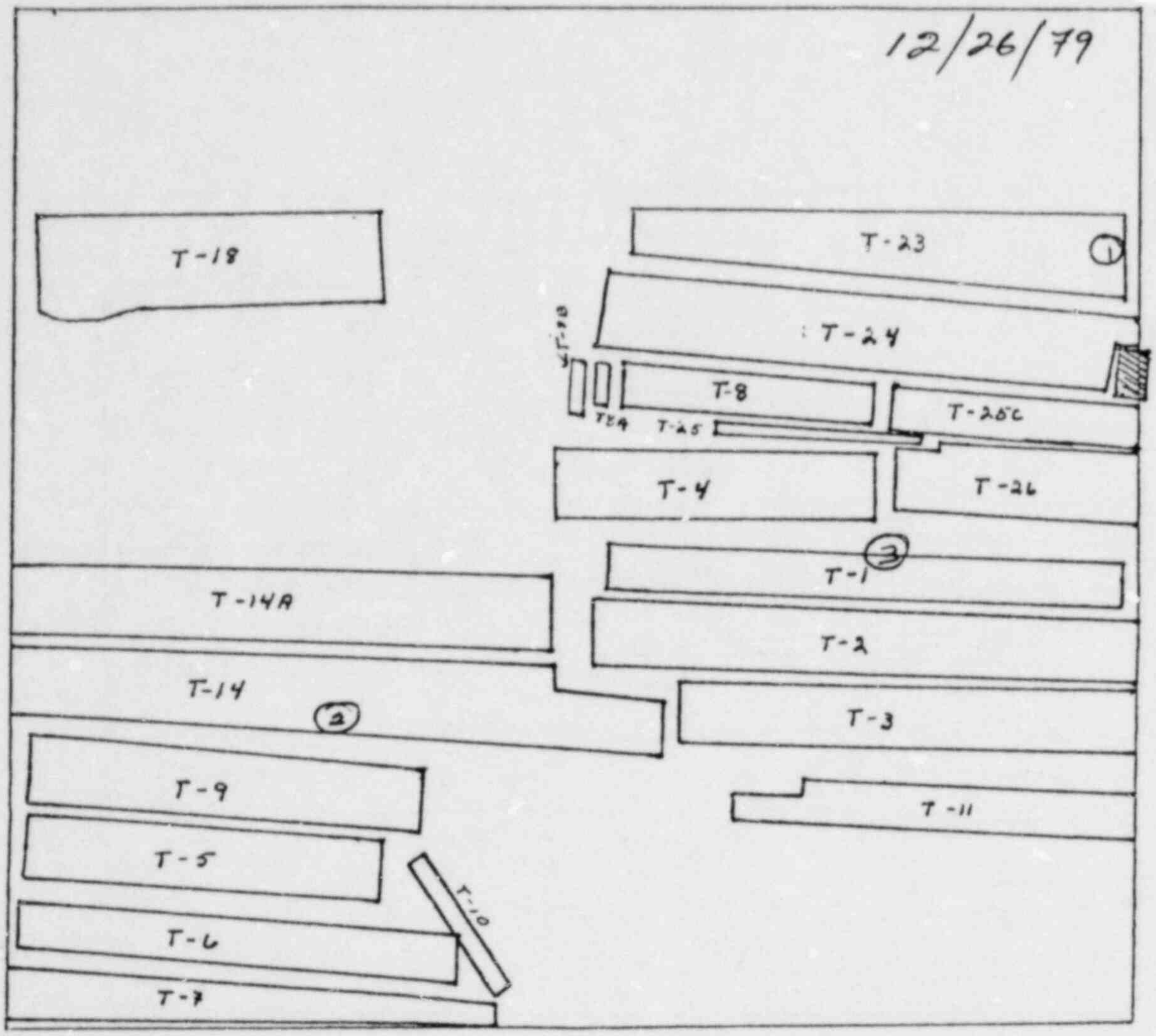
10/25/79



1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

Walked Trench tops found no holes

MONTHLY TRENCH INSPECTION



12/26/79

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

12-26-79

1. 2. Approximately 5' diameter 7' deep - settling around sump pipe - was repaired immediately

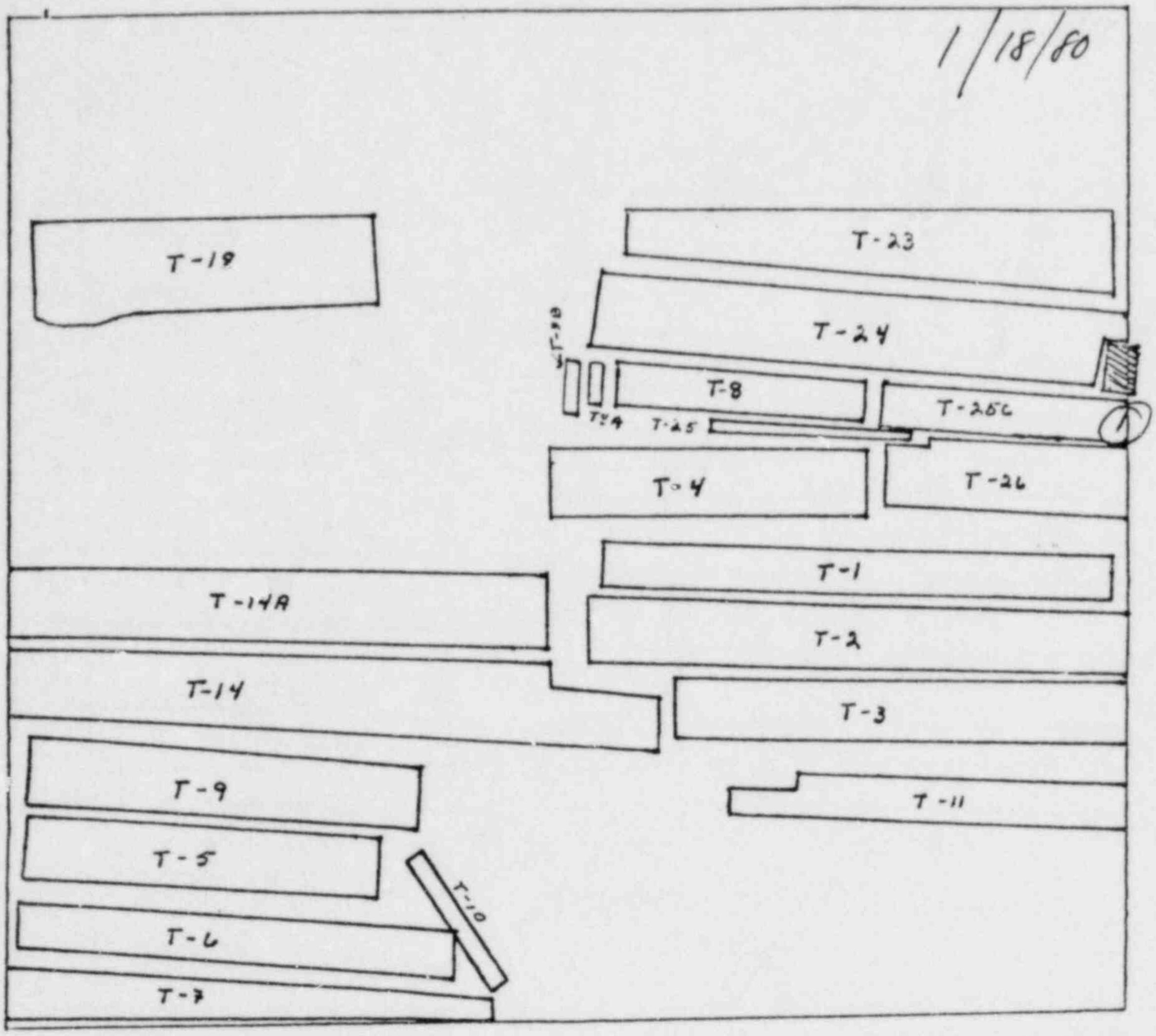
2. 2. settling approximately 2' diameter 1' deep - filled 12-~~26~~ 31 KPM -79

3. 2. settling 5' diameter 1' deep - filled 12-~~26~~ 31 KPM -79

KPM

1/18/80

MONTHLY TRENCH INSPECTION

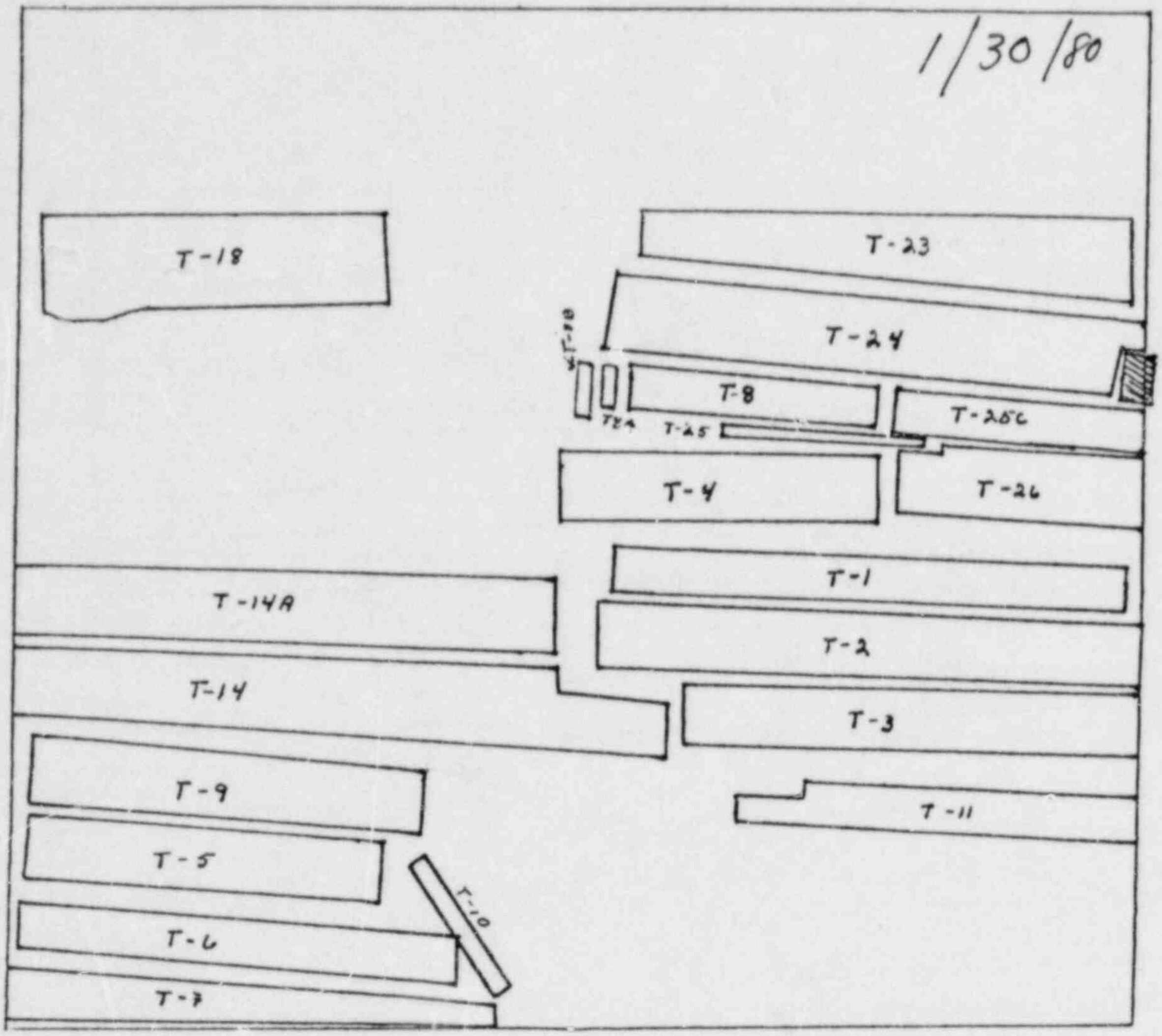


1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① Depression 4' diameter 2' deep around Monument & sump pipe

1/30/80

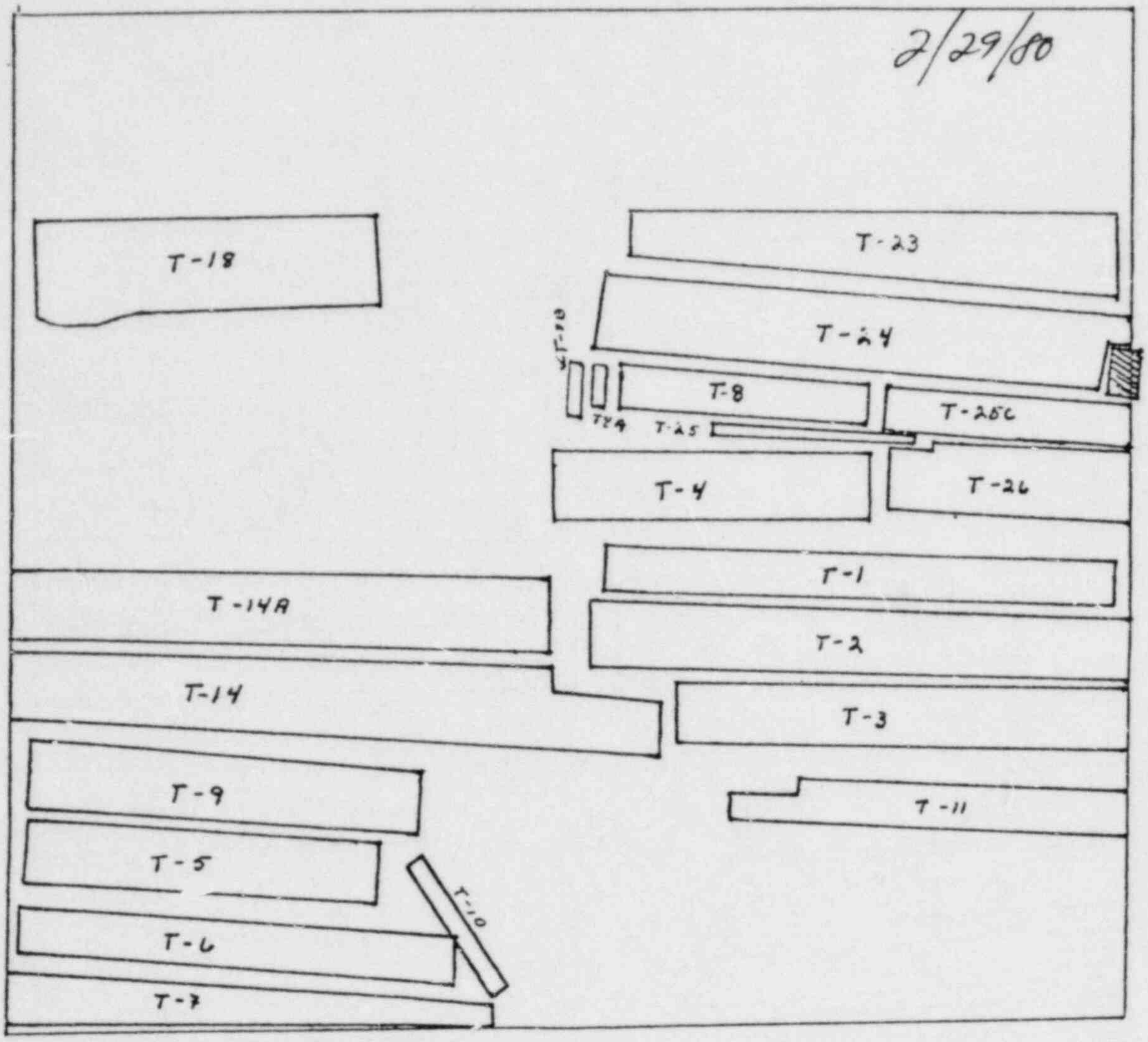
# MONTHLY TRENCH INSPECTION


1/30/80

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

Walked trench tops found no holes

MONTHLY TRENCH INSPECTION 2/29/80



1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

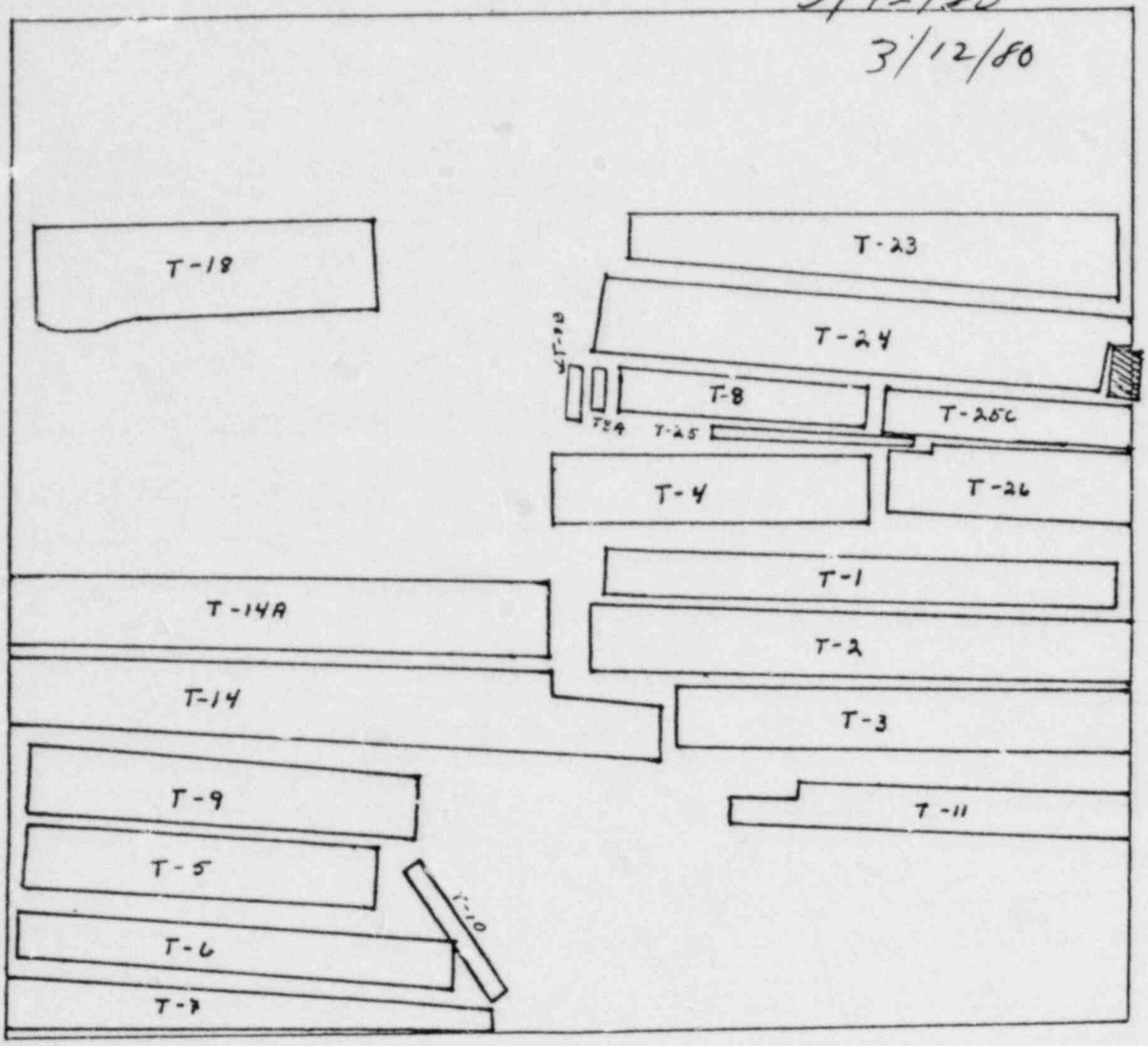
Walked trench tops all snow covered found no holes

RJH

# MONTHLY TRENCH INSPECTION

3/12/80

3/12/80



1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

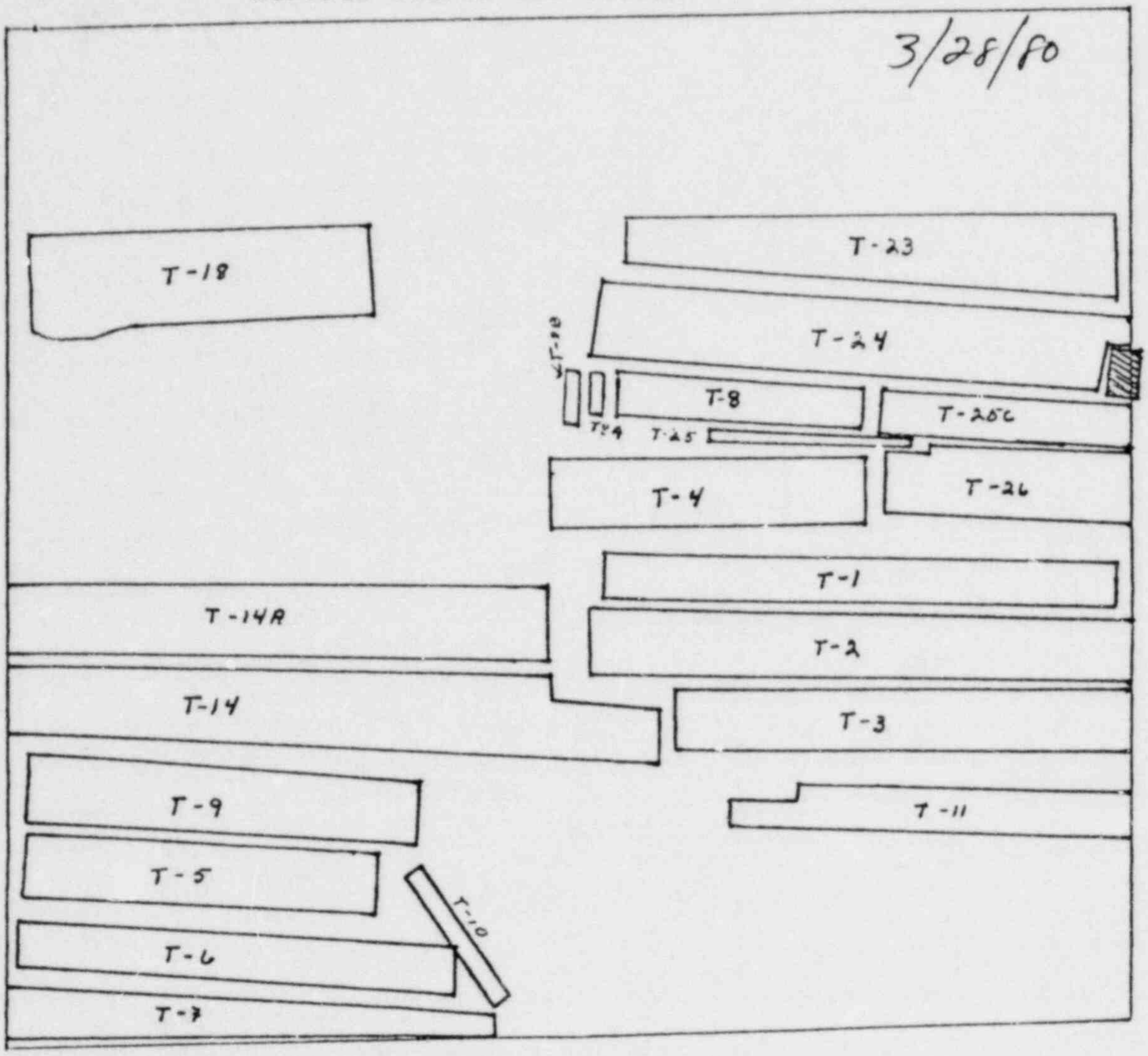
Walked trench tops with IDPH form

no holes.

AJA

## MONTHLY TRENCH INSPECTION

3/28/80



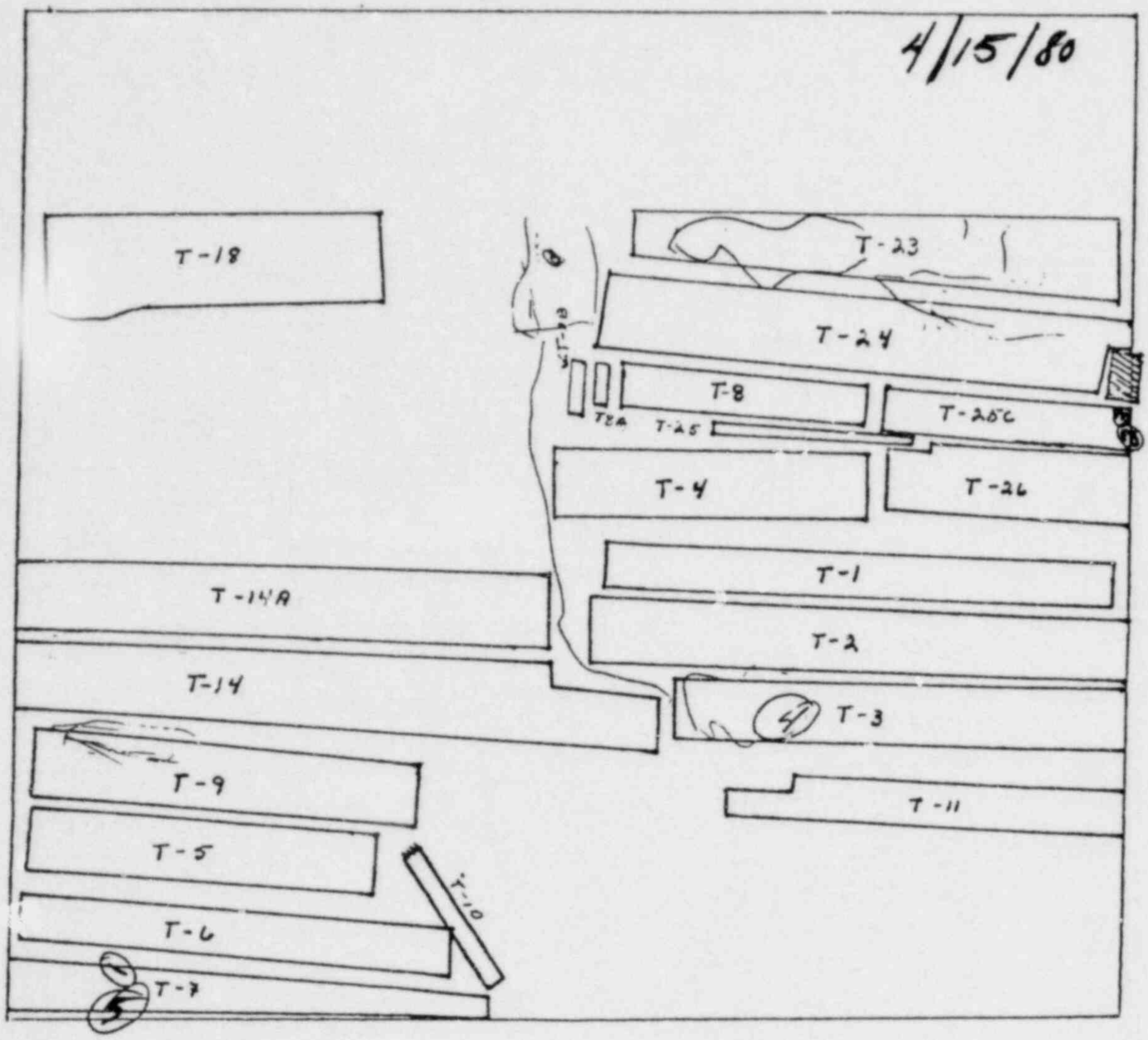
1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

No holes. all trenches

AJA

4/15/80

# MONTHLY TRENCH INSPECTION



4/15/80

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

① Hole 3' diameter 2' deep

② ~~Hole~~ Subsidance around sump pipe ≈ 1' deep 3' dia

③ Hole 1' diameter 2' deep

AJA

④ Hole 5' diameter 3' deep } Found 4/17/80

⑤ Hole 3' diameter 3' deep

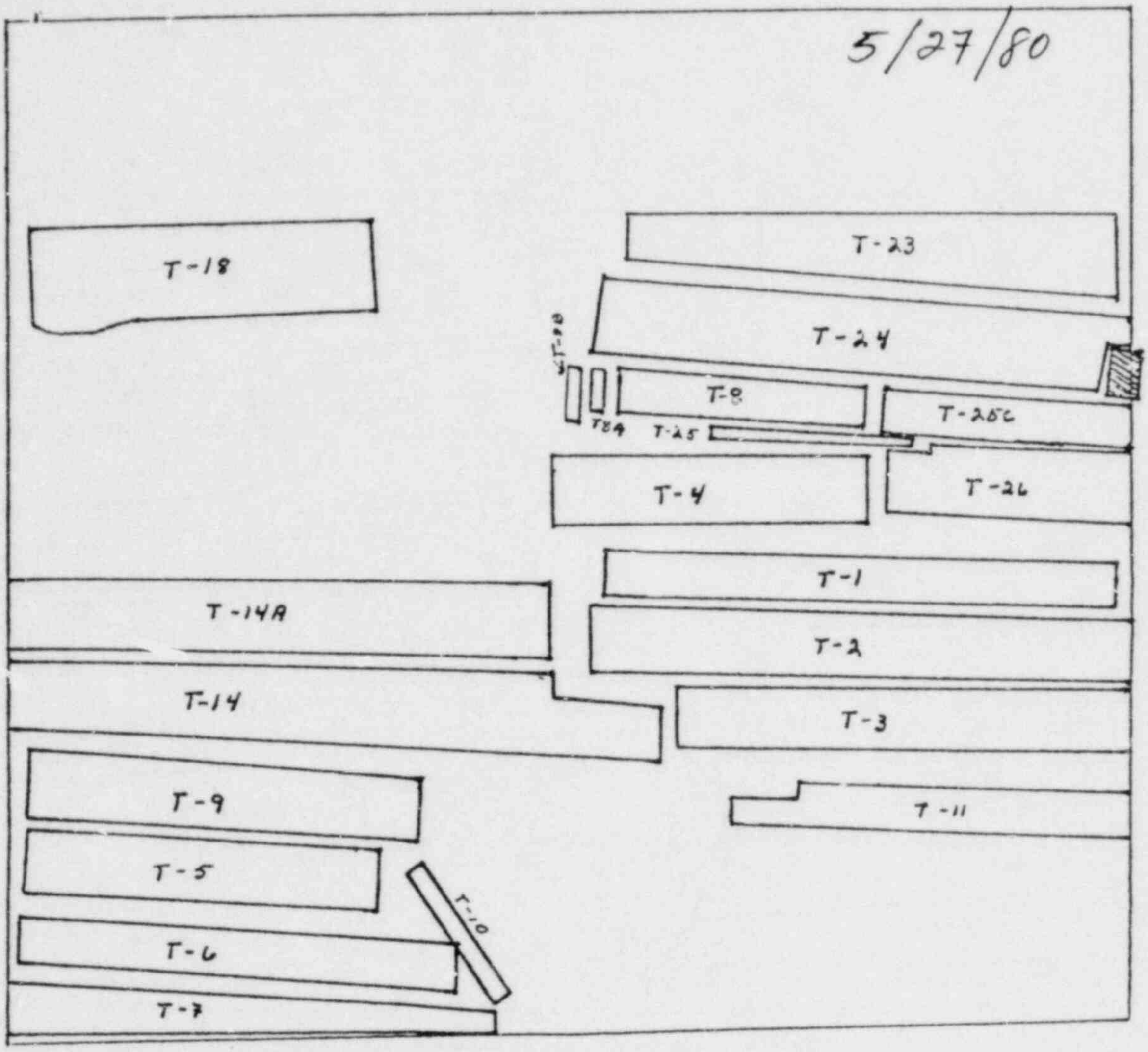
4-18-80 partially filled holes - unable to complete due to soft ground

4-21-80 completed filling all holes as requested

RPM

MONTHLY TRENCH INSPECTION 5/27/80

5/27/80

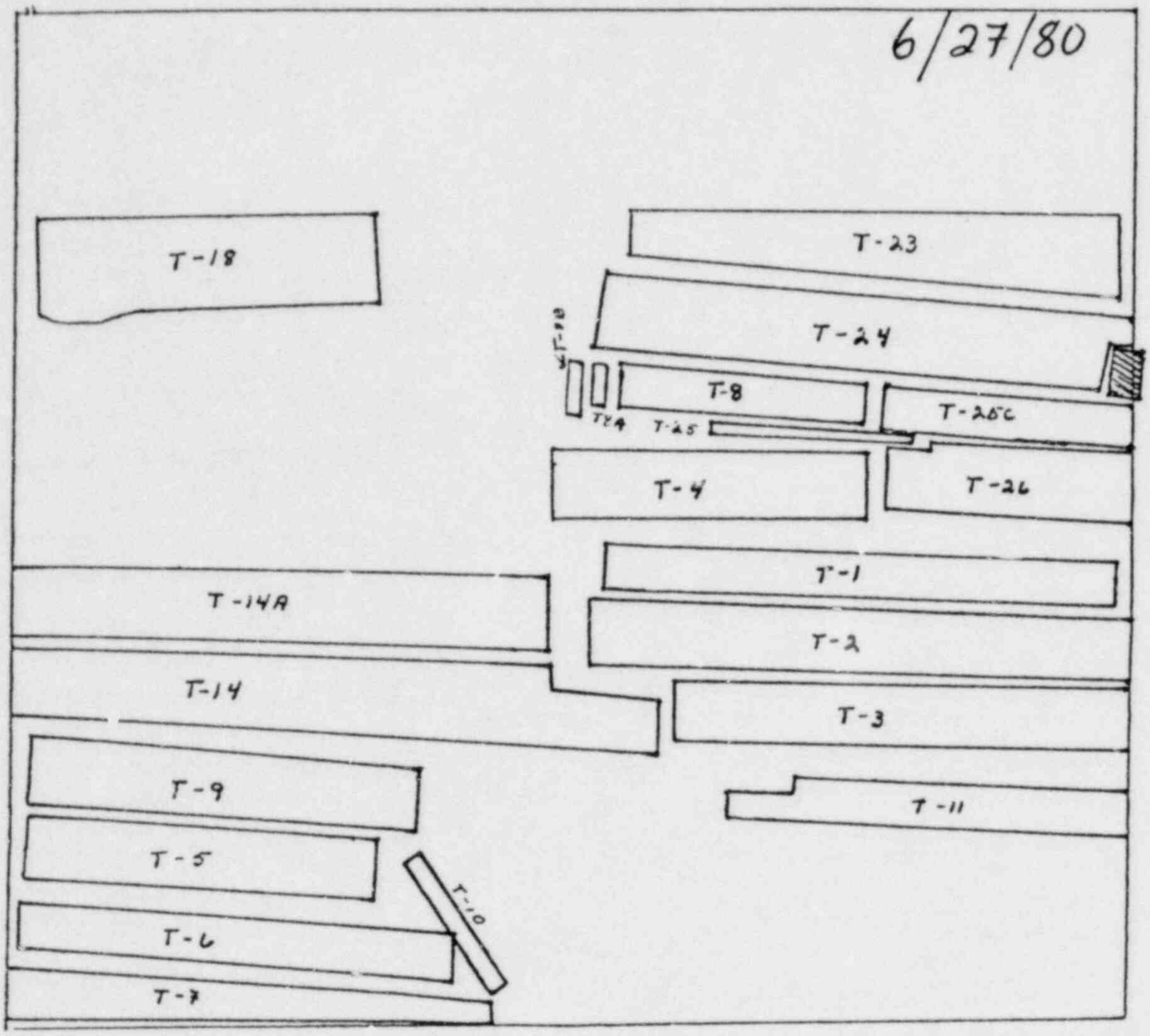


1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

Walked all trenches found no holes. AJB

6/27/80

MONTHLY TRENCH INSPECTION

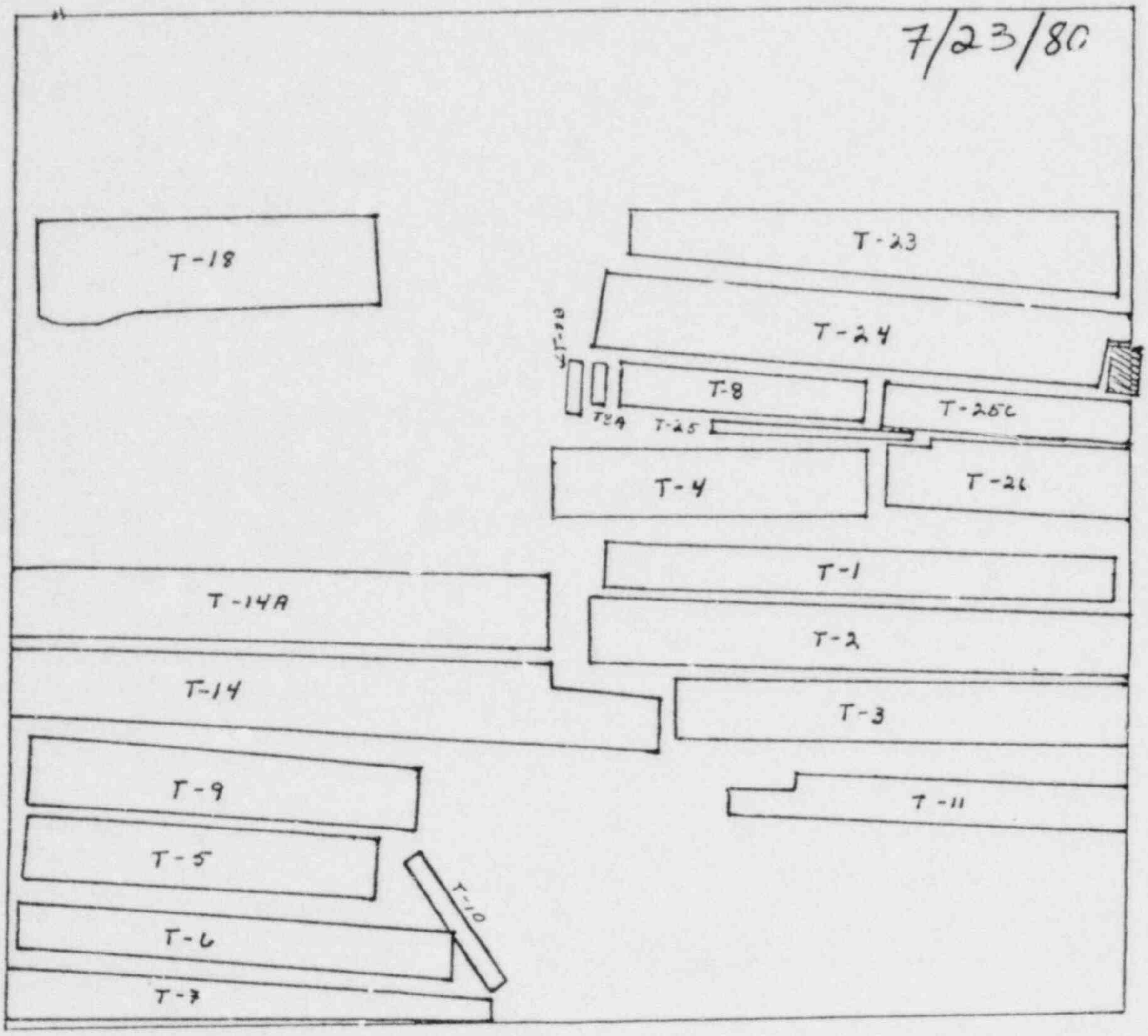

6/27/80

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

Found No holes

MONTHLY TRENCH INSPECTION 7/23/80

7/23/80



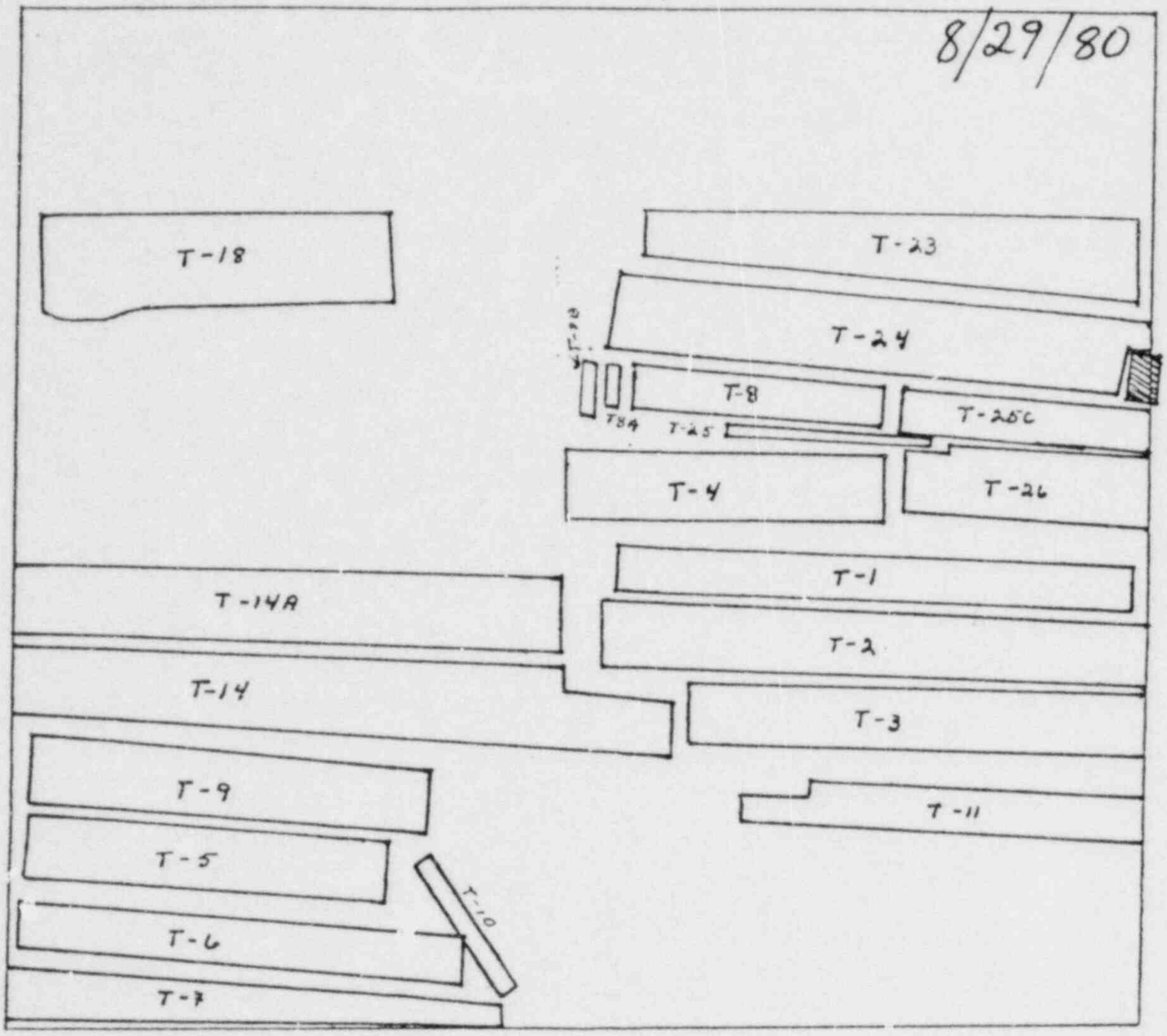
1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

walked all trenches found no holes

AJ Rimbert

8/29/80

## MONTHLY TRENCH INSPECTION


8/29/80

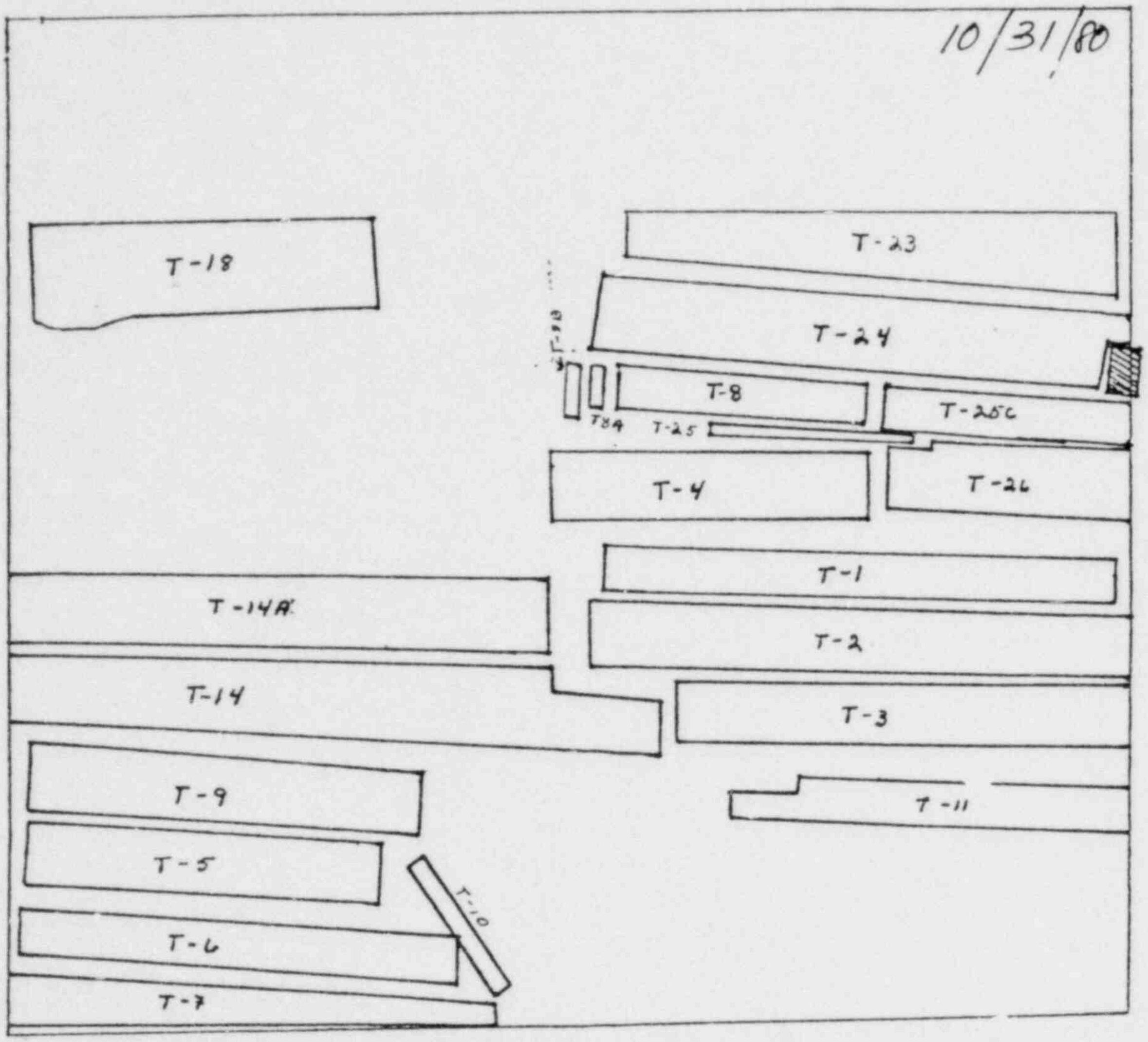
1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

Walked all trenches found no holes

8/29/80

10/31/80

MONTHLY TRENCH INSPECTION



10/31/80

1) Number and circle the location of holes and erosion.
2) Describe below the size and cause of holes.

Walked trenches found no holes

# APPENDIX C

# COST ESTIMATES

# APPENDIX C

## I. INITIAL CONSTRUCTION COST ESTIMATES OF TRENCH STABILIZATION TECHNIQUES

### A. General Assumptions

- Estimates are based on costs as of December 1980.
- The cost/typical trench is rounded off to the nearest $1000.
- A 25 percent contingency factor is added to the total estimated costs.
- Estimates are developed for a "typical" trench with surface dimensions: 350 feet by 50 feet.

### B. Dynamic Consolidation

### B.1. Assumptions

- Up to a 40 ton weight required for the technique is cast of concrete in a steel bin at the site.
- Up to a 80 ton crane is required to lift and drop the weight onto the surface of the trenches.
- The crane is rented for one week.
- Labor is provided by a 5 man crew.
- Import and place 6.0 feet of additional soil over the existing surface of the trenches.
- Following dynamic consolidation treatment of the trenches, it will be necessary to regrade and compact the trench surface. Assume that the trench surface settles by approximately 2.0 feet (i.e. 10 percent of 20 feet trench depth).

### B.2. Cost Estimate

- The volume of concrete required for the formation of the 40 ton weight is:

$$\frac{(40)\ (2000)\ \text{lb}}{(150)\ \text{lb/cu.ft.}} = 533\ \text{cu. ft.} = \frac{533}{27}\ \text{cu.yd.} = 20\ \text{cu.yd.}$$

- The volume of soil imported and placed over each trench is:

$$\frac{(6.0)(350)(50)}{(27)} = 3889 \text{ cu.yd/trench}$$

- The volume of soil to be compacted after dynamic consolidation treatment is:

$$\frac{(2.0)(350)(50)}{(27)} = 1296 \text{ cu.yd/trench}$$

| | Total Cost/Trench ($K) |
|---|---|
| o Form and pour 20 CY @ $250/CY | 5 |
| o Rent 80 ton crane @ $4000/week | 4 |
| o Labor, 5 man crew for 1 week (200) hours @ $15/hour. | 3 |
| o Import and place 3889 CY @ $7.50/CY | 29 |
| o Grade (350)(50) SF @ $ 0.15/SF | 3 |
| o Compact 1296 CY @ $2.00/CY | 3 |
| Subtotal | 47 |
| Contingencies, 25 percent | 12 |
| Estimated Total | 59 |

## C. Compaction by Pile Drivers

### C.1. Assumptions

- Use 12 inch diameter piles.
- Drive the piles to a depth of 15 feet into the trench and at 5 feet intervals.
- Withdraw and reuse the piles.
- Import granular material to backfill the voids formed by withdrawal of the piles.

- o Import and compact additional soil to make-up the original grade of the trench surface following densification and settlement of the backfill soil and waste materials. Assume that the trench surface settles by approximately 2.0 feet. (i.e. 10 percent of 20 feet trench depth).

## C.2. Cost Estimate

- o The number of pile driving location in each trench is:

$$\frac{(50)(350)}{(5)\ (5)} = 700/\text{trench}$$

- o The total length of piles driven in each trench is:

$$(700)(15) = 10{,}500 \text{ ft/trench}$$

- o The volume of granular backfill in each trench is:

$$\frac{(3.14)(0.5)^2(15)(700)}{(27)} = 305 \text{ cu.yd/trench}$$

- o The volume of imported cap soil for each trench is:

$$\frac{(2.0)(350)(50)}{(27)} = 1296 \text{ cu. yd/trench}$$

| | Total Cost/Trench ($K) |
|---|---|
| o Mobilization and removal of pile driver, truck crane. | 6 |
| o Drive and withdraw 10500 LF piles @ $6.00/LF | 63 |
| o Import and backfill 305 CY granular material @ $13.50/CY | 4 |
| o Import and compact 1296 CY @ $9.50/CY | 12 |
| Subtotal | 85 |
| Contingencies, 25 percent | 21 |
| Estimated Total | 106 |

## D. Compaction by Surcharging

### D.1. Assumptions

- Import and place soil mounds of approximately 6 feet in height over the existing trench surface for several months.
- Remove 5 feet of the soil mounds and regrade the surface of the trenches.

### D.2. Cost Estimate

- The volume of the soil imported and placed over each trench is:

$$\frac{(50)(350)(6)}{(27)} = 3889 \text{ cu yd/trench}$$

- The volume of soil removed from each trench is:

$$\frac{(50)(350)(5)}{(27)} = 3241 \text{ cu yd/trench}$$

- The area of soil graded over each trench is:

$$(50)(350) = 17,500 \text{ sq. ft/trench}$$

| | Total Cost/Trench ($K) |
|---|---|
| o Import and place 3889 CY @ $7.50/CY | 29 |
| o Remove and dispose onsite 3241 CY @ $2.20/CY | 7 |
| o Grade 17,500 sq. ft. @ $0.15/SF | 3 |
| Subtotal | 39 |
| Contingencies, 25 percent | 10 |
| Estimated Total | 49 |

## E. Surface Compaction by Heavy Equipment

### E.1. Assumptions

- Excavate the top 3 feet of the existing trench soil cap a distance of 2 feet beyond the outside of the trench boundary.

- Stockpile the removed soil onsite.

- Replace and recompact the soil to 95 percent of maximum density as determined by ASTM 1557.

- The existing soil cap was previously compacted to 80± percent of maximum density.

- Import and compact additional soil to make-up the original grade of the trench surface following increased compaction of the soil cap. An additional 15 percent of the original trench cap volume will be required.

### E.2. Cost Estimate

- The volume of soil removed from each trench is:

$$\frac{3(50+4)(350+4)}{(27)} = 2124 \text{ cu. yd/trench}$$

| | Total Cost/Trench ($K) |
|---|---|
| o Excavate 2124 CY and stockpile onsite @ $1.90/CY | 4 |
| o Backfill and compact 2124 CY from onsite stockpile @ $3.20/CY | 7 |
| o Import and compact (2124)(0.15) CY @ $9.50/CY | 3 |
| o Engineering for excavation and fill | 1 |
| Subtotal | 15 |
| Contingencies, 25 percent | 4 |
| Estimated Total | 19 |

## F. Compaction Grouting using Soil-Cement Grout

### F.1. Assumptions

- Grouting is applied to a depth of 20 feet in the trench.

- The volume of voids in the backfill soil is approximately 50 percent of the total trench volume.

- 30 percent of the voids in the trench backfill soil are filled with soil-cement grout.
- A batch plant is set up on site for batch mixing of the cement.
- Contractor estimates place the cost at $3 per cubic foot for the soil-cement grout.

### F.2. Cost Estimate

- The volume of the voids in the trench backfill soil is:

(0.5)(20)(350)(50) = 175,000 cu.ft./trench

| | | Total Cost/Trench ($K) |
|---|---|---|
| o Grout (0.3 ) (175,000) CF @ $5.50/CF | | 289 |
| | Subtotal | 289 |
| | Contingencies, 25 percent | 72 |
| | Estimated Total | 361 |

## G. Grouting Using Soil-Cement Grout and Acrylamide

### G.1. Assumptions

- Grouting is applied to a depth of 20 feet in the trench.
- The volume of voids in the backfill soil is approximately 50 percent of the total trench volume.
- For initial grouting use the less expensive soil-cement grout to fill 20 percent of the voids.
- Use the more expensive chemical grout to fill 10 percent of the voids.
- The estimated cost of Acrylamide grout is $25 per cubic foot of mixture.

### G.2. Cost Estimate

- The volume of voids in the trench backfill soil is:

(0.5)(20)(350)(50) = 175,000 cu.ft/trench

| | Total Cost/Trench ($K) |
|---|---|
| o Grout (0.2)(175,000) CF @ $5.50/CF | 193 |
| o Grout (0.1)(175,000) CF @ $28/CF | 490 |
| Subtotal | 683 |
| Contingencies, 25 percent | 171 |
| Estimated Total | 854 |

## II. ANNUAL MAINTENANCE COST ESTIMATES

### A. General Assumptions

- o Estimates are based on costs as of December 1980.
- o A 25 percent contingency factor is added to the total estimated costs.
- o The total annual maintenance cost is estimated for the total area of the site.
- o The cost/total area of the site is rounded off to the nearest $1000.

### B. General Site Maintenance

### B.1. Assumptions

- o Carry out monthly site inspections and carry out the necessary repairs on erosion, pot holes and slumps.
- o Each site inspection is carried out by one man and will be completed in a day.
- o Assume that the repairs will be regraded at 3 month intervals.
- o Assume that the vegetation cover over a 17,500 square foot surface area is replaced by grassing and sodding per year.

### B.2. Cost Estimates

- o The total number of man hours to carry out inspection of the site is:

$$(12)(8) = 96 \text{ hours/year}$$

- o The total area of vegetation cover to be replaced is:

$$\frac{(350)(50)}{(9)} = 1945 \text{ sq. yd/year}$$

| | Total Cost/Year ($K) |
|---|---|
| o Inspect site: 96 hours @ $25/hour | 3 |
| o Regrade and repair: 4 times @ $2,500/time | 10 |

|  | Total Cost/Year ($K) |
|---|---|
| o Replace vegetation cover: 1945 SY @ $2 to $5/SY | 4 to 10 |
| Subtotal | 17 to 23 |
| Contingencies, 25 percent | 4 to 6 |
| Estimated Total/site | 21 to 29 |

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**NRC FORM 335**
(7-77)

U.S. NUCLEAR REGULATORY COMMISSION

## BIBLIOGRAPHIC DATA SHEET

1. REPORT NUMBER *(Assigned by DDC)*
NUREG/CR-2101

4. TITLE AND SUBTITLE *(Add Volume No., if appropriate)*
Evaluation of Trench Subsidence and Stabilization at Sheffield Low-Level Radioactive Waste Disposal Facility

2. *(Leave blank)*

3. RECIPIENT'S ACCESSION NO.

7. AUTHOR(S)
Richard Kahle, James Rowlands

5. DATE REPORT COMPLETED

| MONTH | YEAR |
|---|---|
| March | 1981 |

9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS *(Include Zip Code)*
Ralph Stone and Company, Inc.
10954 Santa Monica Blvd.
Los Angeles, California 90025

DATE REPORT ISSUED

| MONTH | YEAR |
|---|---|
| May | 1981 |

6. *(Leave blank)*

8. *(Leave blank)*

12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS *(Include Zip Code)*
U.S. Nuclear Regulatory Commission
Office of Nuclear Material Safety and Safeguards
Division of Waste Management
Washington, DC 20555

10. PROJECT/TASK/WORK UNIT NO.

11. CONTRACT NO.
FIN B6968

13. TYPE OF REPORT
Technical

PERIOD COVERED *(Inclusive dates)*
October 15, 1980 - March 30, 1981

15. SUPPLEMENTARY NOTES
None

14. *(Leave blank)*

16. ABSTRACT *(200 words or less)*

This report presents the results of the evaluation of trench subsidence and possible future stabilization techniques at the Sheffield Low-Level Radioactive Waste Disposal Facility, Sheffield, Illinois. The investigation was based on a review, analysis and summary of available surface maintenance records on the site, and other data obtained from the site operator, the U.S. Nuclear Regulatory Commission, the U.S. Geological Survey, and the Illinois Department of Nuclear Safety.

Analyses were performed to determine subsidence trends and project future subsidence for 21 trenches into which the wastes were placed. The types of subsidence, potholes, sudden slumps, and long term area settlement were evaluated to develop future projections. The mechanisms evaluated as causing subsidence and settlement were: piping and settlement of the trench backfill soil into voids, consolidation of the trench backfill soil, and deterioration of the waste containers and wastes by corrosion and biodegradation. The engineering feasibility and costs of potential trench stabilization techniques were developed. Recommendations were made for stabilization, final capping, and future monitoring of each trench.

17. KEY WORDS AND DOCUMENT ANALYSIS

17a. DESCRIPTORS

Sheffield Low-Level Waste Disposal Facility

17b. IDENTIFIERS/OPEN-ENDED TERMS

18. AVAILABILITY STATEMENT
Unlimited

19. SECURITY CLASS *(This report)*
Unclassified

20. SECURITY CLASS *(This page)*
Unclassified

21. NO. OF PAGES

22. PRICE
$

☆ U.S. GOVERNMENT PRINTING OFFICE : 1981 O - 347-763

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ANO. 8107070080

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