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MATERIEL COMMAND

—COMMITTED TO PROTECTION OF THE ENVIRONMENT—

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Rocky Mountain Arsenal Information Center Commerce City, Colorado

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ROCKY MOUNTAIN ARSENAL ● COMMERCE CITY, COLORADO ● 80022-2180

90032R05
2ND COPY
VOLUME I

ROCKY MOUNTAIN ARSENAL
SANITARY SEWER INTERIM RESPONSE ACTION
DRAFT IMPLEMENTATION PLAN

VOLUME 1

Document Control Number 5300-01-03-AAAH

January 1990
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Prepared for:

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THE PRIMARY OBJECTIVE OF THIS INTERIM RESPONSE ACTION IS TO PREVENT THE POTENTIAL SPREAD OF CONTAMINATION VIA THE SANITARY SEWER SYSTEM. THE IRA WILL CONSIST OF 1) CONSTRUCTION OF A NEW SANITARY SEWER AND 2) SEALING OF THE EXISTING SEWER IN THE NORTH PLANTS AND SOUTH PLANTS AREAS ALONG WITH THE INTERCEPTOR LINE IN SECTION 36.

SECTIONS OF THIS DRAFT IMPLEMENTATION DOCUMENT INCLUDE:

1. PROCEDURES FOR SEALING THE EXISTING SEWER LINES WITH CONCRETE
2. SCHEDULE OF CLOSURE EVENTS
3. DISCUSSION OF ARAR'S
4. HEALTH AND SAFETY PLAN FOR CLOSURE OF EXISTING LINES
5. SPECIFICATIONS AND PLANS FOR THE NEW SANITARY SEWER
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ROCKY MOUNTAIN ARSENAL
SANITARY SEWER INTERIM RESPONSE
DRAFT IMPLEMENTATION PLAN

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ROCKY MOUNTAIN ARSENAL
SANITARY SEWER INTERIM RESPONSE
DRAFT IMPLEMENTATION PLAN

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VOLUME 2

CONSTRUCTION DOCUMENTS FOR NEW SANITARY SEWER LINE

HEALTH AND SAFETY PLAN FOR NEW SANITARY SEWER LINE

SECTION 1.0

OBJECTIVE

The primary objective of this Interim Response (IR) is to prevent the potential spread of contamination via the sanitary sewer system on the Rocky Mountain Arsenal (RMA). Previous studies have found that the sanitary sewer in the South Plants area and across Section 36 may be transporting contaminants to the other areas of RMA. Ground water can infiltrate the sewer line and be transported either to points along the system where it can exfiltrate to surrounding soil, or it may continue within the system to the sewage treatment plant itself. Additionally, the sewer bed may, under some circumstances, act as a transport mechanism.

This action provide for a systematic plan for plugging the existing sewer line, providing alternate sanitary sewer service to tenants in the area, and closing previously identified open sewer connections in the North Plants area.

2.0 BACKGROUND

The RMA occupies about 17,800 acres, 27.8 square miles. It is located 10 miles north of Denver, Colorado in Commerce City, Colorado. See Figure 2.1 for a site location map.

The U.S. Army used the Arsenal to produce and destroy munitions from 1942 through 1970. Nerve agents, mustard gas and lewisite, incendiary and explosive munitions were manufactured, assembled, stored, tested and destroyed at the Arsenal in the North and South Plants area. In 1947, Julius Hyman and Company leased excess RMA facilities to manufacture insecticides. In 1952, Shell Chemical Company took over Julius Hyman and Company's leases and continued to manufacture insecticides along with herbicides and pesticides until 1982. Colorado Fuel and Iron leased facilities at the Arsenal from 1946 to 1948 for the production of chlorobenzene and dichlorodiphenyltrichloroethane. Currently, there are no production activities on RMA.

These production and waste activities produced contaminated ground water in the area. The ground water level in the South Plants area is relatively high and has infiltrated the sanitary sewer line. Past studies have found that the sewer line has transported the contaminants to other areas of RMA. Portions of the sanitary and chemical sewers were reported to have been flooded at one time. The sanitary sewer line in South Plants was inspected by television camera by Black and Vetch in 1980. Their report indicates that there are broken segments, sags and open joints in the system that would allow the infiltration of ground water.

The North Plants area was most recently used to destroy munitions. Prior to that it was used to manufacture, redistill, and store GB nerve agent. Black and Vetch's investigation in 1980 found seven open sanitary sewer connections in this area that may be collecting and transporting surface run-off water that may be carrying contaminated surface soils or leached contaminants. This water is being transported to the sanitary sewer treatment plant.

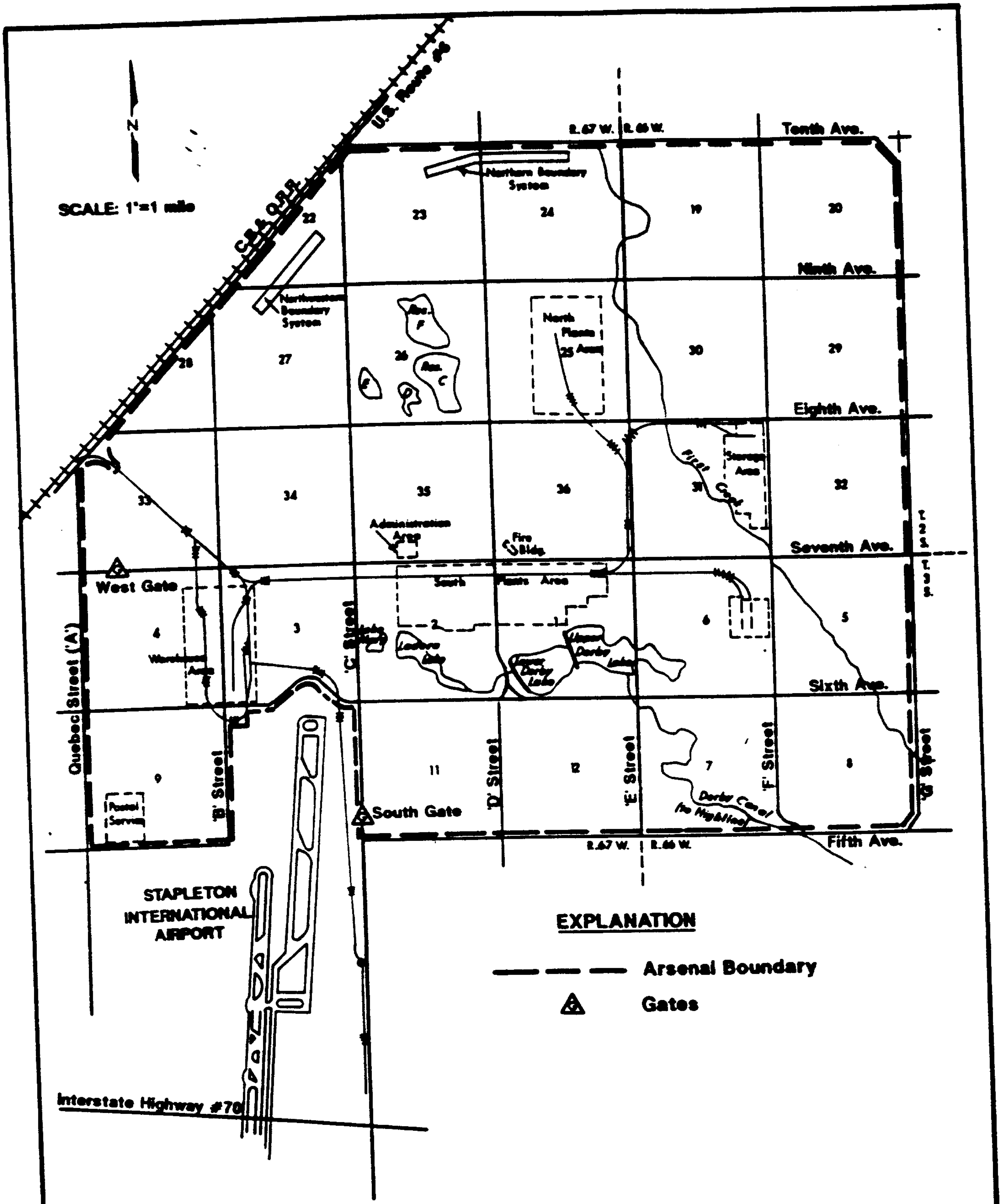

N
SCALE: 1"=1 mile
C.B.& Q.R.R.
U.S. Route 85
R. 67 W.
R. 66 W.
Tenth Ave.
Ninth Ave.
Eighth Ave.
Seventh Ave.
Sixth Ave.
Fifth Ave.
Northern Boundary System
Northwestern Boundary System
22
23
24
19
20
28
27
26
25
30
29
Bas. F
Bas. C
E
D
North Plants Area
33
34
35
36
31
32
First Creek
Storage Area
Administration Area
Fire Bldg.
T. 2 S.
T. 3 S.
West Gate
South Plants Area
2
1
4
3
6
5
Warehouse Area
'C' Street
Ladora Lake
Lower Derby Lake
Upper Derby Lake
Quebec Street ('A')
9
'B' Street
Postal Service
11
'D' Street
12
'E' Street
7
'F' Street
8
'G' Street
South Gate
Derby Canal (to Highline)
STAPLETON INTERNATIONAL AIRPORT
Interstate Highway #70
EXPLANATION
Arsenal Boundary
Gates

FIGURE 2-1

In April 1989, the PMRMA issued a final decision document for the Sanitary Sewer Interim Response Action. The document requires the closing and sealing of the sanitary sewer in the South Plants along with the interceptor line in Section 36. To accomplish this, a new force main sewer system will need to be constructed to provide sanitary sewer service to the remaining tenants in the area. The decision document also directs the previously located open sewer connections in the North Plants area to be sealed.

SECTION 3.0

COURSE OF ACTION

3.1 OVERVIEW OF ACTION

The first step in closing the sanitary sewer system is to provide alternate sanitary service to those tenants who work in buildings in the area. Currently that includes only the fire station. There are future plans for a decontamination pad and buildings in the general area of the fire system. The nature and volume of sanitary waste from these facilities are not presently known. The new sewer is designed for the minimal flows from the fire station with significant reserve capacity for the future additions.

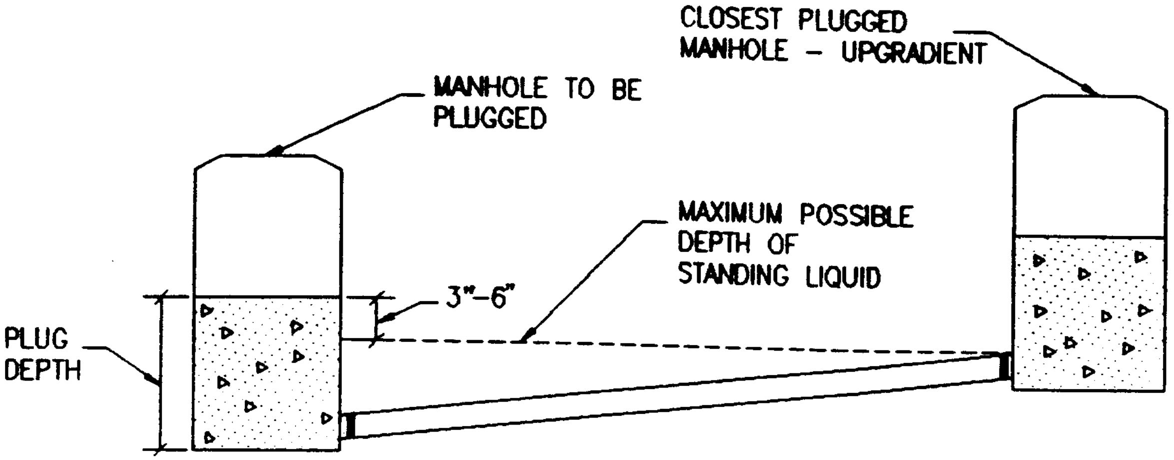
The next phase will be to locate and seal the open sewer connections in the North Plants area. Field surveys in the fall and winter of 1989 by RMA and Roy F. Weston (WESTON) personnel did not find the open connections that were reported in the 1980 studies. Smoke generating devices will be used to locate any open connections along the line and appropriate seals will be designed in the field.

After sealing the North Plants open connections, the sanitary sewer lines in the South Plant area will be plugged and sealed on lines that are no longer needed to serve tenants. As the RMA relocates workers in the area, the sewer line will be sealed up to the next active branch. Once all the workers that require sanitary sewer service have been relocated, the interceptor line in Section 36 will be plugged and sealed.

The plugging and sealing of the sanitary sewer lines in South Plants and Section 36 will be accomplished by placing concrete into selected manholes along the line to a depth sufficient to prevent the flow of liquids through and beyond the manhole. The depth of the concrete plug was designed by determining the highest elevations that liquid could stand in the sewer

FIGURE 3-1

DESIGN CRITERIA FOR DETERMINING PLUG DEPTH



WESTON
MANAGERS DESIGNERS/CONSULTANTS

215 Union Boulevard
Suite 550
Denver, CO 80228
(303) 980-6800

SHEET NO.
1 OF 1

DESIGN CRITERIA FOR DETERMINING PLUG DEPTH

line behind the plug. The final depth of the plug was determined by providing 3-6 inches of plug height over that maximum depth. Figure 3.1 illustrates the design philosophy.

Manholes were selected for plugging using the following criteria:

1) Seal main intersections
2) Seal either side of heavily damaged segments
3) To isolate groups of buildings
4) To maintain sewer service to occupied buildings
5) To prevent backups into abandoned buildings

Additional manholes may be selected in the field should conditions or relocation efforts require it.

The Decision Document requires that the sanitary sewer line trench and bedding be dammed to preclude the ground water from using it as a transport mechanism. Test pits dug along the sewer line for the 1980 study revealed that there is little granular bedding material along the line. The trench backfill was reported as hard, well compacted native soils. Because of the small likelihood of the trench contributing to major contaminant migration, minimal cut-off walls will be constructed across the trench, in conformity with the Decision Document.

To prevent the disturbance of any contamination that may be in the soils, the cut-off walls will be constructed by driving sheet piling through the depth of the trench. This dam will impede flow through the trench which is not associated with the general area groundwater flow pattern. The process does not require excavation of the soils.

3.2 SCHEDULE

The schedule for completing all the tasks contained within this Implementation Plan is dependant upon the RMA relocating tenants out of the South Plant area. The relocation effort is dependant upon the timely construction of new facilities for the current South Plant tenants. Partial closure of sewer lines will occur on lines that do not currently serve tenants. The other areas will be closed as the tenants are relocated. No work can be performed in section 36 until the entire South Plants sanitary sewer is closed as it is the collector line for the South Plants area.

Key dates have been determined for implementing this plan. They are based on information received from RMA staff. The milestone events and dates are as follows:

New Sewer:

Award new sewer contract	Spring 1990
Construct new sewer line	Summer 1990

North Plants:

Award sewer closure contract	Spring 1990
Smoke test North Plants sewer line	May 1990
Design North Plants plugs	May 1990
Install North Plants plugs	May 1990

South Plants:

Install initial South Plants Plugs	April 1990
Relocate facilities engineer shops	April 1, 1990
Close MH SA-4 loop	April 1990
Relocate Shell area service	June 1, 1991
Close MH SA-3 and 116 loop	June 1991
Relocate Laboratory	September 1, 1991
Relocate contractor and trailer areas	September 1, 1991
Close MH 125 and 124 loops	September 1991
Relocate contractor service	October 1, 1991
Close MH 103 loop	October 1991
Close South Plants sewer MH 98	October 1991
Close Section 36 line	December 1991
Install sheet pile cutoff walls	December 1991

3.3 NORTH PLANTS

The previously reported open sewer connections could not be located by visual observations in 1989. To locate the open connections, a smoke generating device will be placed into the downgradient manhole. Temporary plugs will be placed in the line to control the extent of the smoke travel. The appearance of smoke in the field will locate any open connections.

Once located, the openings will be evaluated for the most appropriate closure technique. Round, well formed pipe openings will be sealed using a rubber compression plug and grout fills. Irregular openings will be sealed with a nonexpansive grout plug. In all cases, the ground around the opening will be graded to direct surface water away.

See Appendix A for the short specification for locating and sealing the North Plant open sewer connections and Appendix C for the map indicating the assumed locations of the open connections.

3.4 NEW SANITARY SEWER

To allow the Fire Station and future developments in the Fire Station area to remain operational once the South Plants sewer is disconnected, a new force main sanitary sewer will be constructed. The line will extend from the existing Fire Station tie-in to the main sewer line near Building 111. Plans and specifications for this new construction are included in Volume 2. Calculations for the design of the new sewer system are included in Appendix D to Volume 1.

3.5 SOUTH PLANTS

The closure of the sanitary sewer in the South Plants area will be completed in phases as existing tenants in the region are relocated. As buildings are vacated, water service to the facility will be terminated and all lines and appliances will be drained. All entry points to each facility will be posted with a notice barring the use of drains and appliances. The building sewer line will be plugged to prevent sewer gasses and rising liquids from entering the building.

Sewer lines in the area will then be plugged and sealed as indicated on the plan that is included in Appendix B.

3.6 SECTION 36 INTERCEPTOR

Following the closure of all South Plants sanitary sewer lines, the interceptor line in Section 36 will be plugged and sealed in the same manner as the South Plants line. The plan for this closure is included in Appendix C and uses the same detail as shown on the plan in Appendix B.

3.7 ARAR's

3.7.1 Ambient or Chemical Specific ARARs

The Decision Document specifically states that there are no chemical specific standards which are considered either applicable or relevant and appropriate for this IRA.

3.7.2 Location Specific ARARs

The Decision Document references two requirements that are not ARARs but need to be complied with as part of this IRA. The requirements involve wildlife habitat and changing the geophysical characteristics that may impact natural drainage. The activities of this IRA do not impact these issues.

3.7.3 Performance, Design, or Other Action-Specific ARARs

3.7.3.1 Air Emissions

The Health and Safety Plans (HASP) for each activity require air monitoring for volatile organic compounds that may be present in the work area. The operations of this IRA do not themselves produce air emissions. The HASPs require upgraded personal protection in the presence of detected chemical components.

3.7.3.2 Regulations Protective to Workers

The HASP developed for each work activity requires contractor compliance with all applicable OSHA standards, and sets forth additional levels of worker protection.

3.7.3.3 General Construction Activities

The construction of the new sanitary sewer line will require minor disturbance of ground vegetation. It is not anticipated that fugitive dust will exceed Colorado Air Pollution Control Commission Regulations. The construction specifications do require the contractor to be in compliance with State standards. Construction vehicles required for this IRA are required by the specifications to be in compliance with State requirements, including air emissions.

Noise issues are addressed in the individual HASPs. While the pile driving activities will produce noise levels at the site exceeding regulations, the distance to the property boundary is at least three miles. It is not anticipated that noise limits at the property boundary will be exceeded. Personal protection for workers in the area is required by the HASP.

3.7.3.4 Removal of Soil

The excavation required by this IRA is not in areas where the soil has been identified as being contaminated. It is anticipated that all excavated soils associated with the new sanitary sewer construction will be returned to the trench as backfill. The soils are to be monitored with an Organic Vapor Analyzer (OVA) to confirm the lack of contamination. The construction specification requires that contaminated soils that are encountered, which may be found at the chemical sewer crossing, be drummed according to RMA procedures.

Sewer pipe is not being removed by this IRA, so asbestos contaminated soils are not expected to be encountered.

SECTION 4.0

COST ESTIMATES

The following cost estimates were prepared using industry published unit prices for the various components of each project. Allowances for overhead, project administration, and contract support were added to the hard cost estimates for the constructed elements to reach the final total cost.

TOTAL CONSTRUCTION COST ESTIMATE

North Plants Identification and Plugging of Open Sewer Connections	$ 15,000.00
New Sanitary Sewer Construction	$ 150,000.00
Add for Encountering Contamination	$ 20,000.00
South Plants Sanitary Sewer Closure	$ 425,000.00
Section 36 Sanitary Sewer Closure	$ 110,000.00

APPENDIX A

APPENDIX A

SHORT SPECIFICATIONS FOR LOCATING AND SEALING

Locating The Open Connections

1) This procedure shall be performed during periods of minimal sewer usage, but during the daylight hours. Acceptable times shall be as follows:

Monday - Friday	before 7:30 A.M. and after 5:00 P.M.
Saturday & Sunday	all day
Holidays	all day

The wind during testing should be less than 5 mph.

2) Place a rubber expansion plug into the outlet of Manhole 530 to prevent smoke form going upgradient from this manhole and to prevent sewerage from flowing downgradient.

3) Place a rubber expansion plug into the outlet of Manhole 536 to prevent the smoke from going downgradient.

4) Using a manhole ventilator, plastic sheeting, and duct tape create an air tight seal at Manhole 536 and create a positive pressure using the ventilator.

5) Introduce a smoke generating device capable of producing white or colored smoke for a 1 hour period of time.

6) As the smoke reaches consecutive manholes, seal each ring with duct tape or caulking.

7) Watch for indications of smoke between manholes and mark each location with surveyors lath and record the location on the plan.

8) Temporarily plug each opening found with a rubber expansion plug or with plastic sheeting.

9) When all seven openings have been located, remove the sealed manhole covers and allow the sewer to ventilate the smoke until smoke is no longer observed in the sewer, then, also unplug the open connections. This will require that MH0531 be uncovered first followed by consecutively increasing numbered manholes.

10) If all sewer openings cannot be located, or if the density of smoke is too light to detect, introduce smoke generating devices in additional manholes.

Sealing Discovered Open Connections

1) Using hand tools, excavate around the marked open connections to fully expose the opening.

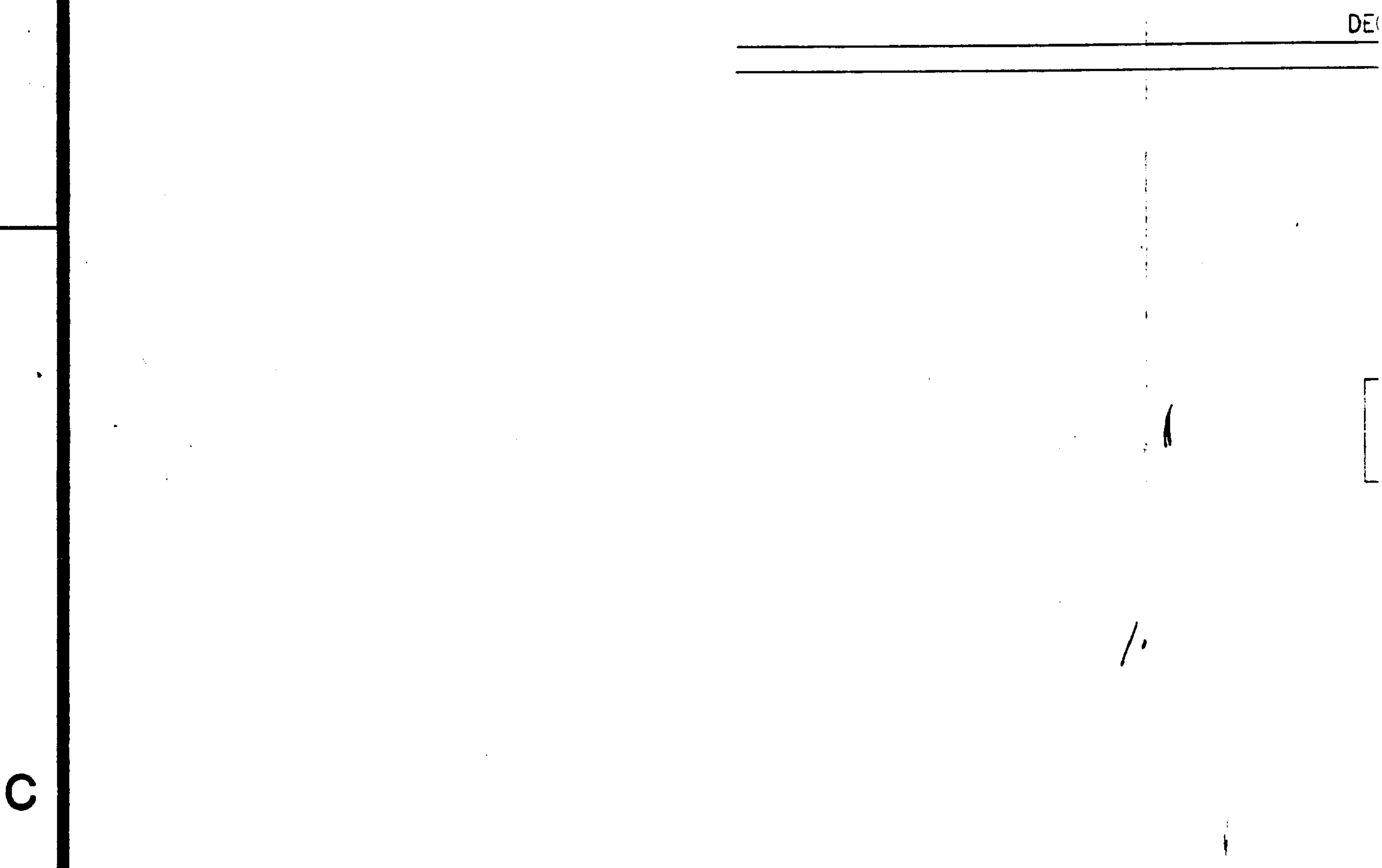
2) If the opening is a round, well formed pipe, place a rubber expansion plug into the hole and tighten.

3) If the opening is irregular, place a temporary plug 2 feet into the opening. The plug may be an air supported pillow, rag wadding or other material that will support 2 feet of grout. Place non-shrinking cement grout into the top two feet of the pipe and strike off at the top of the opening. The top of the grout shall be struck off such that it slopes enough to shed rain and surface water. Steel trowel the surface of the grout as it sets to achieve a hard, smooth surface.

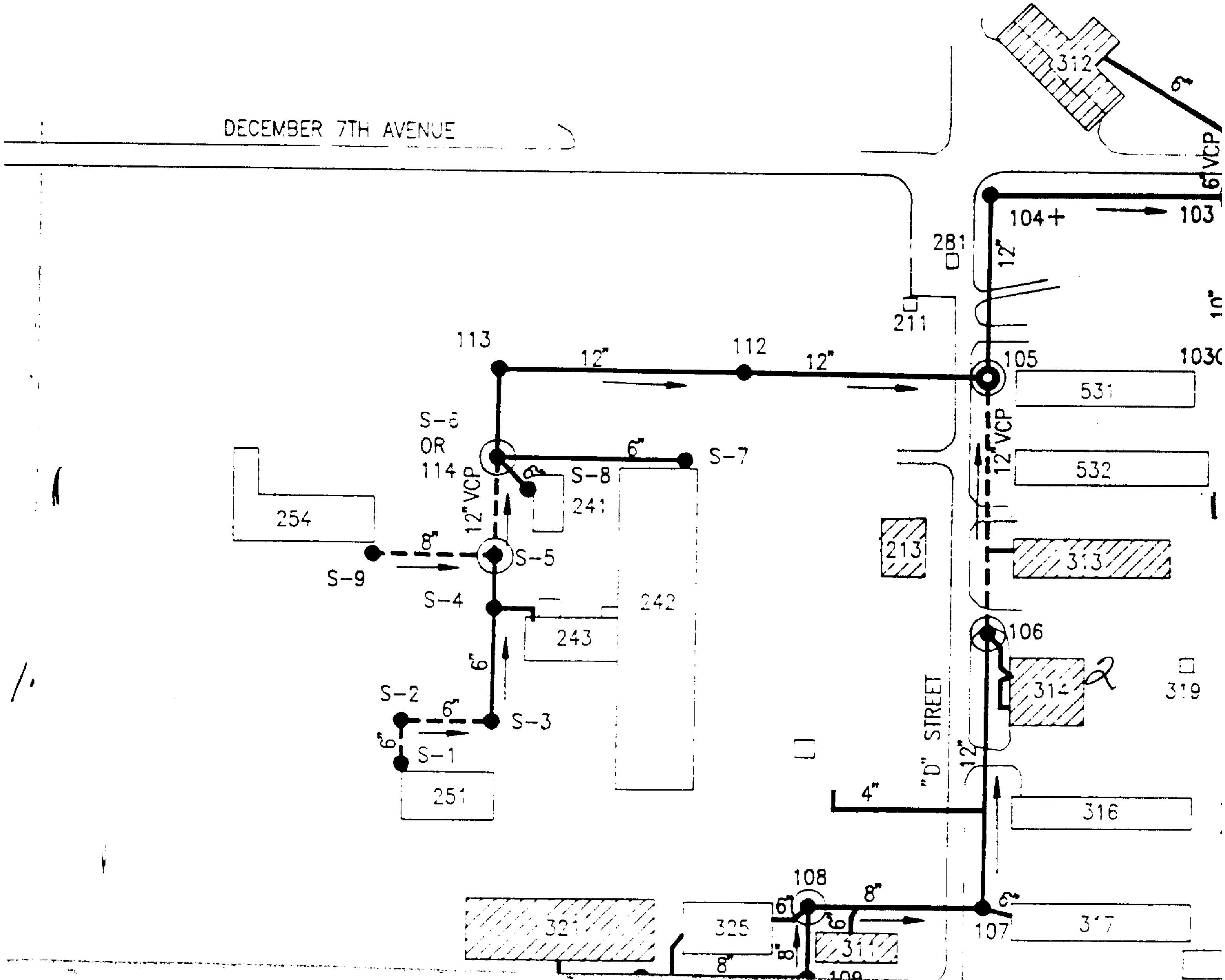
4) Using hand tools, regrade the vicinity of the opening to positively direct surface water away from the opening.

APPENDIX B

①

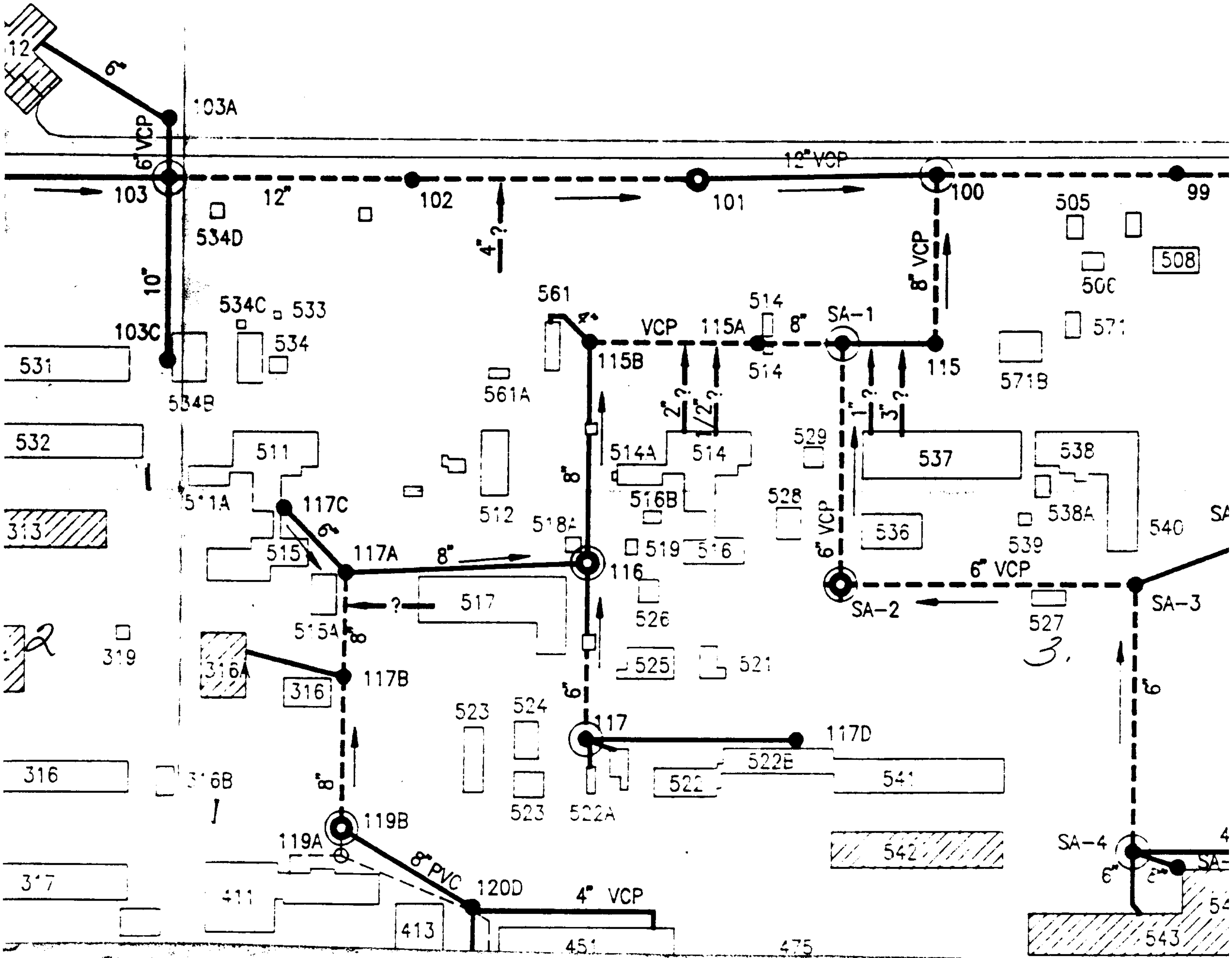


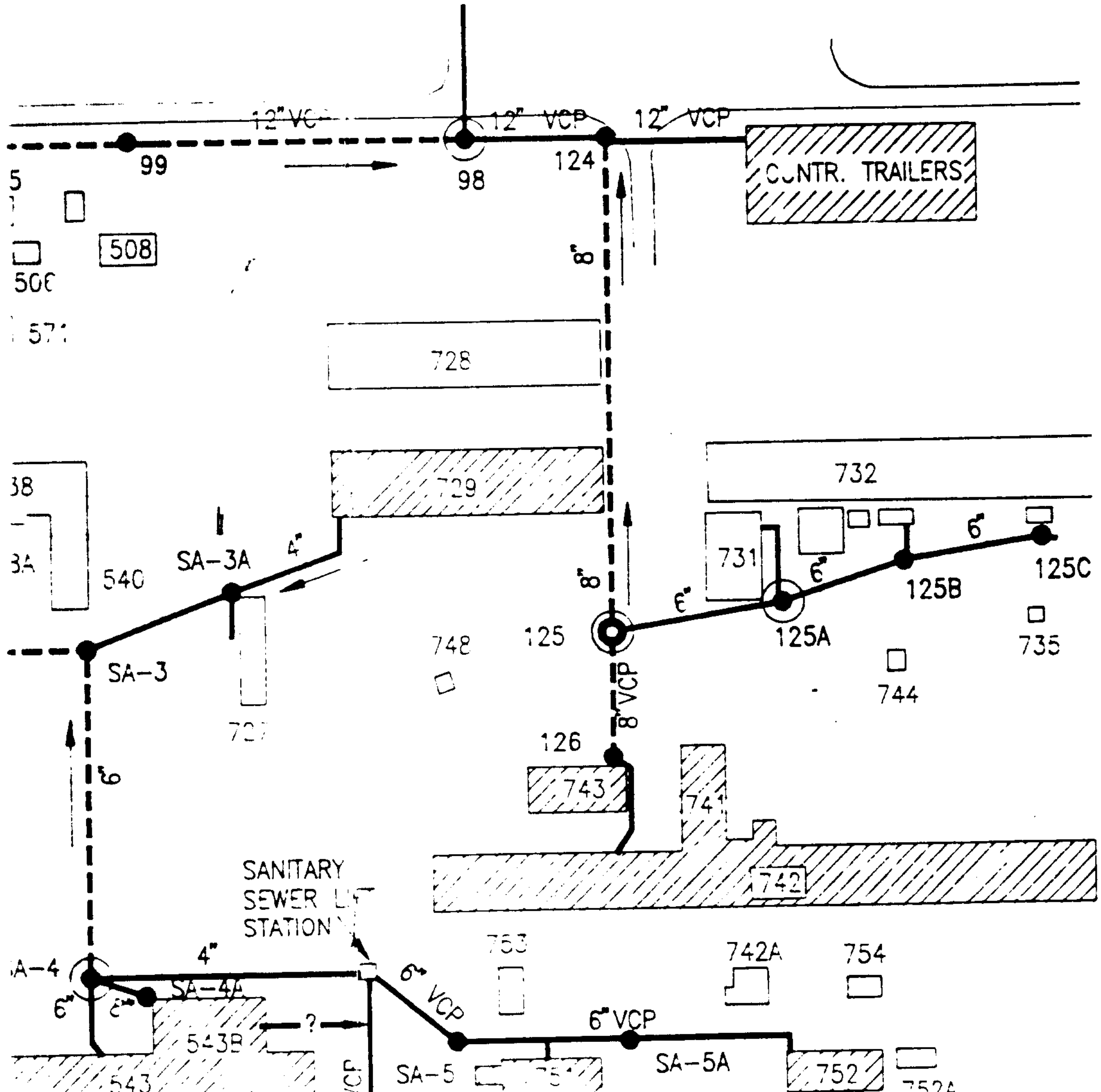
SANITARY
SOUTH



2

ARY SEWER PLAN
SOUTH PLANT




12" VCP
12" VCP
12" VCP
99
98
124
CONTR. TRAILERS
5
508
50(
57
728
8"
729
732
38
3A
540
SA-3A
4"
731
6"
6"
125C
125B
8"
6"
125A
125
735
748
744
SA-3
8"VCP
727
126
743
741
742
8"
SANITARY
SEWER LIFT
STATION
SA-4
4"
SA-4A
6"
6"
543B
?
543
6" VCP
753
742A
754
6" VCP
SA-5
SA-5A
751
752
752A
VCP

4

LEGEND

VCP	VITRIFIED CLAY PIPE
RC	REINFORCED CONCRETE
18" ——	SEWER MAIN, WITH SIZE
- - - - - -	BAD SEWER LINE
—?→	PIPE FROM UNIDENTIFIED SOURCE
←——	ARROW INDICATES DIRECTION OF F
●	MANHOLE, WITH NUMBER
○	CONTAMINATED MANHOLE
◉ ◎	MANHOLE, WITH NUMBER PE: TABLE 1 & 2
▨	OCCUPIED BUILDING

TABLE 1

MANHOLES FOR PRESENT CLOSURE			
MH	ELT	ELB	Q(CU.FT.)
111I	*	*	81.68
111D	5259.57	5255.075	47.75
SA-5	5273.91	5266.24	55.67
SA-6	5271.64	5262.47	66.22
119B	5274.12	5260.20	119.21
121	*	*	81.68
117	5270.59	5264.09	81.68
125A	*	*	81.68

LEGEND

TRIFIED CLAY PIPE

INFORCED CONCRETE

WER MAIN, WITH SIZE

D SEWER LINE

E FROM UNIDENTIFIED SOURCE

ROW INDICATES DIRECTION OF FLOW

NHOLE, WITH NUMBER

NTAMINATED MANHOLE

NHOLE, WITH NUMBER
TABLE 1 & 2

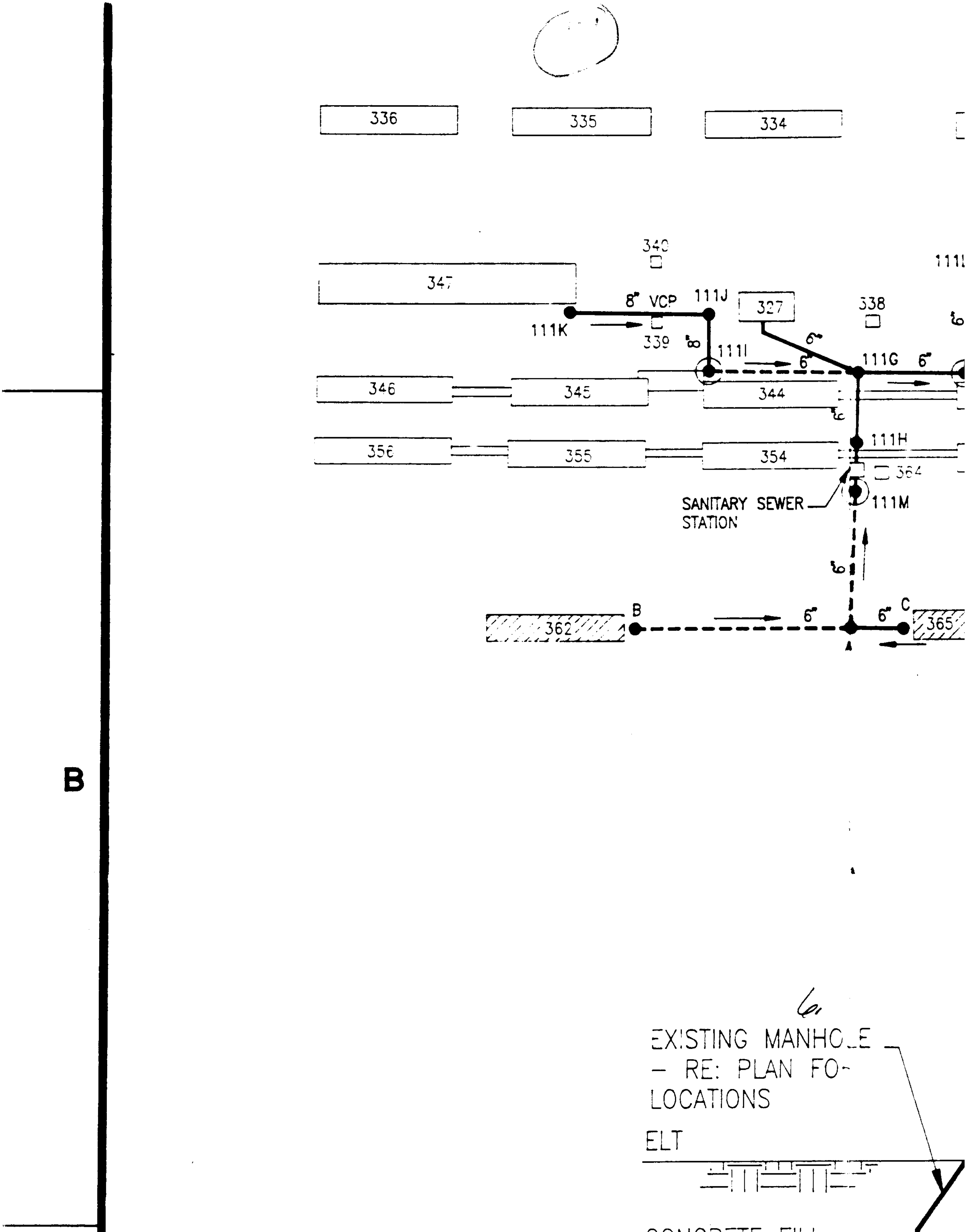
CUPIED BUILDING

D

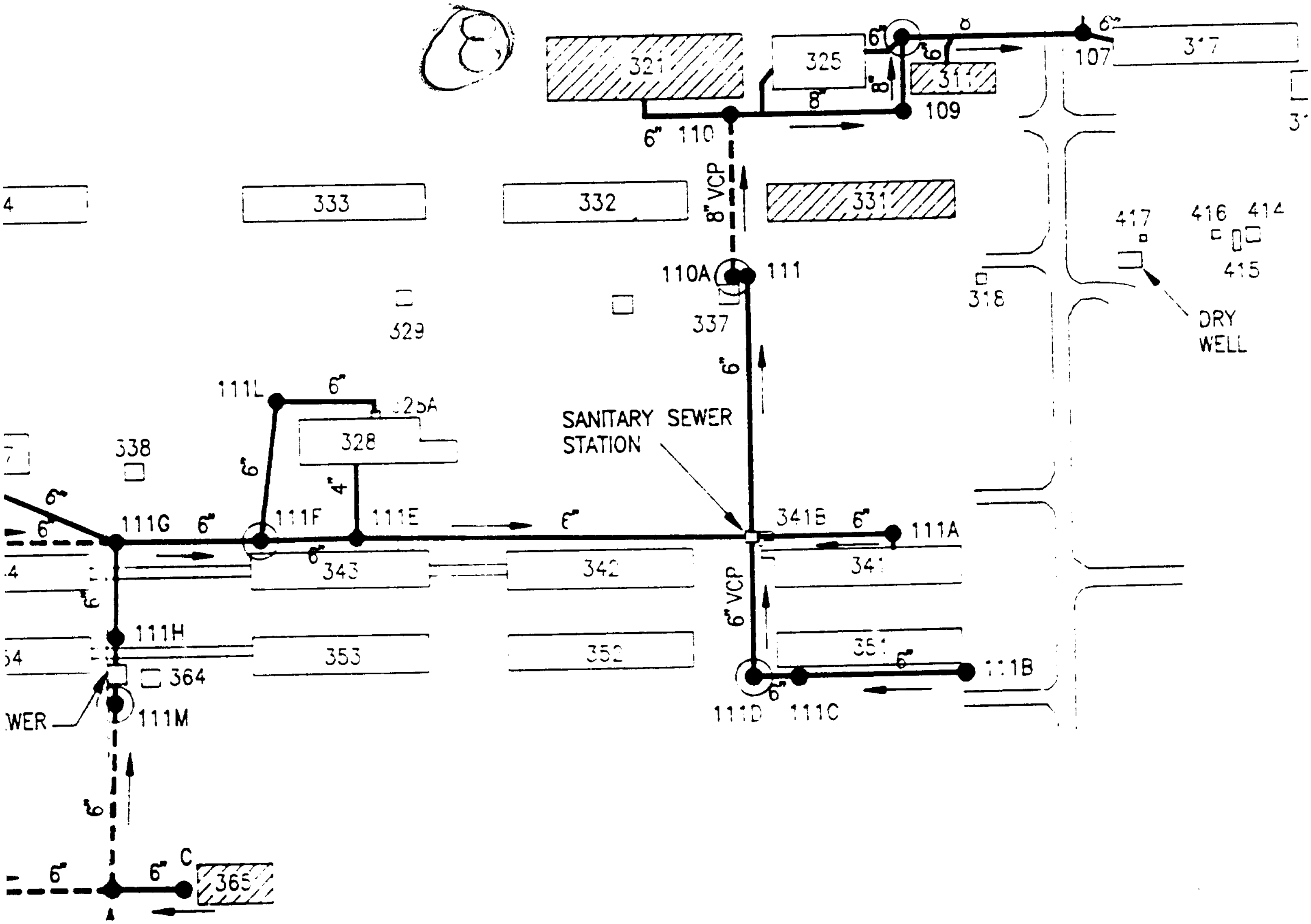
TABLE 1

OR PRESENT CLOSURE		
ELB	Q(CU.FT.)	D
*	81.68	6.50
5255.0~~7~~5	47.75	4.00
5266.24	55.67	5.00
5262.47	66.22	5.50
5260.20	119.21	10.00
*	81.68	6.50
5264.09	81.68	6.50
*	81.68	6.50

C


336
335
334
340
347
8" VCP
111J
111K
339
8"
111I
327
6"
6"
338
111G
6"
346
345
344
6"
356
355
354
111H
364
SANITARY SEWER STATION
111M
6"
B
6"
6"
C
362
365
A
B
6
EXISTING MANHOLE – RE: PLAN FO LOCATIONS
ELT

8

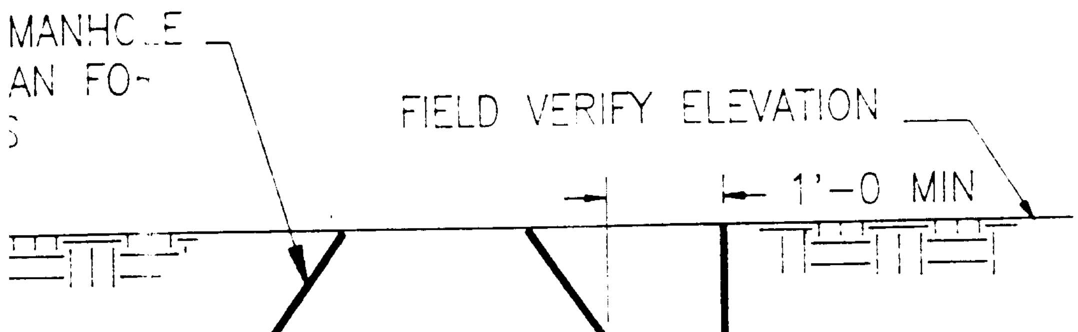


MANHOLE CL

NOT TO SCALE

7,

6,



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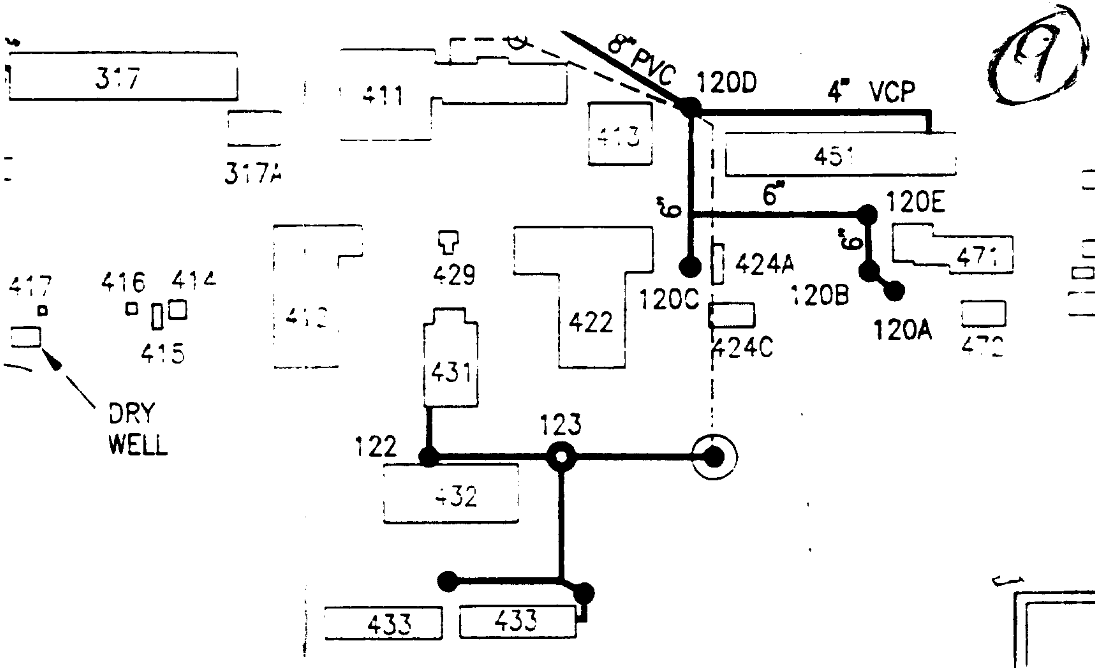
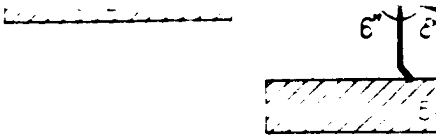




TENTATIVE SCHEDU

INSTALL INITIAL SOUTH PLANTS PLUGS -
RELOCATE FACILITIES ENGINEER SHOPS
CLOSE MH SA-4 LOOP
RELOCATE SHELL AREA SERVICE
CLOSE MH SA-3 AMD 116 LOOP
RELOCATE LABORATORY
RELOCATE CONTRACTOR AND TRAILER ARE
CLOSE MH 125 AND 124 LOOPS
RELOCATE CONTRACTOR SERVICE
CLOSE MH 103 LOOP
CLOSE SOUTH PLANTS SEWER MH 98
CLOSE SECTION 36 LINE
INSTALL SHEET PILE CUTOFF WALLS

LE CLOSURE DETAILS

E

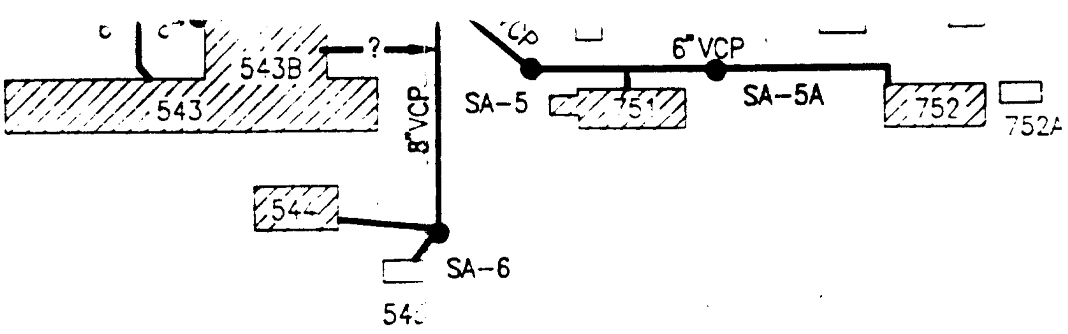
7,

NOTES

1. CONCRETE FILL SHALL DE
STRENGTH IN 28 DAYS AI
OF 4-1/2 SACKS OF CE
SLUMP SHALL NOT EXCEE

2. COMPLY WITH ALL REQUIR

3. USE STD RUBBER COMPR



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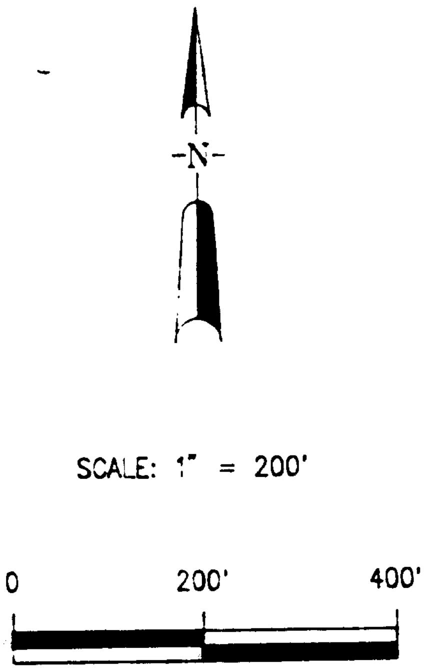


ENTATIVE SCHEDULE FOR WORK

LANTS PLUGS - TABLE 1	APRIL 1990
INEER SHOPS	APRIL 1, 1990
	APRIL 1990
ERVICE	JUNE 1 1990
16 LOOP	JUNE 1991
	SEPTEMBER 1, 1991
AND TRAILER AREAS	SEPTEMBER 1, 1991
LOOPS	SEPTEMBER 1991
SERVICE	OCTOBER 1, 1991
	OCTOBER 1991
EWER MH 98	OCTOBER 1991
	DECEMBER 1991
OFF WALLS	DECEMBER 1991

SHALL DEVELOP 2500 psi COMPRESSIVE
8 DAYS AND SHALL CONTAIN A MINIMUM
KS OF CEMENT PER CUBIC YARD.
NOT EXCEED 6".

LL REQUIREMENTS OF HEALTH & SAFETY PLAN.

ER COMPRESSION PIPE PLUG TO PLUG
PRIOR TO PLACING CONCRETE

8. DRAIN ALL FIXTURES & SI
OFF WATER TO ALL BUILD
IN AREA TO BE SEALED P
TO PLUGGING SEWER LIN
INSTALL RUBBER COMPRES
PLUG IN SEWER LINE AT
BUILDING OR IN MANHOLE
BUILDING SERVICE CONNE
TO MAIN LINE

11

125A	*	*	81.6

TABLE 2

MANHOLES FOR FUTURE CLOSU			
MH	ELT	ELB	Q(CU.F
111M	*	*	81.6
111E	5259.93	5251.10	38.7
110A	5271.82	5267.74	81.6
108	5275.39	5264.89	50.4
106	5373.63	5363.13	81.6
105	5269.18	5263.60	35.0
103	5264.74	5256.49	108.2
116	*	*	81.6
SA-4	*	*	81.6
SA-2	*	*	81.6
SA-1	*	*	81.6
100	5263.40	5254.15	48.2
125	*	*	81.6
98	5264.85	5252.10	44.6

NOTE: DEPTHS OF CONCRETE ARE SUB
FIELD MODIFICATIONS BASED ON
CONDITIONS.

* ELEVATIONS NOT DETERMINED

400'

JRES9& SHUT
ALL BUILDINGS
SEALED PRIOR
SEWER LINE.
COMPRESSION
LINE AT
MANHOLE WHERE
E CONNECTS

*	81.68	6.50

⑫

TABLE 2

FOR FUTURE CLOSURE

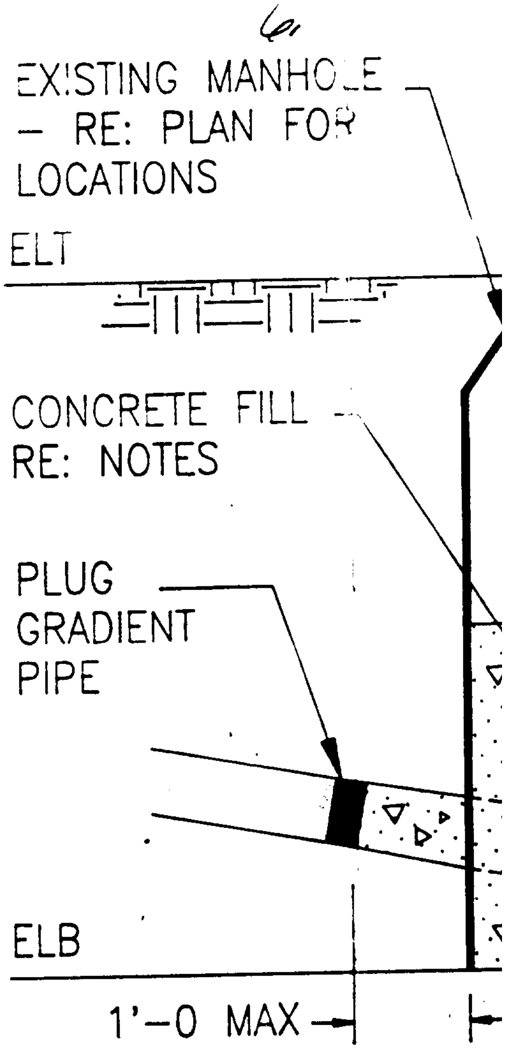
ELB	Q(CU.FT.)	D
*	81.68	6.50
5251.10	38.70	3.50
5267.74	81.68	6.50
5264.89	50.47	4.50
5363.13	81.68	6.50
5263.60	35.06	3.00
5256.49	108.20	9.00
*	81.68	6.50
*	81.68	6.50
*	81.68	6.50
*	81.68	6.50
5254.15	48.25	4.00
*	81.68	6.50
5252.10	44.61	4.00

ONCRETE ARE SUBJECT TO
ATIONS BASED ON ACTUAL

NOT DETERMINED/0.

B

⑬

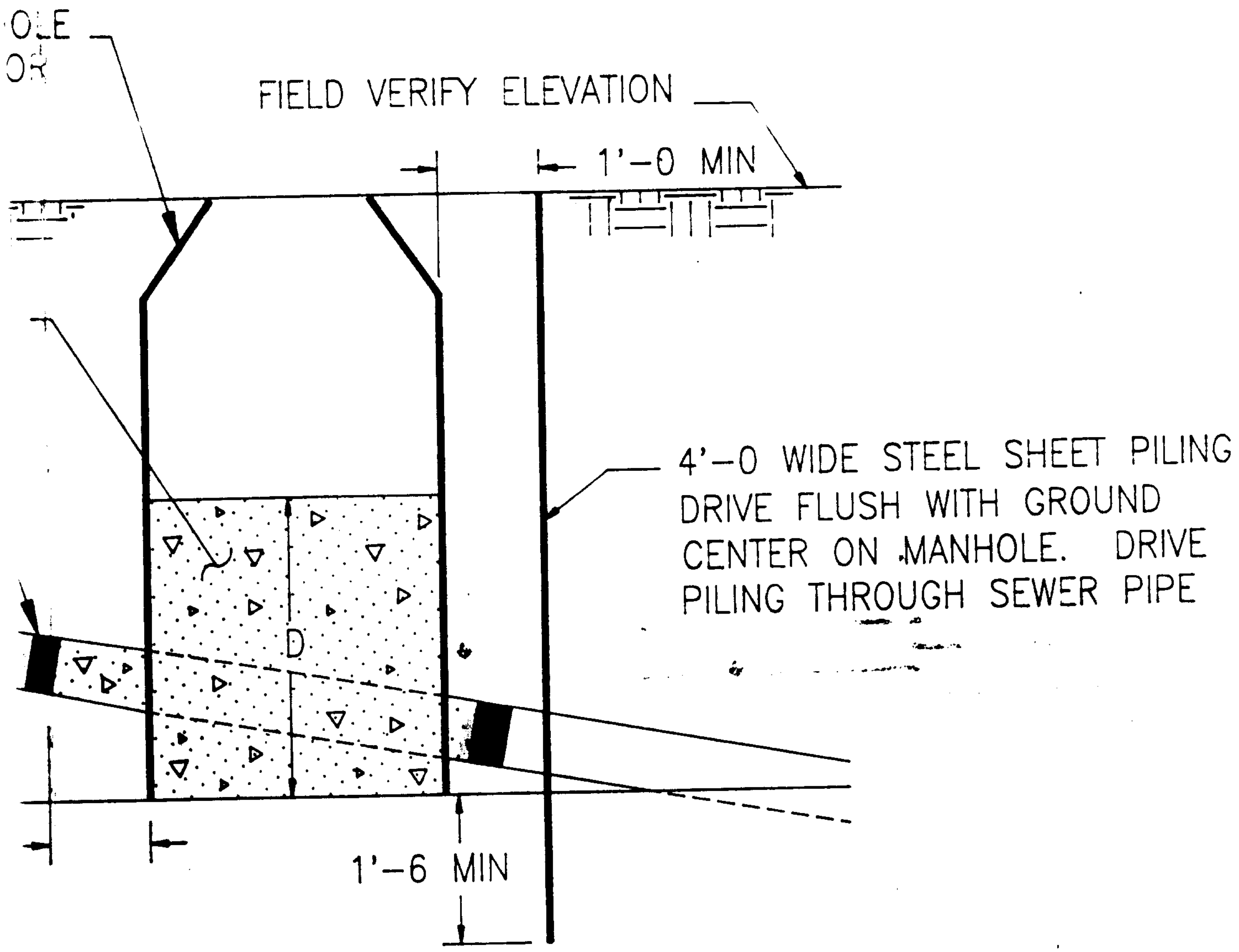

6
EXISTING MANHOLE
– RE: PLAN FOR
LOCATIONS
ELT
CONCRETE FILL
RE: NOTES
PLUG
GRADIENT
PIPE
ELB
1'–0 MAX

A

(14)

NOT TO SCALE

7,



7,

(15)

NOTES

1. CONCRETE FILL SHALL DEVEL
STRENGTH IN 28 DAYS AND
OF 4-1/2 SACKS OF CEMEN
SLUMP SHALL NOT EXCEED

2. COMPLY WITH ALL REQUIREM

3. USE STD RUBBER COMPRESS
PIPES. PLACE PRIOR TO PL

4. VIBRATE CONCRETE AT 12" I
COMPACTION.

5. WET BOTTOM AND SIDES OF
TO PLACING CONCRETE.

6. PLACE CONCRETE TO DEPTH
RECORD VOLUME PLACED IN

7. PLACE NOTICE ON ALL DOOR
SEWER SERVICE HAS BEEN T

ING

'E

NOT

THIS BUILDING IS
BY SANITA

DO

RUN WATER OR
INTO DRAINS, SI

3

HAS DEVELOP 2500 psi COMPRESSIVE
DAYS AND SHALL CONTAIN A MINIMUM
S OF CEMENT PER CUBIC YARD.
T EXCEED 6".

REQUIREMENTS OF HEALTH & SAFETY PLAN.

COMPRESSION PIPE PLUG TO PLUG
RIOR TO PLACING CONCRETE.

E AT 12" INTERVALS TO ENSURE UNIFORM

SIDES OF MANHOLE WITH WATER PRIOR
RETE.

TO DEPTH INDICATED IN TABLES AND
PLACED IN EACH MANHOLE.

ALL DOORS TO BUILDINGS WHERE
AS BEEN TERMINATED THAT STATES:

NOTICE
DING IS NO LONGER SERVED
BY SANITARY SEWER
DO NOT
TER OR PLACE ANYTHING
RAINS, SINKS, OR TOILETS

8. DRAIN ALL FIXTURES 9 & SHUT
OFF WATER TO ALL BUILDINGS
IN AREA TO BE SEALED PRIO
TO PLUGGING SEWER LINE.
INSTALL RUBBER COMPRESSIO
PLUG IN SEWER LINE AT
BUILDING OR IN MANHOLE WH
BUILDING SERVICE CONNECTS
TO MAIN LINE

(17)

FIELD MODIFICATIONS BASED ON
CONDITIONS.

* ELEVATIONS NOT DETERMINED

ES & SHUT
L BUILDINGS
EALED PRIOR
WER LINE.
COMPRESSION
INE AT
ANHOLE WHERE
CONNECTS

$$ THINK VALUE ENGINEERIN

	Revisions
Symbol	**Descriptions**

ROY F. WESTON, INC.
DENVER, COLORADO

U.S. ARMY
CORPS
OMAH

Designed by: KKK	ROCKY MOUNTAIN ARSE SANITARY S BASIN F WAST **SOUTH SITE PLAN**
Drawn by: MFB	
Checked by: CPW	
Reviewed by:	**Scale:** AS SHOWN
	Spec. No.
Submitted by:	**Contract No.**

Sheet Referenc Number.

ICATIONS BASED ON ACTUAL

⑱

NS NOT DETERMINED/0,

11,

LUE ENGINEERING $$

Revisions		
	Date	Approved

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
OMAHA, NEBRASKA

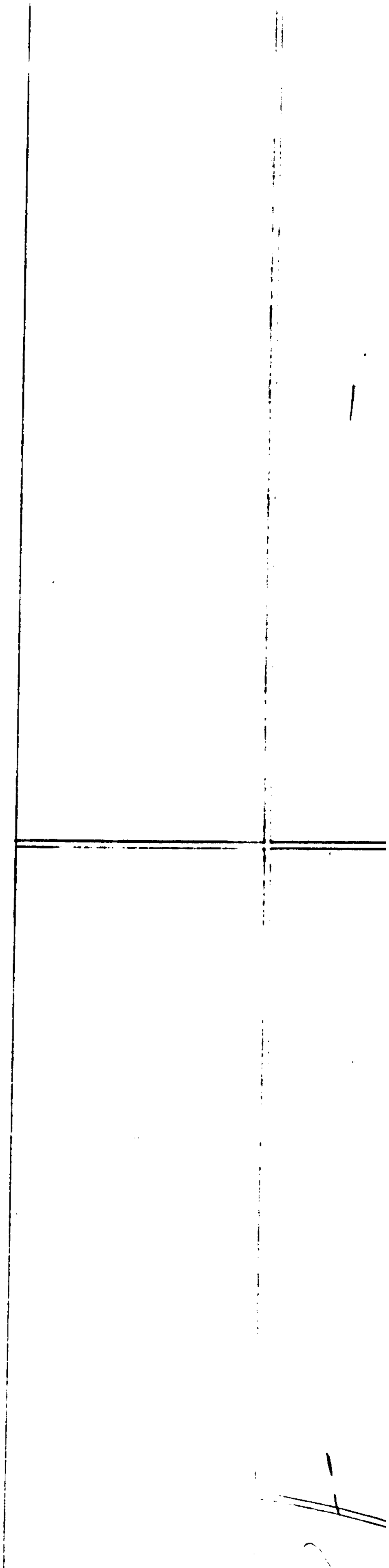
Y MOUNTAIN ARSENAL, COLORADO
SANITARY SEWER
BASIN F WASTE PILE

TH SITE PLAN AND DETAIL

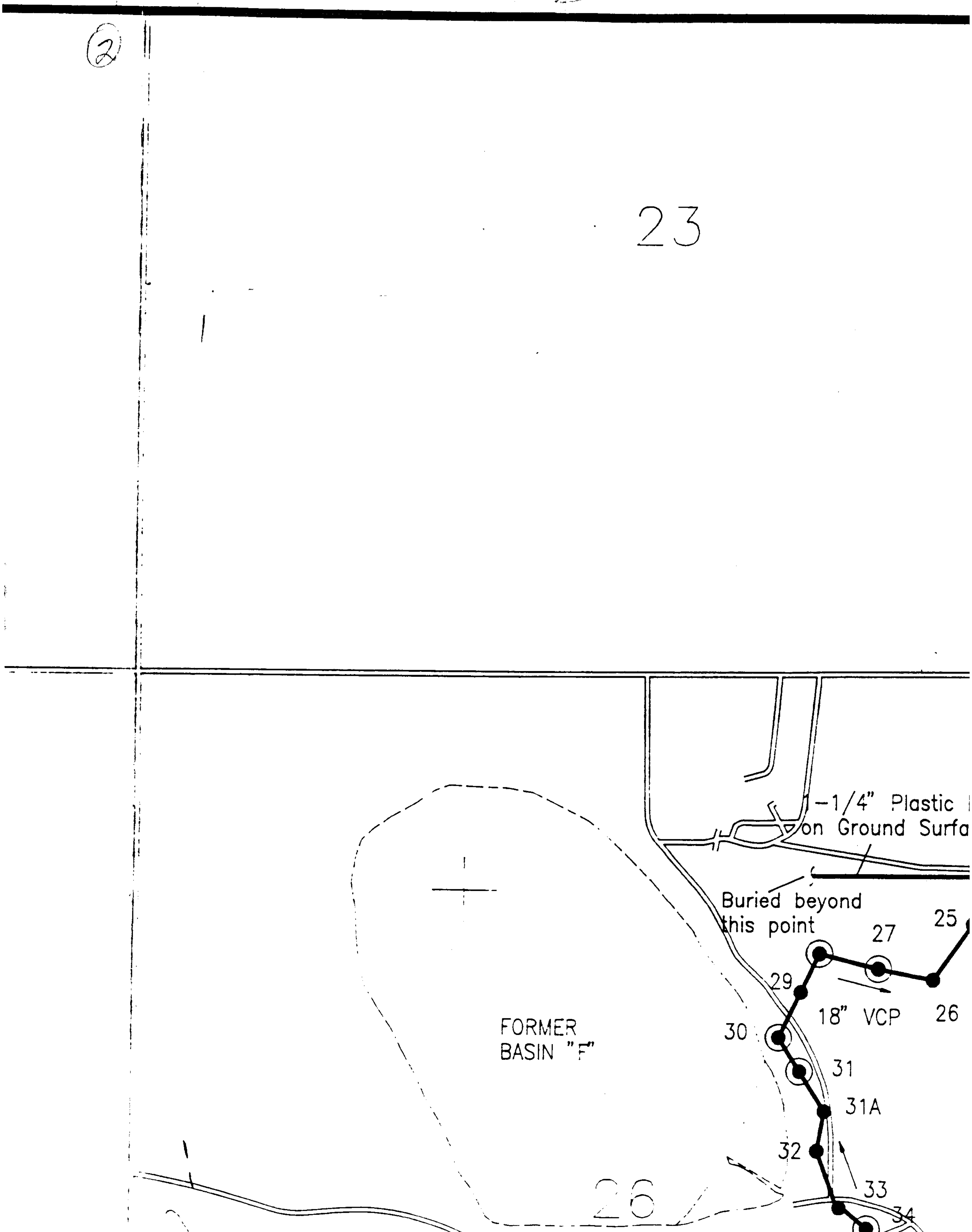
A

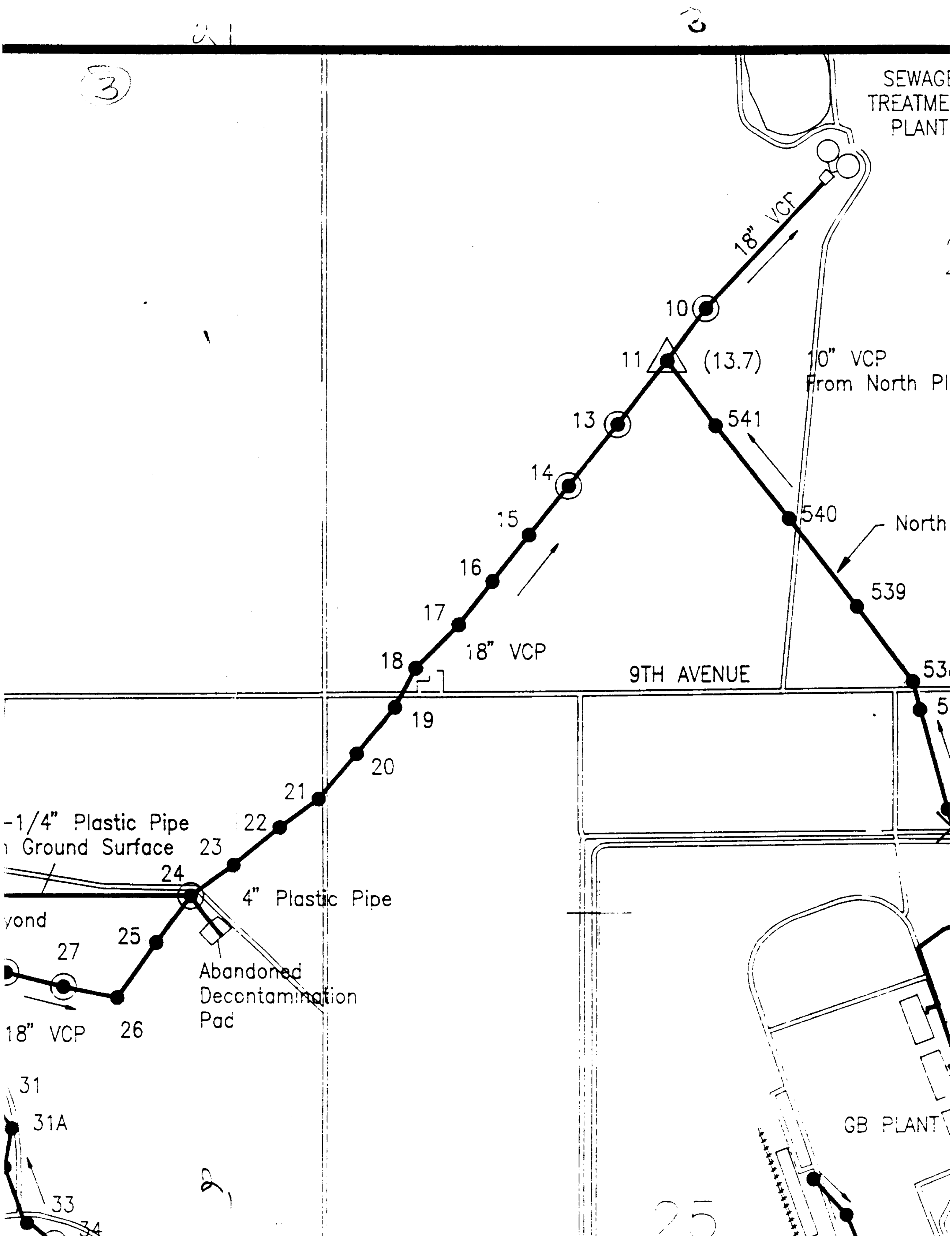
HOWN	Sheet Reference Number.	Date: JANUARY 1990
		Drawing Code:

APPENDIX C

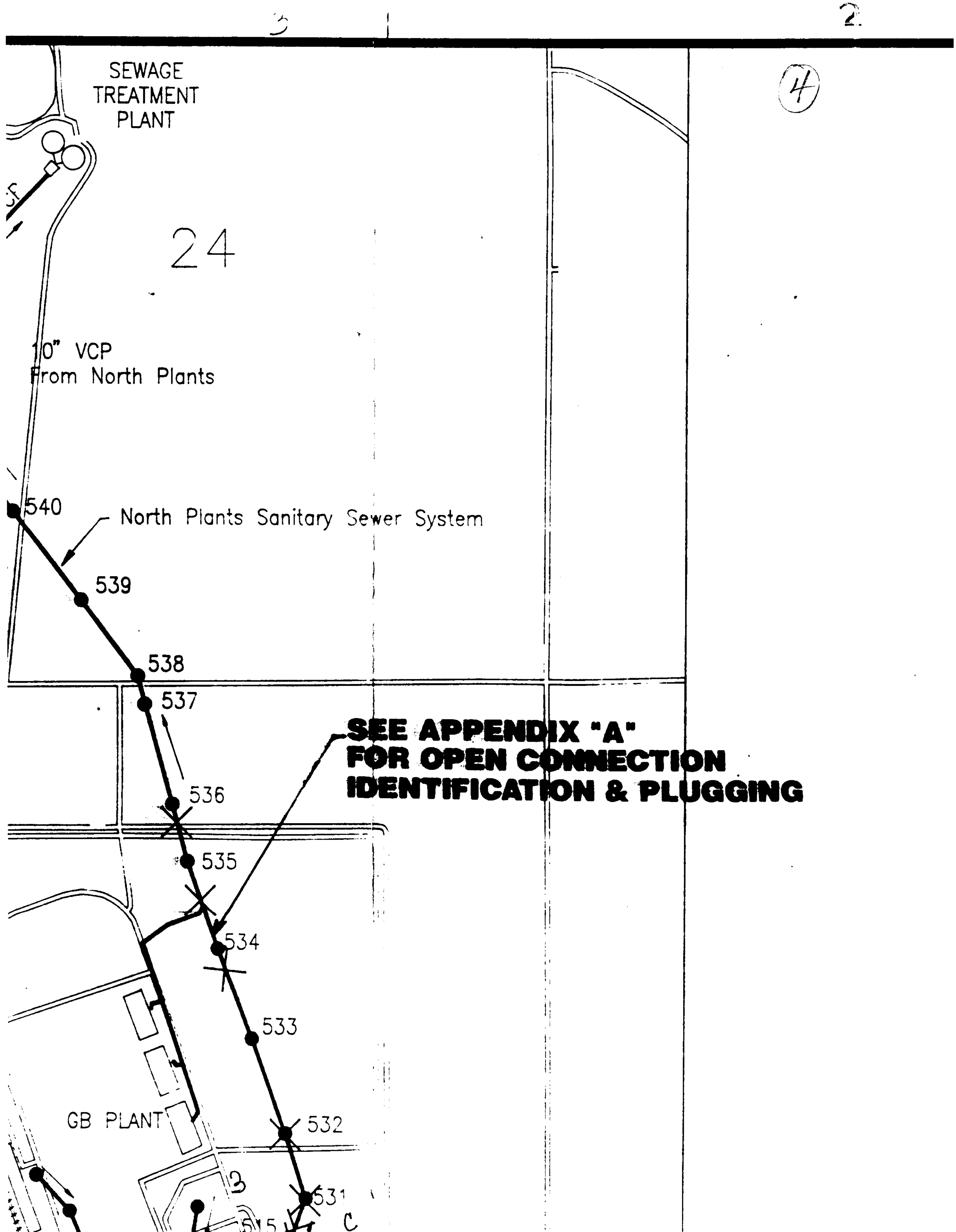

D
C

②


23
1-1/4" Plastic
on Ground Surfa
Buried beyond
this point
25
27
26
29
18" VCP
30
31
31A
32
33
34
FORMER
BASIN "F"
26



③
21
28
SEWAGE
TREATME
PLANT
18" VCP
10
11
(13.7)
10" VCP
From North Pl
13
541
14
540
15
North
16
539
17
18" VCP
18
53
9TH AVENUE
19
5
20
21
-1/4" Plastic Pipe
Ground Surface
22
23
24
4" Plastic Pipe
yond
25
27
Abandoned
Decontamination
Pad
18" VCP
26
31
31A
33
34
GB PLANT
22
25



SEE APPENDIX "A" FOR OPEN CONNECTION IDENTIFICATION & PLUGGING

⑤

NG

LEGEND

18" ▬	SEWER MAIN, WITH SI
VCP	VITRIFIED CLAY PIPE
RC	REINFORCED CONCRET
←	ARROW INDICATES DIR
●	MANHOLE, WITH NUMB
◉	MANHOLE INSPECTED
△	MANHOLE BORING, WI BORING (FT)
▩	TRENCH, WITH NUMB
☒	SEPTIC TANK
×	POSSIBLE OPEN SEW
⊡	INDICATES MANHOLE PLANT SEWER SHEET

4

6

LEGEND

MAIN, WITH SIZE

ED CLAY PIPE

RCED CONCRETE

INDICATES DIRECTION OF FLOW

LE, WITH NUMBER

LE INSPECTED DURING SURVEY

LE BORING, WITH DEPTH OF
G (FT)

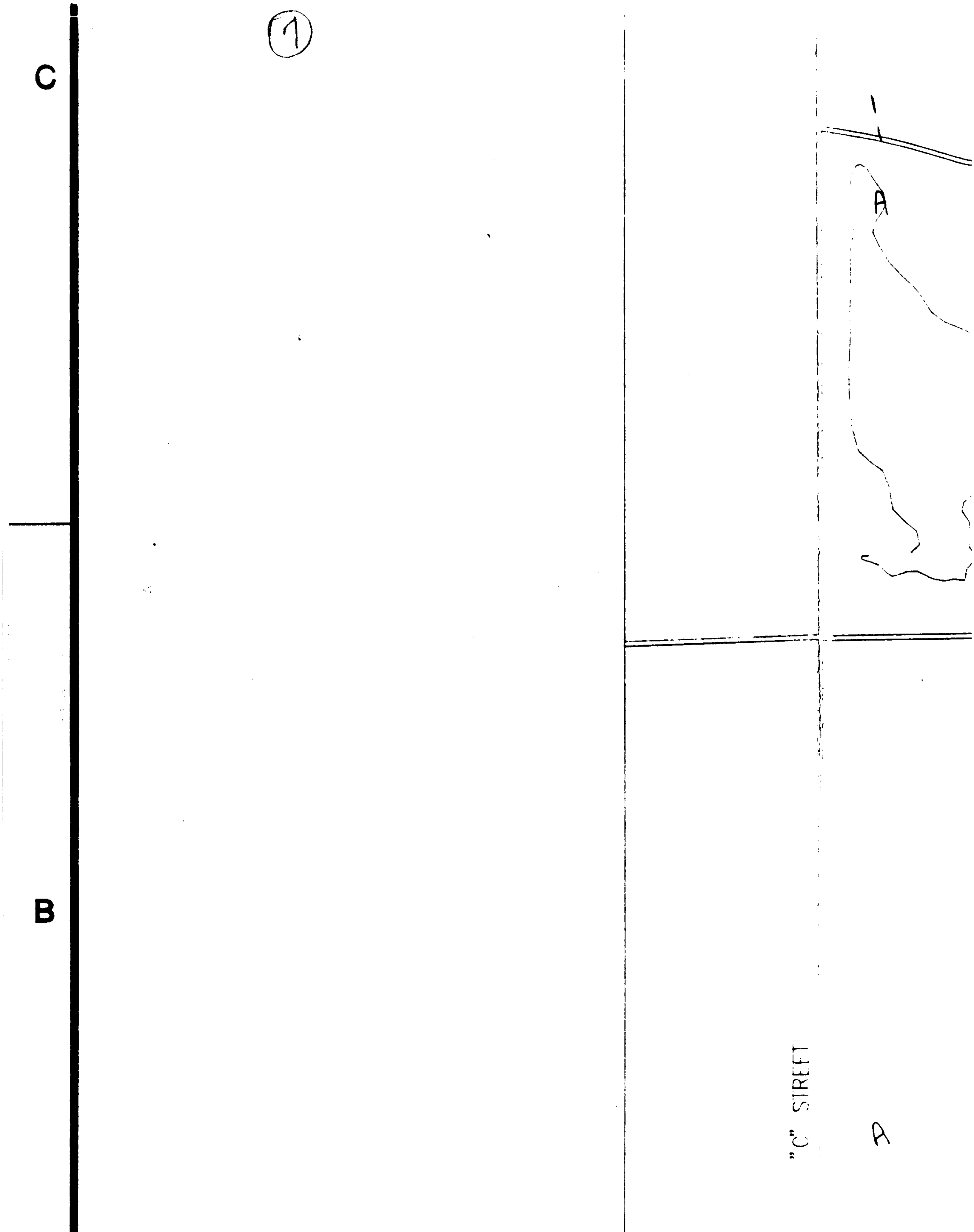
H, WITH NUMBER

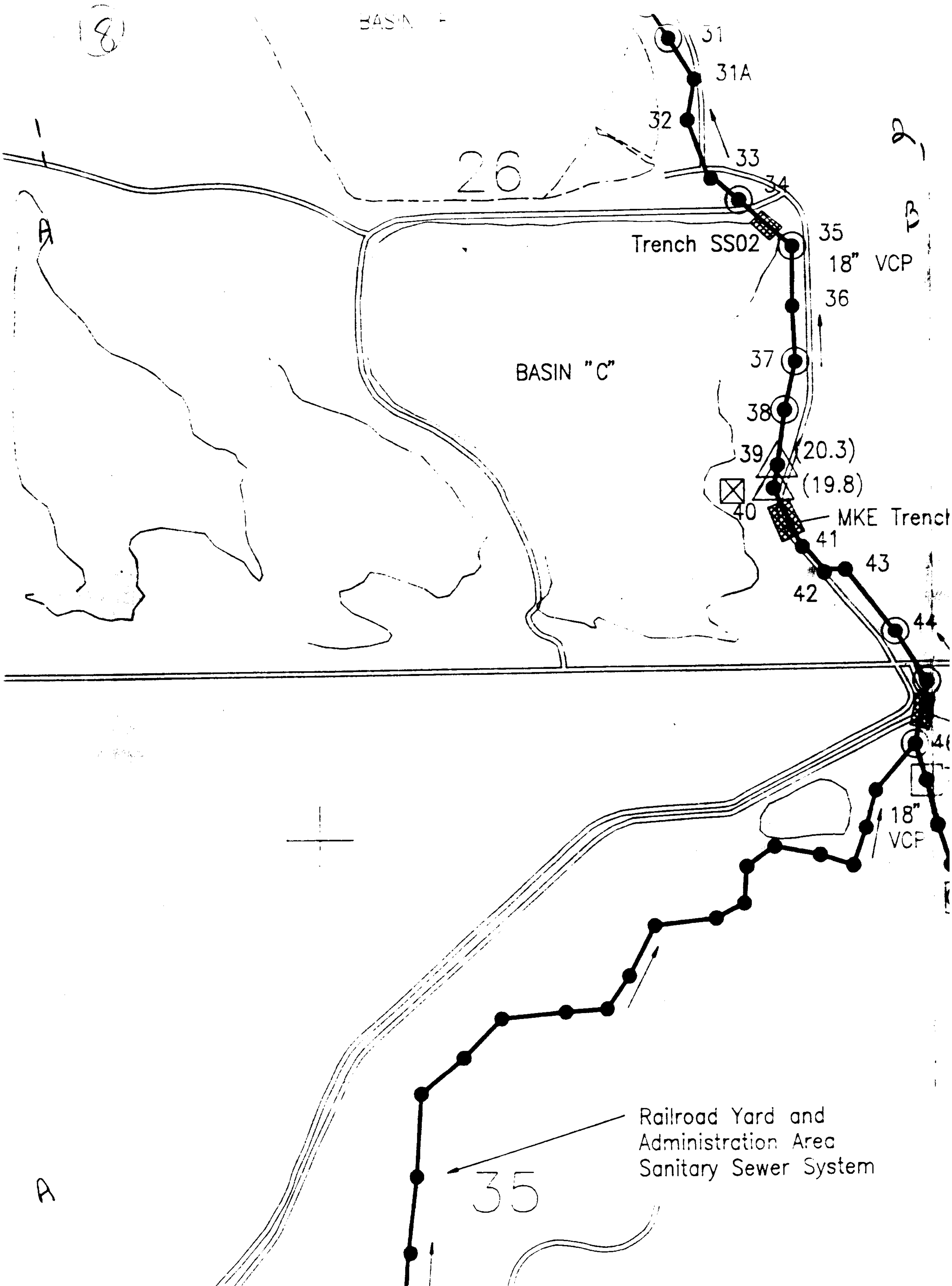
TANK

BLE OPEN SEWER CONNECTIONS

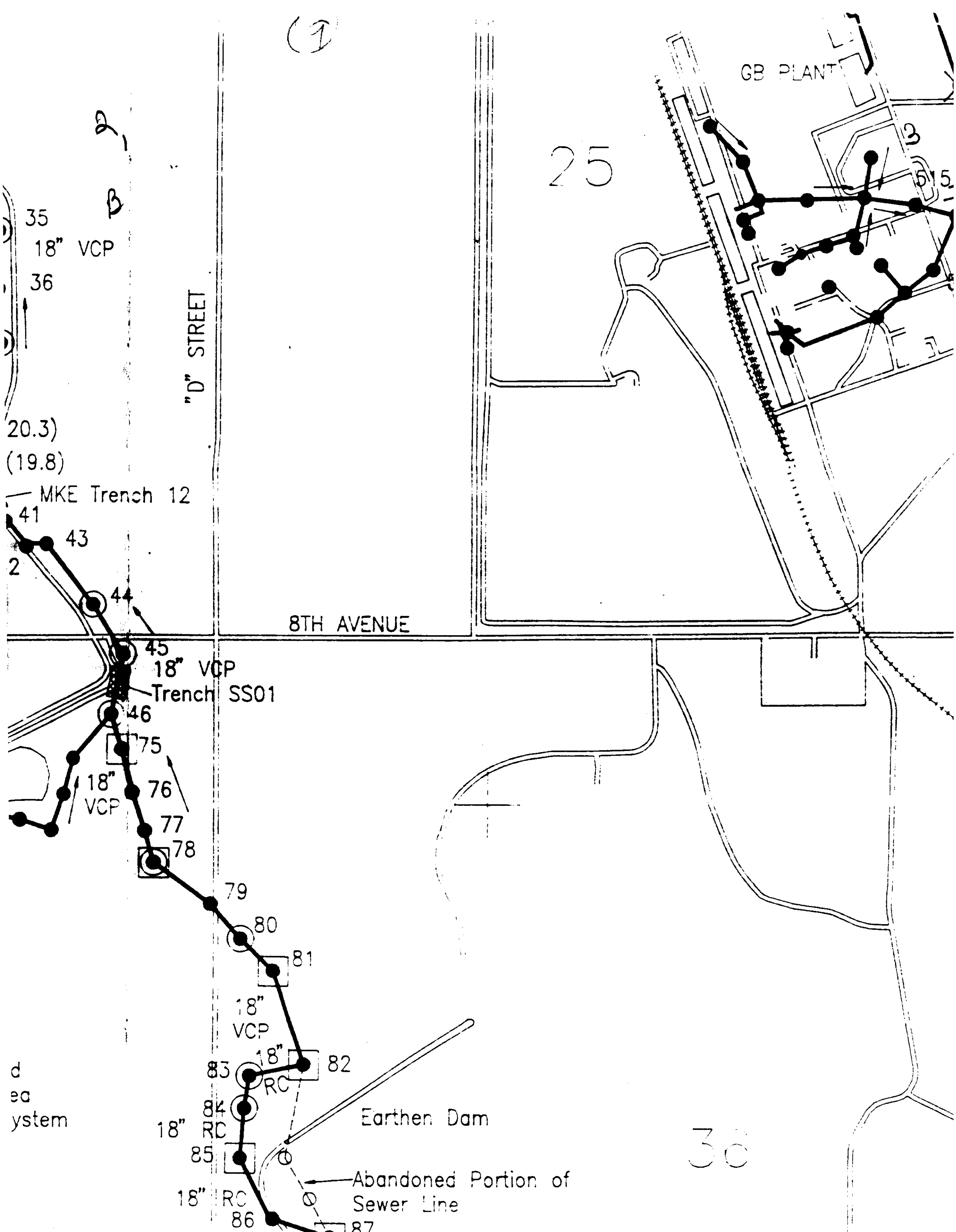
TES MANHOLE FOR CLOSURE – RE: SOUTH
SEWER SHEET FOR DETAIL

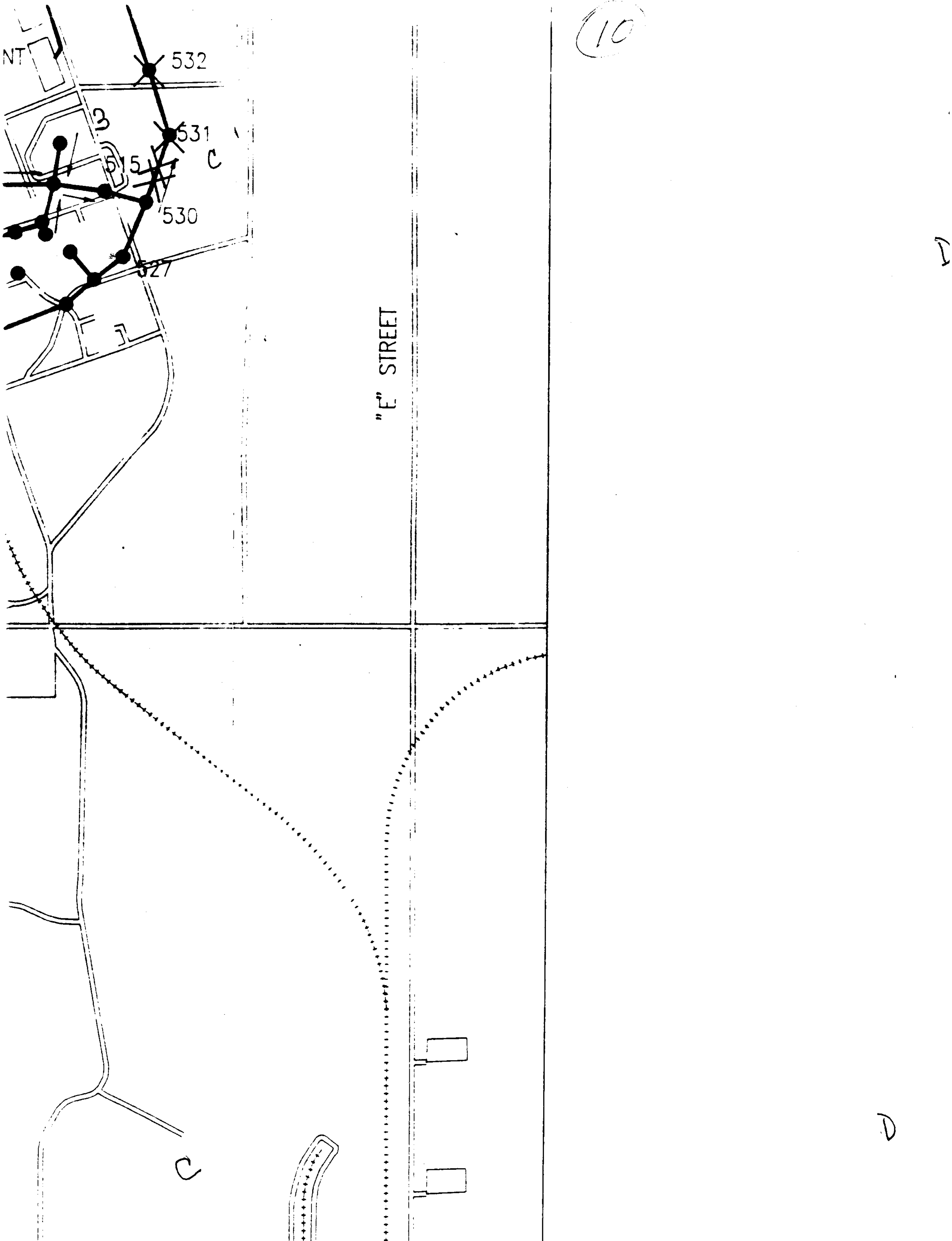
5


⑦
C
1
A
B
"C" STREET
A



Railroad Yard and
Administration Area
Sanitary Sewer System


(1)
2
β
GB PLANT
3
5 5
25
35
18" VCP
36
"D" STREET
20.3)
(19.8)
MKE Trench 12
41
43
2
44
8TH AVENUE
45
18" VCP
Trench SS01
46
75
18" VCP
76
77
78
79
80
81
18" VCP
82
83
18" RC
84
18" RC
85
18" RC
86
87
d
ea
ystem
Earthen Dam
Abandoned Portion of Sewer Line
36

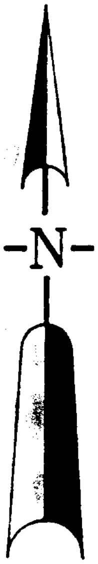

10
NT
532
3
531
515
C
530
527
"E" STREET
D
C
D

⑪

4

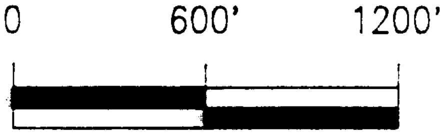
⊡ INDICATES MANHOLE FOR CLOSURE –
PLANT SEWER SHEET FOR DETAIL

D



SCALE: 1" = 600'

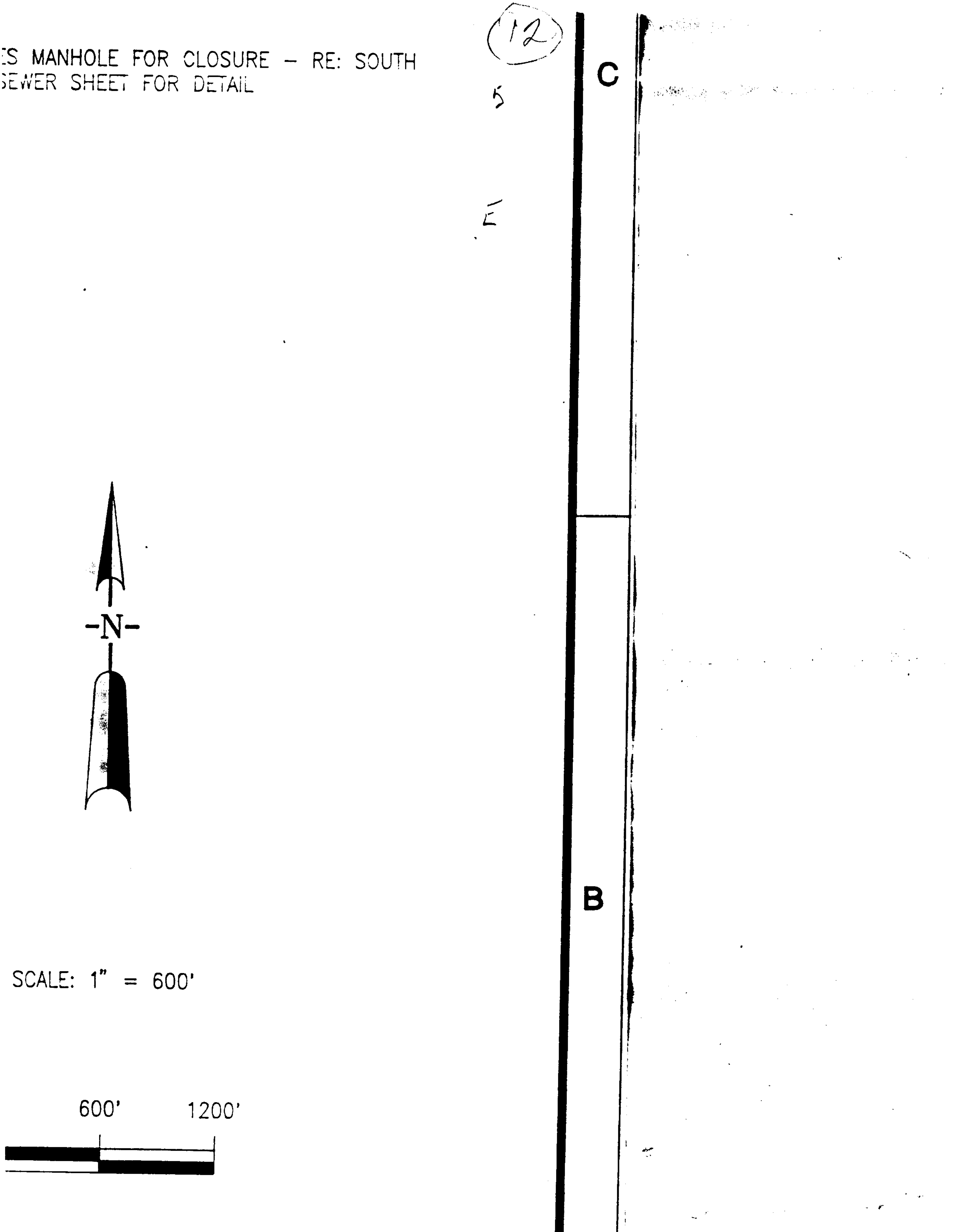
D

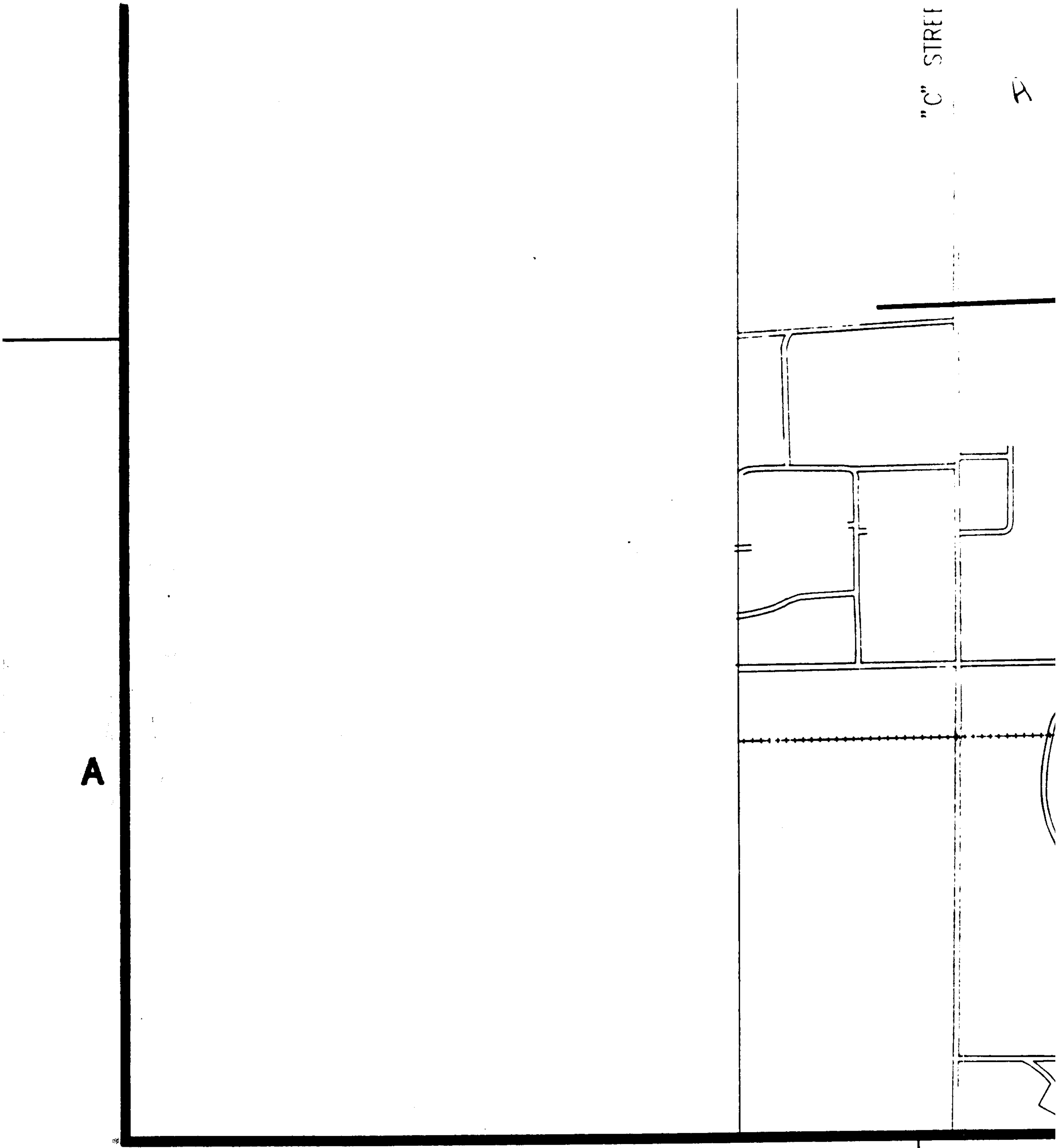


12

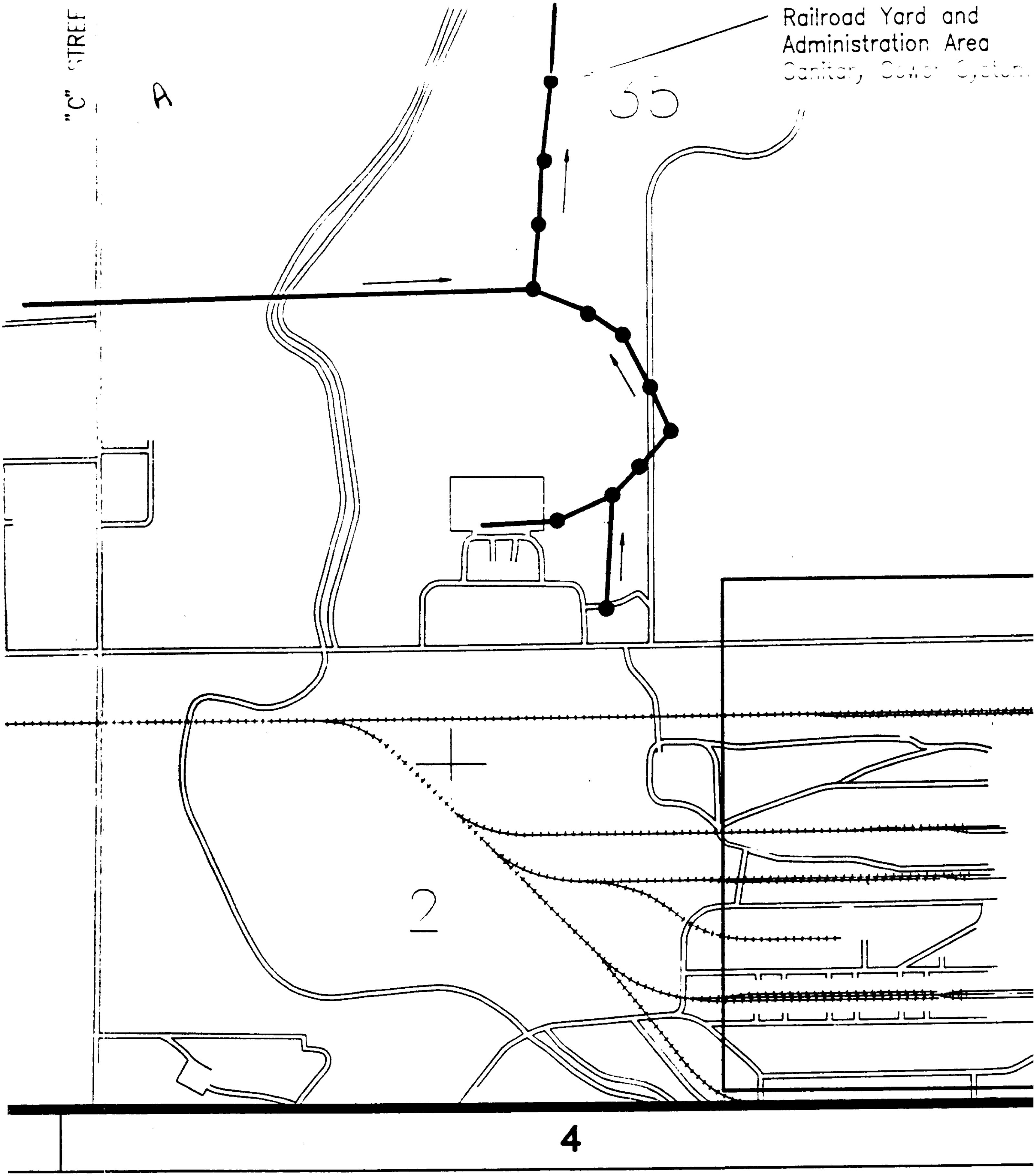
5

E

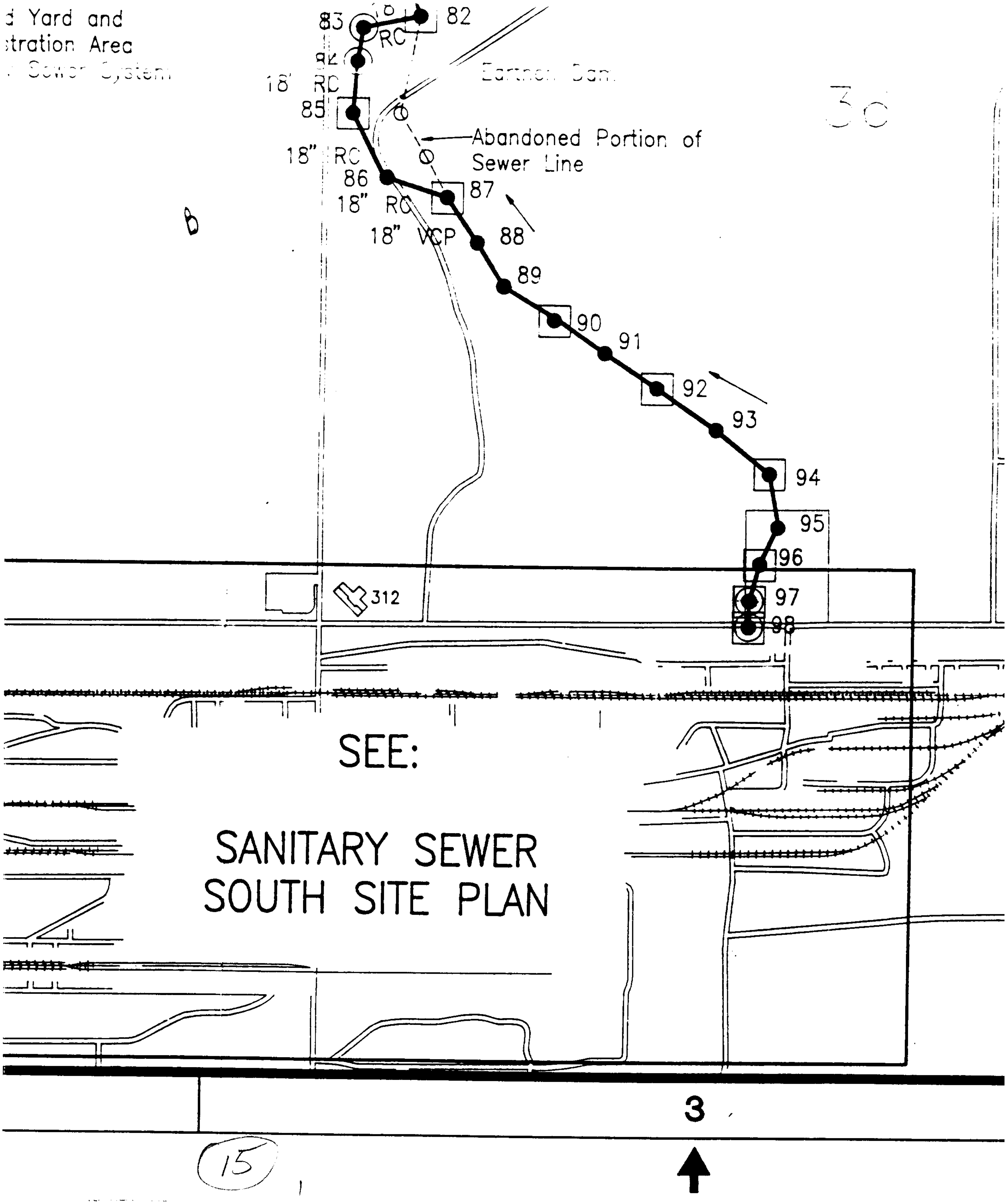

S MANHOLE FOR CLOSURE – RE: SOUTH
EWER SHEET FOR DETAIL
C
B
-N-
SCALE: 1" = 600'
600'
1200'



RMA600A.MB011590

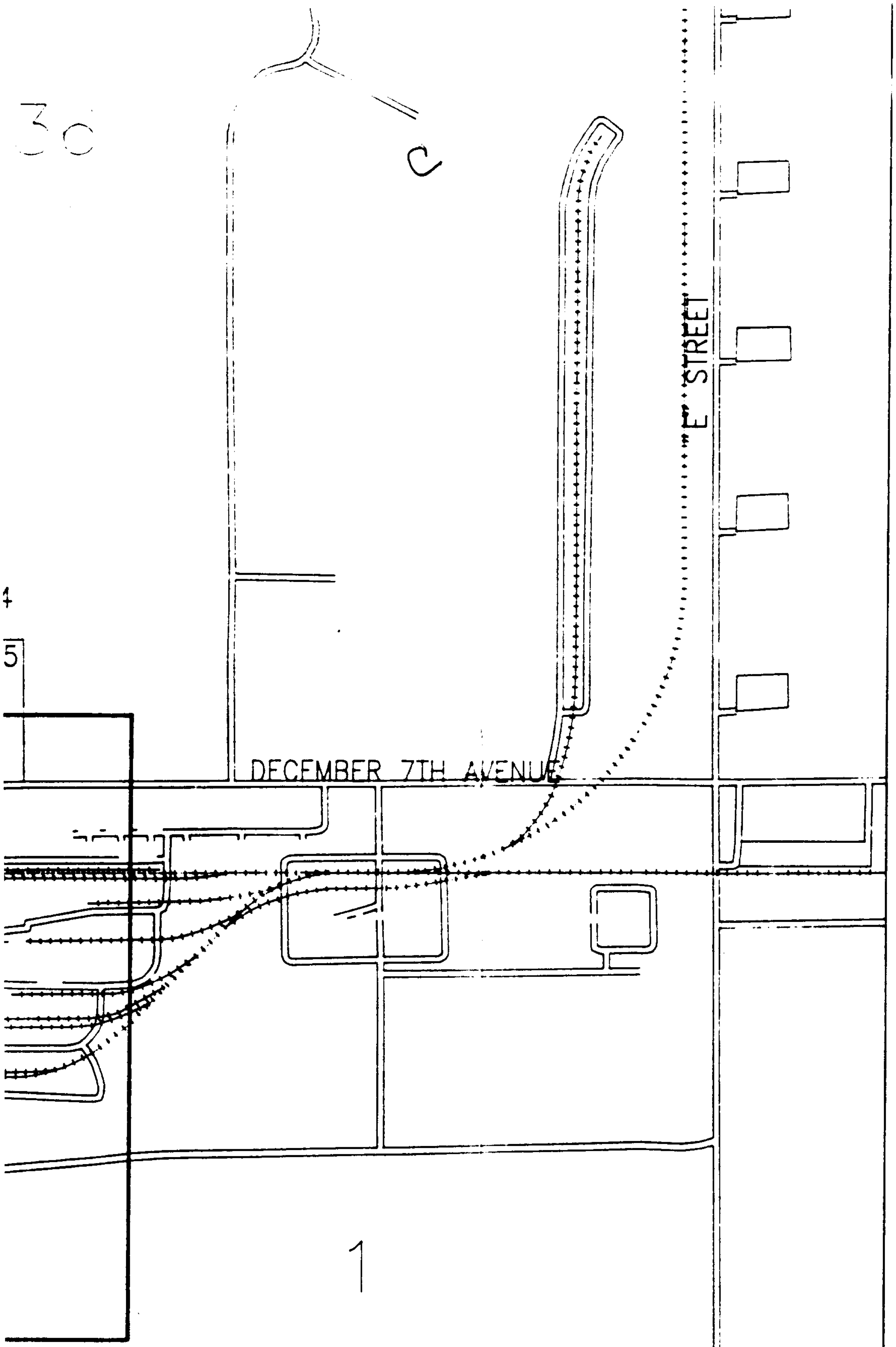

Railroad Yard and
Administration Area
Sanitary Sewer Syste

14


d Yard and
stration Area
Sewer System
Earthen Dam
30
82
83
18
RC
84
18' RC
85
18" RC
86
18" RC
18" VCP
87
Abandoned Portion of
Sewer Line
88
89
90
91
92
93
94
95
96
97
98
312
SEE:
SANITARY SEWER
SOUTH SITE PLAN
3

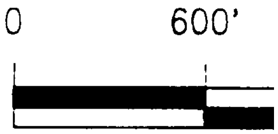
15

3c



2

16



$$ THINK VALUE EN

	Revisions
Symbol	Descriptions

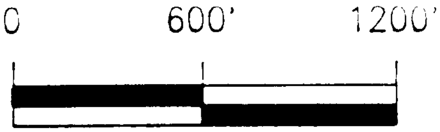
ROY F. WESTON, INC.
DENVER, COLORADO

U

Designed by: KKK	ROCKY MOUN SA NOR
Drawn by: MFB	
Checked by: CPW	
Reviewed by:	Scale: 1" = 600'
	Spec. No.
Submitted by:	Contract No.

2

⑰



$$ THINK VALUE ENGINEERING $$

Revisions		
Descriptions	Date	Approved

WESTON, INC.
R, COLORADO

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
OMAHA, NEBRASKA

ROCKY MOUNTAIN ARSENAL, COLORADO
SANITARY SEWER

NORTH SITE PLAN

A

Scale: 1" = 600'	Sheet Reference Number.	Date: JANUARY 1990
Spec. No.		Drawing Code:
Contract No.		

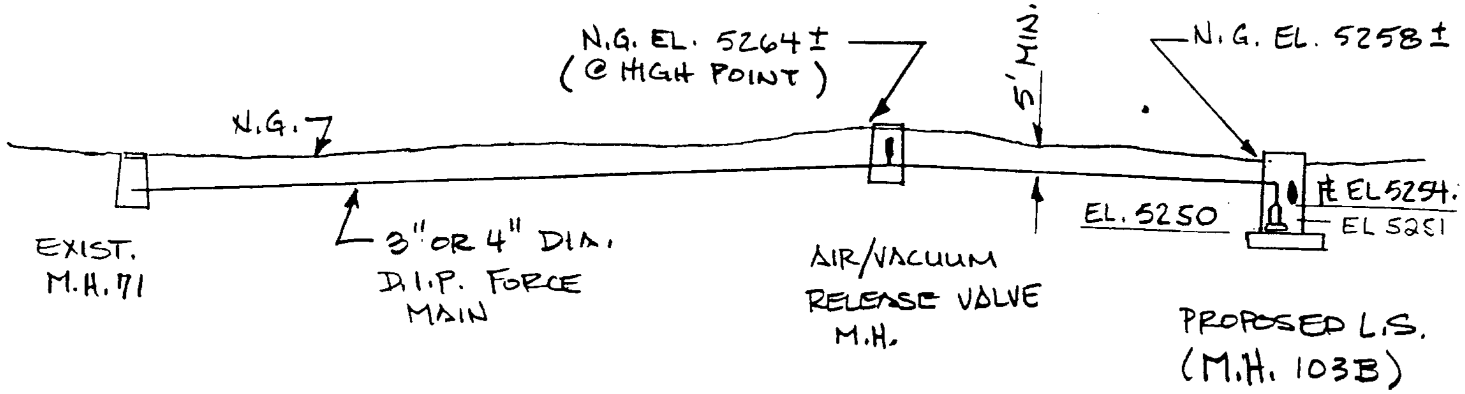
18

APPENDIX D

WESTON
MANAGERS DESIGNERS/CONSULTANTS

CLIENT/SUBJECT Rocky Mtn. Arsenal
SHEET 1 of 10
W.O. NO. 5300-01-03
TASK DESCRIPTION Lift Station & Force Main
TASK NO. 0050
PREPARED BY MAA DEPT 1920 DATE 11-29-89
MATH CHECK BY ______ DEPT ______ DATE ______
METHOD REV. BY ______ DEPT ______ DATE ______
APPROVED BY ______
DEPT ______ DATE ______

DESIGN CRITERIA



FORCE MAIN PROFILE

FLOW

$Q_{\text{FIRE HOUSE}}$ = 1,250 GPD (PEAK) NOTE using a 2.5 peaking factor.
$Q_{\text{DECON PAD}}$ = 7,500 GPD.
$Q_{\text{INTERM.}}$ = 8,750 GPD.
$Q_{\text{CONSTR. TRAILERS}}$ = 5,000.
Q_{PEAK} = 13,750 GPD (9.5 gpm)

TDH

STATIC HEAD = 5259 - 5251 = 8 FT.

LINE LOSSES: ASSUME 3"φ D.I.P.

a) LEAD ON - C = 100 ← Old Ductle Iron.
- C = 140 ← Ductle Iron New.

b) LEAD + LAG - C = 100
C = 140

SHEET 2 of 10
CLIENT/SUBJECT ROCKY MOUNTAIN ARSENAL
W.O. NO. 5300-01-03
TASK DESCRIPTION PUMP SELECTION
TASK NO. 0050
PREPARED BY JBM DEPT 1920 DATE 12-3-89
MATH CHECK BY DEPT DATE
METHOD REV. BY DEPT DATE
APPROVED BY
DEPT DATE

DESIGN CRITERIA SUMMARIZED:

Two - Grinder Sewage Pumps. -

Design Flow: Q_{in}. $Q_{firehouse} + Q_{deconpad} = Q_{design}$.

$1{,}250$ GPD + $7{,}500$ GPD = $8{,}750$ GPD.

$8{,}750 \text{ GPD} \left(\frac{\text{Day}}{24 \text{hr}}\right) \frac{1 \text{hr}}{60 \text{min}} = 6.08 \text{ GPM}$.

Static Head: $H_s = 11'$

Pipe: Assume 3" ϕ P.I.P. - 3,300 LF

$Q_{out} = 60$ GPM . . . . Higher flow rate used - for more efficient, reliable pump. & to provide velocities over 2'/sec.

STATION PIPING

2 × 90° Bend 3" ϕ @ 7.67' = 15.34'
Straight Run - of station piping = 9.0'
1 × 3" Check Valve - full open. = 25.5'
1 × 3" Gate Valve - full open. = 2.04'
1 - Standard Tee - branch flow. = 15.3'

Total Equivalent L.F = 67.0'

DESIGN EQUIVALENT L.F.

$L.F._{station} + L.F._{force\ main} = L.F.$

$67' + 3{,}300' = 3{,}367'$

SHEET 3 of 10
CLIENT/SUBJECT ROCKY MOUNTAIN ARSENAL. W.O. NO. 5300-01-03
TASK DESCRIPTION PUMP SELECTION TASK NO. 0050
PREPARED BY JBM. DEPT 1920 DATE 12-4-89.
MATH CHECK BY DEPT DATE
METHOD REV. BY DEPT DATE
APPROVED BY
DEPT DATE

C = 140 (Ductle Iron New).
3" ∅ - 3,370 LF of Pipe

Q (GPM).	h_f. loss per 1000'	H_f	Hs.	TDH	$V_{3''}$ ft/sec.
0	0	0	8'	8'	
10	.37	1.3.		9'	.45
15	.79.	2.7		11'	.68
20	1.35	4.5		12.5	.91
25.	2.04	7.0		15	1.13
30	2.87	9.7		18	1.36
35	3.81	12.8		21	1.59.
40	4.89.	16.5		25	1.82
50	7.4	25.0		33	2.27
60	10.3	34.7		43	2.72
80.	17.6	59.0	8'	67.	3.63

WESTON
MANAGERS DESIGNERS CONSULTANTS

SHEET 4 of 10

CLIENT/SUBJECT ROCKY MOUNTAIN ARSENAL W.O. NO. 5300-01-03
TASK DESCRIPTION PUMP SELECTION TASK NO. 0050
PREPARED BY JBM. DEPT 1920 DATE 12-4-89.
MATH CHECK BY DEPT DATE
METHOD REV. BY DEPT DATE

APPROVED BY
DEPT DATE

C = 100 (Old Ductle Iron)
3" ∅ - 3,370 LF of pipe).

Q (GPM)	hf (per 1000')	Hf.	Hs	TDH.	V3" ft/sec.
0	0	0	8'	8'	
10	.7	2.36		10	.45
15	1.5	5.06		13	.68
20	2.5	8.42		16.5	.91
25	3.8	12.81		21	1.13
30	5.4	18.2		26	1.36
35	7.1	24.0		32	1.59
40	9.1	30.67		39.	1.82
50	13.8	46.51		55.	2.27
60	19.2	64.70		73	2.72
80	32.8	110.54.	8'	119	3.63

← MIN SELECTED (50)

3-INCH PIPE.

(Actual diameter, 3.00 ins.)

Discharge in Gallons.		Velocity in Feet per Second.	Velocity Head, Feet.	Loss of Head in Feet per 1000 feet of length.						
Per Minute.	Per 24 Hours.			Very Smooth and Straight Brass, Tin, etc. c=140	Ordinary Straight Brass, Tin, etc. c=130	Smooth New Iron. c=120	Ordinary Iron. c=100	Old Iron. c=80	Very Rough. c=60	Badly Tuberculated. c=40
10	14,400	0.45	0.00	0.37	0.43	0.50	0.7	1.0	1.8	3.8
15	21,600	0.68	0.01	0.79	0.91	1.06	1.5	2.2	3.8	8.1
20	28,800	0.91	0.01	1.35	1.55	1.80	2.5	3.8	6.5	13.8
25	36,000	1.13	0.02	2.04	2.34	2.71	3.8	5.8	9.8	20.8
30	43,200	1.36	0.03	2.87	3.29	3.81	5.4	8.1	13.8	29.2
35	50,400	1.59	0.04	3.81	4.38	5.1	7.1	10.7	18.3	38.9
40	57,600	1.82	0.05	4.89	5.6	6.5	9.1	13.8	23.5	49.7
50	72,000	2.27	0.08	7.4	8.5	9.8	13.8	20.8	35.5	75
60	86,400	2.72	0.12	10.3	11.8	13.7	19.2	29.1	49.6	105
70	100,800	3.18	0.16	13.8	15.8	18.3	25.7	38.8	66	140
80	115,200	3.63	0.20	17.6	20.2	23.4	32.8	49.6	84	179
90	129,600	4.09	0.26	21.9	25.1	29.1	40.8	62	105	223
100	144,000	4.54	0.32	26.7	30.6	35.2	49.6	75	128	271
120	172,800	5.45	0.46	37.2	42.8	49.7	70	106	179	380
140	201,600	6.35	0.63	49.6	57	66	92	139	238	510
160	230,400	7.26	0.82	64	73	84	118	179	306	650
180	259,200	8.17	1.04	79	91	106	148	223	380	810
200	288,000	9.08	1.28	96	110	128	178	271	461	980
220	316,800	9.99	1.55	114	132	153	213	323	550	1170
240	345,600	10.89	1.84	134	154	179	251	380	650	1370
260	374,400	11.80	2.16	156	170	208	291	440	750	1590
280	403,200	12.71	2.51	179	206	238	331	510	860	1830
300	432,000	13.62	2.88	204	233	271	380	580	980	2080
320	460,800	14.52	3.28	229	263	306	428	650	1110	2330
340	489,600	15.43	3.71	257	294	342	479	720	1230	2610
360	518,400	16.34	4.15	286	328	380	530	800	1370	2910
380	547,200	17.25	4.62	317	361	420	590	890	1520	3210
400	576,000	18.16	5.11	348	399	461	650	980	1670	3520
420	604,800	19.06	5.64	380	436	510	710	1070	1830	3870
440	633,600	19.97	6.20	414	475	550	770	1170	1980	4220
460	662,400	20.88	6.78	449	520	600	840	1270	2160	4570
480	691,200	21.79	7.38	488	560	650	910	1370	2330	4980
500	720,000	22.70	8.00	530	610	700	980	1480	2520	5400
550	792,000	24.96	9.70	620	720	840	1170	1770	3010	6400
600	864,000	27.23	11.50	740	840	980	1370	2070	3520	7400

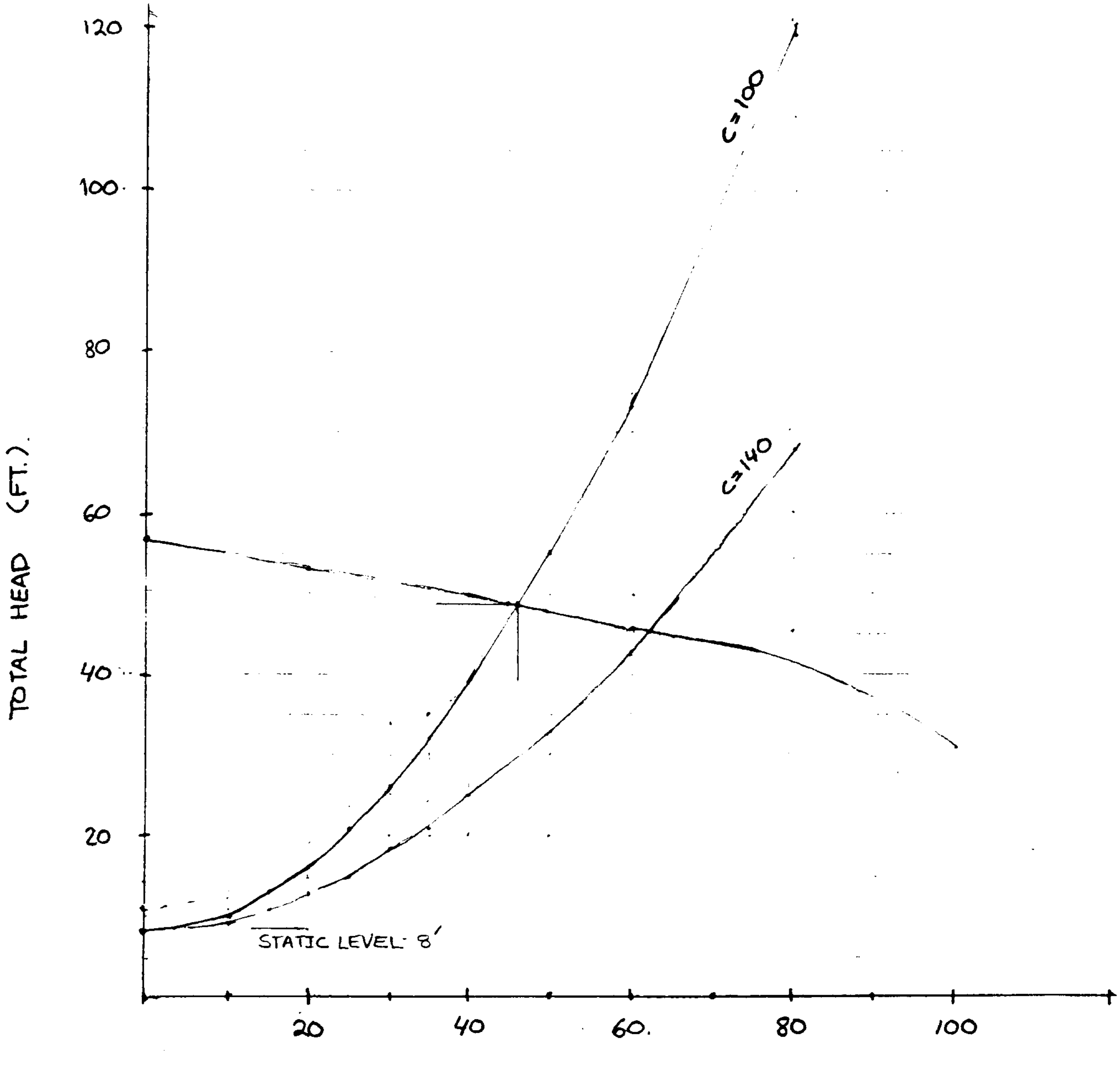
WESTON
MANAGERS DESIGNERS/CONSULTANTS

SHEET 6 of 10

CLIENT/SUBJECT Rocky Mountain Arsenal W.O. NO. 5300-01-03

TASK DESCRIPTION Pump Selection TASK NO. 0050

PREPARED BY JBM.	DEPT 1920.	DATE 12-4-89.	APPROVED BY
MATH CHECK BY	DEPT	DATE	
METHOD REV. BY	DEPT	DATE	DEPT DATE



Q (GPM). Design = 60 GPM.

HYDROMATIC PUMP - MODEL 62FX500.
w/ impeller dia. 8 1/4"
MOTOR RATED @ 5 H.P., 1750 rpm.
from Hydromatic Pump Bulletin SPG-207.

SUBMERSIBLE GRINDER PUMPS

Model	Discharge (Inches)	H.P.	Capacities GPM to	 LPM to	Heads To (ft.)	 (m)	Motor Speeds RPM	Electrical Voltage
SPG200/NSPG200/G1X	1¼	2	60	227	102	31.1	3450	200/230/460
SPGL200/G1LX	1¼	2	52	197	68	20.7	3450	200/230/460
SPGH300/G2HX300	2	3	102	386	105	32.0	3450	200/230/460
SPGF300/G2FX300	2	3	140	530	52	15.8	1750	200/230/460
SPGH500/G2HX500	2	5	112	424	165	50.3	3450	200/230/460
SPGF500/G2FX500	2	5	185	700	97	29.6	1750	200/230/460
SPGH750	2	7½	118	446	202	61.6	3450	230/460
G2FX750	2	7½	200	757	110	33.5	1750	230/460

NOTE: All models thru 5 HP available in single phase except G2FX500

HORIZONTAL GRINDER PUMPS

Model	Discharge (Inches)	H.P.	Capacities GPM to	 LPM to	Heads To (ft.)	 (m)	Motor Speeds RPM	Electrical Voltage
PG200/NPG200	1¼	2	42	159	92	28.0	3450	200/230/460

NOTE: "X" in model number denotes explosion-proof construction
"N" in model number denotes Naval bronze construction

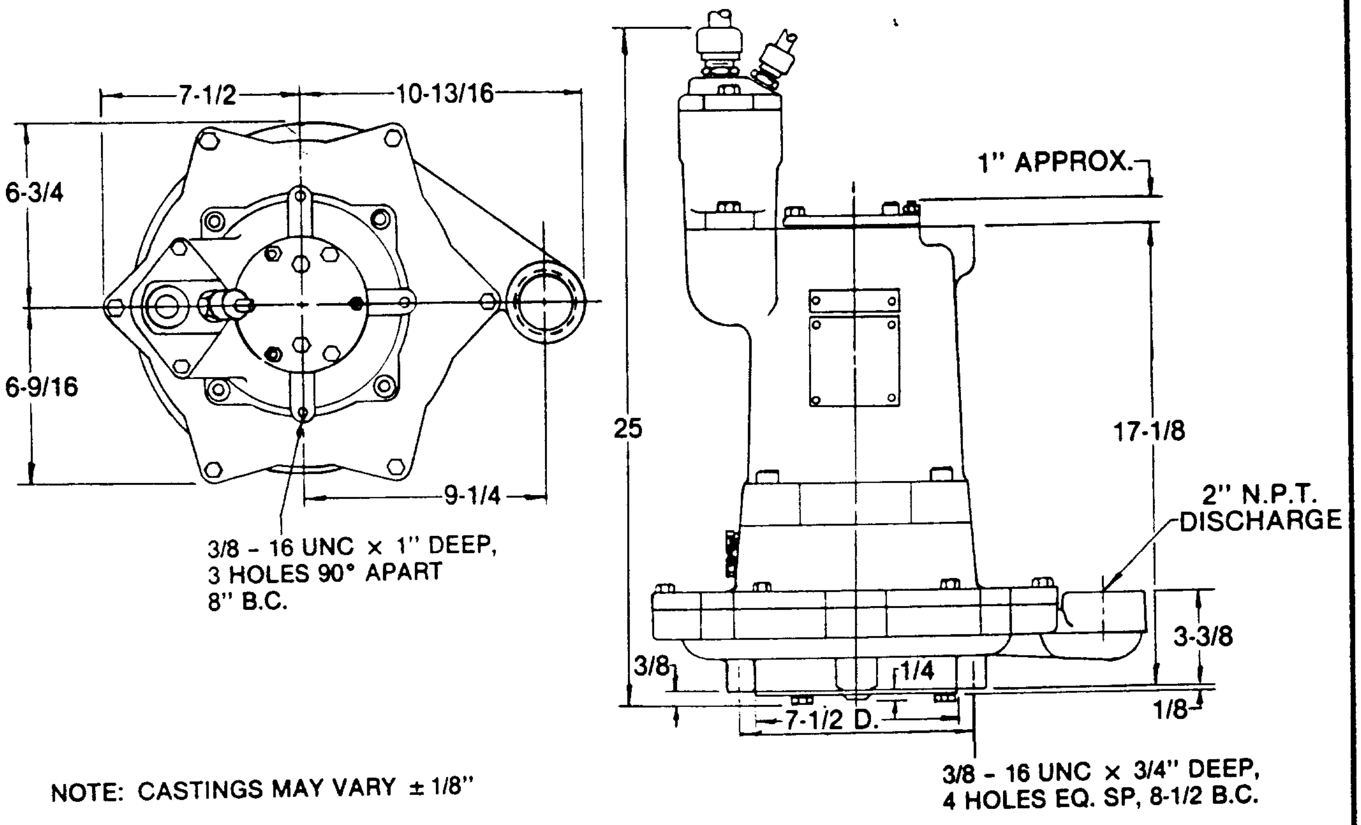
HYDROMATIC PUMPS

AMERICA'S

MARLEY
THE MARLEY PUMP COMPANY

The Marley Pump Company • 5800 Foxridge Drive, Mission, KS 66202 • Phone 1-800-HOT-PUMP

MODEL G2FX SUBMERSIBLE GRINDER PUMP

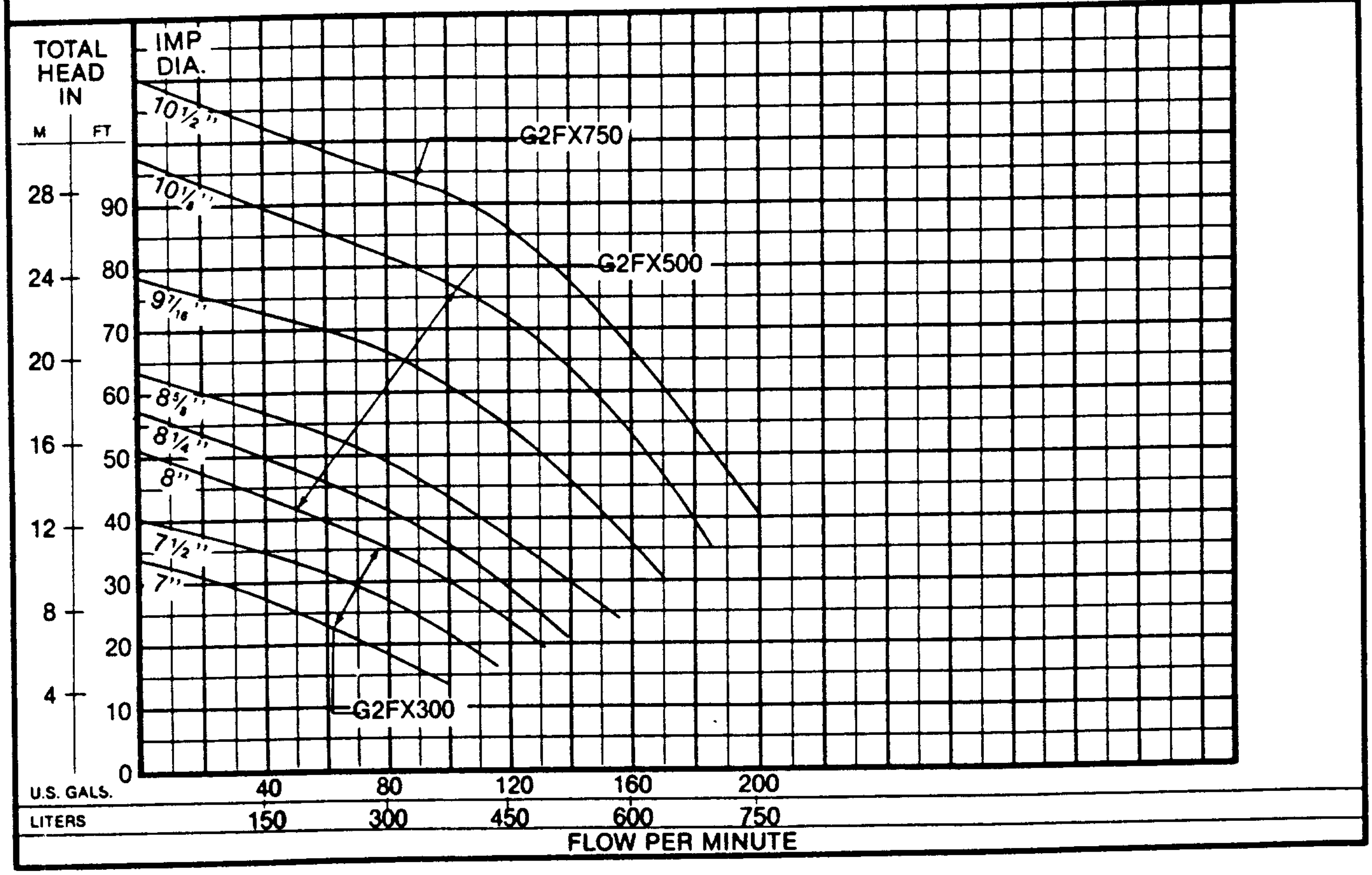


3/8 - 16 UNC × 1" DEEP,
3 HOLES 90° APART
8" B.C.

3/8 - 16 UNC × 3/4" DEEP,
4 HOLES EQ. SP, 8-1/2 B.C.

NOTE: CASTINGS MAY VARY ± 1/8"

MODELS G2FX300, G2FX500, G2FX750 3, 5, & 7½ HP GRINDERS 1750 RPM



SHEET 9 of
CLIENT/SUBJECT Rocky Mountain Arsenal
W.O. NO. 5300-01-03
TASK DESCRIPTION Storage Depth
TASK NO. 0050
PREPARED BY JBM DEPT 1920 DATE 12-5-89
MATH CHECK BY DEPT DATE
METHOD REV. BY DEPT DATE
APPROVED BY
DEPT DATE

DETERMINE STORAGE DEPTH:

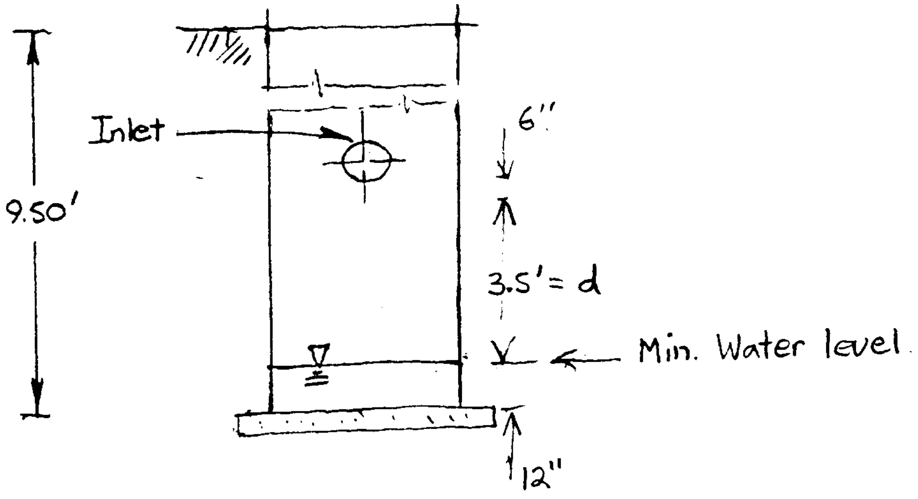
Design. Criteria

- 2 Alternating pumps.
- Only one pump used at a time.
- Use 5' I.D. R.C.P. Wet Well.
- Minimum Cycle Time for ½-15 HP motors = 10 min.
- Q = Flow of One Pump = 60 GPM

$$V = \frac{T_c}{4} Q_p$$

$$\frac{10\,\text{min}}{4} \cdot 60\,\text{GPM} = 150\,\text{Gal} \Rightarrow 150\,\text{Gal}\left(\frac{\text{ft}^3}{7.48\,\text{Gal}}\right) = 20.\ \text{ft}^3$$

$$d = \frac{V}{\pi r^2} = \frac{20\,\text{ft}^3}{\pi (2.5')^2} = 3.20' \quad \text{use} \quad \underline{\underline{3.5'}}$$



WESTON
MANAGERS DESIGNERS CONSULTANTS

SHEET 10 of 10

CLIENT/SUBJECT ROCKY MOUNTAIN ARSENAL. W.O. NO. 5300-01-03
TASK DESCRIPTION PUMP STATION BOUYANCY TASK NO. 0050
PREPARED BY JBM. DEPT 1920 DATE 12-6-89.
MATH CHECK BY ______ DEPT ______ DATE ______
METHOD REV. BY ______ DEPT ______ DATE ______

APPROVED BY ______
DEPT ______ DATE ______

Upward. forces:

Volume displaced = Vol pipe + Vol base.

$= \pi r^2 l + \pi r^2 l.$

$= \pi 3^2 (9.5) + \pi (4)^2 \cdot 2' = 369 \text{ ft}^2.$

Uplift. $396 \text{ ft}^3 \cdot 64 \frac{\text{lbf}}{\text{ft}^3} = 25,344 \text{ lb.}$

Note: Assuning water table at top of grade.

Downward Forces.

Base WT. $= \pi (4)^2 (2') \times \frac{150 \text{ lb}}{\text{ft}^3} = 15,072 \text{ lb.}$

Pipe WT $= [\pi 3^2 (9.5) - \pi (2.5)^2 9.5] \frac{150 \text{ lb}}{\text{ft}^3} = 12,305 \text{ lb.}$

Soil Forces $= [\pi (4)^2 (9.5) - \pi (3)^2 9.5] \frac{90 \text{ lb}}{\text{ft}^3} = \underline{18,793 \text{ lb.}}$

↓ Total Forces. 46,190.

$\frac{46,190 \text{ lb}}{25,344 \text{ lb.}} = 1.82.$ Safety Factor.

APPENDIX E

HEALTH & SAFETY PLAN FOR LOCATING AND PLUGGING OPEN CONNECTIONS IN NORTH PLANTS

INTRODUCTION

This Health and Safety Plan provides guidance and establishes procedures for activities at the Rocky Mountain Arsenal, Denver, Colorado. The intention of the plan is to establish a safety policy and general standards, and to provide the framework for more specific safety requirements to be employed. This plan applies to all prime and subcontractor personnel working on this assignment and to visitors at project work locations. All affected personnel will be required to sign a statement to the effect that this document has been reviewed and understood prior to commencement of on-site activities and/or visits to the work location.

SECTION 1.0

PROJECT BACKGROUND

The North Plants facility operated during the time between 1950 and 1976. From 1973 to 1976 demilitarization of GB munitions was performed in the North Plants area. Chemical compounds and their by-products have migrated into the environment throughout the years. Soils, ground water, and surface water have been recognized as contaminated from North Plants production activities.

Black and Vetch identified seven lateral openings of the North Plant sewer line located in Section 25 of the RMA which were noted as either extending above ground, flush with ground, or flush with concrete slab. These several lateral openings were recognized as potential sources contributing to the contaminated surface water infiltration mainly because of primary contaminant source location.

SECTION 2.0

SCOPE OF WORK

To prevent further surface water infiltration into the sewer line, the seven lateral sewer pipe openings at ground level will be plugged. PVC or similar material will be used to plug the opening.

SECTION 3.0

HAZARD IDENTIFICATION AND RISK ASSESSMENT

The hazards classes to be encountered with the locating and plugging of open sewer connections in the North Plants area includes chemical contaminants, biological hazards and physical hazards.

This section describes those hazards and determines the likelihood of exposure with concurrent or subsequent adverse effects.

3.1 PHYSICAL HAZARD ASSESSMENT

Accidents involving physical hazards can directly injure workers. Construction projects have their own variety of potential physical hazards including heat and cold stress disorders related to hard physical labor. These topics are discussed in detail below.

3.1.1 Inclement Weather

Heat, rain, cold, snow, ice and lightning are natural phenomena which complicate work activities and add or increase risk. Much of the responsibility for protection from inclement weather hazards falls upon the Site Health and Safety Coordinator (SHSC). The SHSC must recognize the inclement weather hazards affecting site for which he is responsible and complete the pre-site activity risk assessment when inclement weather occurs. The SHSC must recognize which weather conditions affect instrument and Personal Protective Equipment function and constantly remind site workers of the effects and need for more careful attention to check-out, donning and doffing and monitoring of function and integrity. The SHSC must make decisions on the proper safety procedures to use if work must continue or to stop work if the risk is too great.

3.1.1.1 Heat Stress

The potential for heat stress is a concern when field activities are performed on warm, sunny days, and is accentuated when chemical protective clothing is worn. Heat stress prevention measures and monitoring will be implemented if site temperatures are above 70 degrees Fahrenheit F.

Precautions to prevent heat stress will include work/rest cycles so that rest periods are taken before excessive fatigue occurs, and regular intake of water to replace that lost from seating. Work/rest cycles will be based on monitoring the heart rate (pulse) of each individual worker. Rest breaks will be long enough to reduce the heart rate (HR) below levels calculated according to the following method:

1. The worker will initially determine his/her resting HR prior to starting work activities.
2. At the start of the first rest period, the worker will determine his/her HR. This initial HR should not exceed the individuals age-adjusted maximum HR, which equals [0.7)(220-age in years)]. At 1 minute into the rest period, the recovery HR will be determined. The recovery HR should not exceed 110 beats per minute.
3. If the initial HR exceeds the age-adjusted maximum HR, or the 1-minute recovery HR is greater than 110 beats p er minute, then the next work period will be decreased by 10 minutes.

Heat stress due to water loss can be prevented. To prevent dehydration, water intake must approximate sweat loss. Water intake guidelines are as follows:

1. The sense of thirst is not an adequate regulator of water replacement needs during heat exposure. Therefore, water must be replaced at prescribed intervals.
    a. Before work begins, drink two 8-ounce glasses of water.
    b. During each rest period, drink at least two 8-ounce glasses of water.
2. Plain water, served cool, is excellent. An adequate supply of potable water and drinking cups will be readily available, such as in a support vehicle, to provide water during rest periods.
3. Adding salt to water is not recommended. However, other fluids, in addition to water, could include diluted fruit juices and electrolyte replacement drinks diluted 3:1 with water. Do <u>not</u> use salt tablets!

An initial work/rest cycle of 1 hour and 15 minutes rest is recommended for protection of staff when the heat stress hazards is high. The recommended cycle will be adjusted up or down based upon worker monitoring, environmental conditions, and the judgement of the SSO. At any time, field team members recognize the signs or symptoms of heat stress prior to a scheduled rest period, they will notify the SAY immediately in order that a rest period can be called.

Heat stress, if not prevented, results in heat stress illness. Two critical illnesses, if not recognized and treated immediately, can become life-threatening. These are heat exhaustion and heat stroke. Heat exhaustion will result if the prevention measures described above are not implemented. Ignoring the signs and symptoms of heat exhaustion will lead to the development of heat stroke.

Heat stroke is an immediate, life-threatening condition that results because the body's heat regulating mechanisms shut down, and the body cannot cool itself sufficiently. As heat is excessively stored in the body, brain damage can results causing permanent disability or death.

3.1.1.2 Cold Stress

The potential for cold stress is a particular concern when field activities are performed while air temperatures at the site are below 40 degrees F. If winds are blowing at 5 mph or greater and/or the weather is damp or wet, cold stress is even more of a potential hazard. Precautions that will be taken to prevent cold stress include wearing cold-protective clothing appropriate for the level of cold and physical activity, changing clothing if it becomes wet, and establishing a work/warming regiment. Cold-protective clothing will include layering of garments and use of gloves and hats. The warming breaks should be taken in a warm location if at all possible; this can include improvising a wind break shelter at the site. During warming breaks taken in the site support zone, warm, sweet beverages and not soups should be consumed to provide calories and fluids. Drinking coffee or other caffeinated beverages is not recommended.

Cold stress, it not prevented, can result in frostbite and hypothermia. Ignoring the signs any symptoms can be life-threatening. Prevention is the key. As a preventative measure, body core temperature must not drop below 96.8 degrees F. Pain in the extremities is the first early warning of cold stress. Severe shivering sets in when body core temperature has dropped to 95 degrees F. If this occurs, work will stop immediately and the affected worker(s) will take a warming break of sufficient duration that the cold stress signs and symptoms are gone. Additional signs of cold stress include deterioration of physical coordination, slurred speech, and faulty judgement.

3.1.1.3 Lightning

Lightning represents a hazard of electrical shock which is increased when working in flat open spaces, elevated work places are working near tall structures or equipment. Stopping work in open areas, around drill rigs or pile driver which may attract lightening, on or in water and in elevated work places when lightning strikes are sighted or thunder is heard near a work site.

3.1.1.4 Hand and Power Tool Safety

Unsafe hand tools shall not be issued or used. All hand tools will be kept in good repair and used only for the purpose for which they were designed. Wrenches with sprung jaws where slippage could occur, impact tools with mushroomed heads and wooden handled tools with cracks or splinters are examples of unsafe hand tools.

Tools having defects that will impair their strength or render them unsafe will be tagged or made inoperable and removed from service.

Guards must be in place during operation on all power tools designed to accommodate them. Guards and safety devices must remain in place on power tools unless removed according to manufacturers instruction for maintenance by a competent person and must be replaced before use. Belts, gears, shafts, drums, fly wheels, chains or other rotating, reciprocating or moving parts exposed to employee contact or representing other hazard must be guarded.

Proper PPE must be used when operating power tools or hand tools which may produce projectiles, cuts or abrasions, dusts, fume, mists or light or which pose a risk of harm to arms, legs, or feet if dropped.

Throwing tools or materials from one location to another, from one person to another, or dropping them to lower levels, is not permitted.

Power tools will be inspected, tested, and determined to be safe for operation prior to use. Continued periodic inspections will be made to assure safe operating condition and proper maintenance.

Electric powered tools must be approved double insulated or grounded in accordance with 1926.404.

Rotating or reciprocating portable power tools will have a constant pressure switch that will shut off the power when the tool is released by the operator. A portable power tool may have a lock-on control provided turn-off can be accomplished by a single motion of the same finger or fingers that turned it on.

Loose and frayed clothing, loose long hair, dangling jewelry, rings, chains, and wrist watches will not be worn while working with any power tool or machine.

3.2 CHEMICAL HAZARD ASSESSMENT

Chemical hazards which may be encountered during the sewer line plugging activity are directly related to the chemical and physical properties of the compounds that are present in the ground water that is infiltrating the sewer line and those compounds that are contained in the soil. The compound in Table 3.1 have been identified in ground water at the Rocky Mountain Arsenal. Attachment 1 provides compound specific information.

For these compounds to represent a hazard to works, there must be contact through inhalation, skin, or ingestion at a concentration high enough to result in health effects. Chemical exposure will be controlled by eliminating worker contact through the use of personal protective equipment (PPE).

3.3 BIOLOGICAL HAZARD ASSESSMENT

The only known biological hazard to workers at the RMA is the plague. The Arsenal's prairie dog population carries fleas that are infected with the plague. Workers should avoid any contact with dead animals. By taping pants to the boots, the flea cannot come in contact with the worker's legs.

3.4 REGULATORY STATUS

The RMA must comply with both Federal and State regulatory requirements. The Federal regulatory requirements include CERCLA as amended by SARA, RCRA, OSHA, and DOD. State requirements for RCRA and OSHA are also included in the regulatory status of RMA. Since RMA is on the National Priorities List (NPL), and under CERCLA authority for clean-up and remediation, additional federal and state regulatory requirements may be applicable, or relevant and appropriate.

TABLE 3-1

POTENTIAL CONTAMINANTS

Aldrin/Dieldrin
Dicyclopentadiene (DCPD)
Dibromochloropropane (DBCP)
Diisopropylmethylphosphonate (DIMP)
Endrin
Chloroform
1,2-Dichloroethane
1,1-Dichloroethene
T-1,2-Dichloroethene
1,1-Dichloroethane
Benzene
Chlorobenzene
DDT
DDE
Carbon Tetrachloride
Methylene Chloride
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Isodrin
Toluene
Ethylbenzene
M-xylene
O&P-xylene
Trichloroethene
Tetrachloroethene
1,4-Oxathiane
1,4-Dithiane
Arsenic
Mercury
Lead
Cadmium
Zinc
Hydrazine
Nitrosodimethylamine

SECTION 4.0

KEY PERSONNEL/IDENTIFICATION OF HEALTH AND SAFETY PERSONNEL

4.1 KEY PERSONNEL

Listed below are personnel with RMA and WESTON which are key players regarding the activities at this site. Also identified are each key persons roles and responsibilities with site.

	RMA Representative	Address	Telephone
Tim Kilgannon	Environmental Energy	72nd & Quebec St. Commerce City, CO 80222	(303) 289-0289

Roles and Responsibilities: Shall be Task Manager and responsible for the interim response activities conducted at this site shall ensure all contractors complete and fulfill all contract requirements.

WESTON Representatives	Address	Telephone
Paul Warbington Senior Project Manager	215 Union Blvd., Suite 550 Lakewood, CO 80228	(303) 980-6800

Roles and Responsibilities: Shall manage manhole-sewer line closure activities. Shall assure proper health and safety programs which are functional according to the designed health and safety plans. Assure that all regulations and policies are being followed and that the potential hazards are presented before work begins.

WESTON Representatives	Address	Telephone
Frank Kabot Regional Safety Officer	215 Union Blvd., Suite 550 Lakewood, CO 80228	(303) 980-6800

Roles and Responsibilities: Shall audit the health and safety related activities at this site to ensure compliance with the approved HASP.

4.2 SITE SPECIFIC HEALTH AND SAFETY PERSONNEL

The Site Health and Safety Coordinator (SHSC) for activities to be conducted at this site is ____________________________.

The Site Health and Safety Coordinator (SHSC) has total responsibility for ensuring that the provisions of this Site HASP are adequate and implemented in the field.

Changing field conditions may required decisions to be made concerning adequate protection programs. Therefore, the personnel assigned as SHSC's are experienced and meet the additional training requirements specified by OSHA in 29 CFR 1910.120.

SECTION 5.0

FIELD HEALTH AND SAFETY PROCEDURES

The task associated with plugging the lateral sewer pipe openings is described in terms of the likelihood of exposure to the hazards identified and the personal protective equipment required for this task.

The area in vicinity of each of the sewer pipe openings will be surveyed with OVA and HNu organic vapor analyzers. PVC or similar plastic material will be used to plug the sewer openings. Since the sewer line has been inactive, entry and approach will begin in sewer opening level D. If organic vapor analyzer readings are above background, upgrade to level C is required. Hand tools will be used to install the sewer plugs.

Prior to initiating the tasks described above the Site Safety Coordinators will conduct a pre-task safety briefing of all project personnel. This briefing will include discussions of the following areas:

- Delegation of individual project staff responsibilities
- Review of physical, chemical and biological hazard assessment and health effects
- Discussion of applicable safety rules and protocols relevant to physical, chemical, and biological hazard assessment
- Review personal protection equipment and rationale for levels of protection and action levels.
- Decontamination protocols
- Emergency response procedures

5.1 PERSONAL PROTECTIVE EQUIPMENT

	PPE REQUIRED	
	LEVEL D (MODIFIED)	LEVEL C
Head	(X) hard hat	(X) hard hat
Eye and Face	(X) safety glasses	( )
Hearing	(X) ear plugs or muffs	

Whole Body	(X) Tyvek	
Hand - gloves	(X) latex inner	(X) latex inner
- gloves	(X) outer butyl/nitrile	(X) outer butyl
Foot - Boots	(X) steel toe	(X) steel toe
- Boots	(X) latex outer	(X) latex outer
Full Face Respirator		(X) GMC-H or equivalent

5.2 FIELD MONITORING INSTRUMENTS

- Photoionization Organic Vapor Analyzer supplied with a 10.2 eV detector module
- Flame Ionization Detector Organic Vapor Analyzer

5.3 PERSONAL PROTECTIVE EQUIPMENT ACTION LEVELS

Level D - Organic Vapor Analyzer reading does not exceed background in breathing zone.

Level C - Organic Vapor Analyzer reading exceeds background in breathing zone

5.4 ANALYZER CALIBRATION

All survey instruments will be calibrated daily prior to use in the field. An instrument calibration log will be used to document daily calibrations.

SECTION 6.0

MEDICAL SURVEILLANCE REQUIREMENTS

All WESTON employees and subcontractors who will be performing field work in areas either suspected or known to be contaminated will be required to participate in a medical surveillance program. For all site personnel, a release for work will be verified by the Site Health and Safety Coordinator (SHSC) before an employee or subcontractor can begin on-site activities.

The physical exam will be administered prior to the onset of any field work and upon termination of employment or field involvement. Episodic examinations may also be administered, at the discretion of the SHSC.

6.1 OBJECTIVES

The medical surveillance program has been designed specifically to address those activities associated with invasive operations conducted at the Rocky Mountain Arsenal. All physical examinations falling under the program will be administered by a licensed physician.

In general, the principal objectives of the medical surveillance program are to:

- Provide respirator certification as required under 29 CFR 1910.134.
- Determine an individual's ability to perform work while wearing protective equipment.
- Assist in evaluating the adequacy of the personal protective equipment prescribed.
- Establish a physiological baseline necessary to assess the degree and/or effects of exposure to hazardous materials.
- Provide data for future epidemiological studies and evaluations.

6.2 MEDICAL INFORMATION DISCLOSURE AND CONFIDENTIALITY

The personal medical information obtained through WESTON's medical surveillance program shall be treated as strictly confidential, and may be released only through adherence to the corporate guidelines.

Consistent with this policy, all personnel will be requested to complete a "Medical Record Release Authorization" form and submit it to the examining physician with a completed medical history questionnaire at the time of the exam. With this release, the examining physician will be able to inform each employe and project management of an individual's physical status and ability to perform work on the project site with or without any specified work restrictions.

6.3 SITE PERSONNEL AND CERTIFICATION STATUS

A. WESTON

Name	Title	Task(s)	Medical Current a.	Fit Test Current Qual. b.	Fit Test Current Quant. b.	Training Current c.	Certification Level or Description
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

C. Subcontractor

	Name	Title	Task(s)	Medical Current a.	Fit Test Current Qual. b.	Fit Test Current Quant. b.	Training Current c.	Certification Level or Description
1.								
2.								
3.								
4.								
5.								
6.								

SECTION 7.0

EMERGENCY CONTACTS AND PHONE NUMBERS

Agency	Contact	Phone Number
Local Medical Emergency Facility		(303) 363-7200
WESTON Medical Emergency Contact	AGATHA	(513) 421-3063
WESTON Health and Safety	Frank Kabot	(303) 980-6800
Fire Department	RMA - on site	(303) 289-0187
Police Department	Post Security	(303) 289-0369
On Site Coordinator		
Site Telephone	WSI	(303) 287-6884
Nearest Telephone	WESTON	(303) 980-6800

LOCAL MEDICAL EMERGENCY FACILITY(S)

Name of Hospital: Aurora Presbyterian

Address: 700 Potomac Street

Phone No.: (303) 363-7200

Type of Service: Physical Trauma & Chemical Exposure and Available 24 Hours

Route to Hospital: (Attach Map) Exit RMA through West Gate to Quebec Street; South to I-70 East; I-70 to I-225 South to 6th Avenue. Right on 6th Avenue West to Potomac Street. Potomac North to Aurora Presbyterian.

Travel Time From Site (Minutes):	20
Distance to Hospital (Miles):	15
Name/No. of 24 Hr. Ambulance Service:	(303) 289-0187

SECTION 8.0

SITE PERSONNEL TRAINING AND CERTIFICATION REQUIREMENTS

Access to project areas, within the scope of WESTON's control and the Site Health and Safety Plan (HASP), is limited to those persons who met WESTON Certification Requirements. All persons to whom this HASP applies must be informed of site hazards, Standard Procedures and site specific requirements for personnel protection.

Access to this site shall be limited to those WESTON persons and Subcontractors certified by training, medical evaluation and Fit Testing per the Standard Practices and Subcontractor Services Agreements.

a)	Training (General):	All personnel, including visitors, entering the exclusion or contamination reduction zones must have certification of current training status in accordance with OSHA 29 CFR 1910, 1926 or 1910.120. Appendix A defines the WESTON Training Program and requirements for maintaining current status.
b)	Training and Qualifications:	Site manager and Site Health and Safety Coordinators (SHSC) must meet experience criteria and have additional training prior to being assigned to these positions. In addition to an 8-Hour Certification Course, Site Managers and SHSC's must have current First Aid and CPR status.
c)	Medical Monitoring Requirements:	All personnel, including visitors, entering the exclusion or contamination reduction zones must be currently certified as medically fit to work, and to wear a respirator, if required, in accordance with 29 CFR 1910, 1926 or 1910.120.
d)	Respirator Fit Testing:	All persons, including visitors, entering any area requiring the use or potential use of any negative pressure respirator must have had as a minimum, a qualitative fit test, administered in accordance with OSHA 29 CFR 1910.134 or ANSI within the last 12 months. If site conditions require the use of a full face negative pressure, air purifying respirator, employees must have had a quantitative fit test, administered according to OSHA 29 CFR 1910.1002, .1018 or .1025 within the last six months.

SECTION 9.0

DECONTAMINATION OF PERSONNEL AND EQUIPMENT

Personnel contact with contaminants will be minimized as far as can be reasonably achieved. Personnel and equipment that have been in contact with contaminated materials may carry residual contamination. Despite protective clothing, equipment, and good work practices, decontamination is necessary to prevent personnel exposure and migration of contaminants. Decontamination will be done under the direction of the Site Safety Coordinator.

The following general guidelines will be used in the development of decontamination procedures:

- The level of decontamination will depend on the nature and magnitude of contamination, and the type of protective clothing.
- Personnel assisting in the decontamination activities will be attired in clothing to protect them from contamination released during the decontamination process.
- Under emergency conditions, decontamination procedures will be omitted and lifesaving measures initiated without delay if:
    - decontamination activities could aggravate or cause more serious health effects, or if
    - prompt lifesaving first aid and/or medical treatment is required.

Personnel decontamination for Level D protection will consist of washing hands and face with soap and water after leaving the exclusion zone and before eating or drinking.

Personnel in Level B protection will wash their outer gloves and boots with a solution of trisodiumphosphate, Alconox, and water followed by a tap water rinse. Personnel will also wash their hands and face after removing all protective clothing.

All personnel working at the RMA will change from personal clothing to work clothing prior to performing any work. Prior to leaving RMA each evening, personnel will shower and change. Field work clothing is not to be worn off the RMA.

All disposal coveralls, gloves, booties, etc. will be placed in drums, labeled, and given to the hazardous waste contractor at RMA. All waste from the exclusion zone will be considered hazardous waste and kept separate form other waste.

Heavy equipment will be decontaminated by moving equipment to the decontamination pad and cleaning with high pressure hot water. Liquid is to be transferred to the tank at the decontamination pad. Personnel performing the decontamination will be dressed in Level C attire with a face shield to protect from splashback.

SECTION 10.0

EMERGENCY RESPONSE

10.0 CONTINGENCY PLAN

The contingency plan identifies for the project staff the actions to be taken in the event of medical emergencies, fires, and explosions.

10.1 MEDICAL EMERGENCIES

Emergency medical treatment must be available and provided as quickly as possible when needed. This requires careful planning and a pre-determined sequence of events, a contingency plan, if it is to be effective, and meet regulatory requirements.

There must be at least one person on every site who has current certification in First Aid and CPR. If field teams are more than five minutes apart, each team must have a member current in First Aid and CPR.

There must be at least one approved First Aid Kit on every site. If work crews are out of line of sight with each other, each crew must have a First Aid Kit.

When work involves potential eye contact or exposure to chemical hazards, either contaminants, process materials or laboratory reagents, eye washes must be immediately available with minimum clean water flow duration of 15 minutes.

When the potential for chemical splash exists, safety showers with a minimum flow duration of 15 minutes must be immediately available.

There must be provisions for transportation of an ill or injured worker to the emergency medical facility if an ambulance service is unable to respond within ten minutes.

10.2 FIRES AND EXPLOSIONS

Fires and explosions must be responded to quickly and efficiently if control and minimization of risk is to be accomplished. The key to fire and explosion response is identification of risk, fire and explosion prevention plans, having a pre-designed response plan and training.

10.2.1 Fire and Explosion Risk Assessment

Fire and explosion potential exists when ignition sources are used in the vicinity of explosive, flammable or combustible materials and when chemicals interact. The Site HASP risk assessment must identify the potential for fires or explosions occurring on site, and appropriate Prevention and Response Plans must be implemented.

10.2.2 Fire and Explosion Prevention

Preventing fires and explosions is an integral part of a contingency plan. Prevention programs, if not totally successful, minimize the chance of occurrence, reduce the magnitude of a fire or explosion and allow quicker response. Fire prevention procedures include use of the "Hot Work" Permitting System, safe welding procedures, safe storage/use of flammable and explosive materials, smoking restriction policies, fire watches, vapor freeing/tank inerting, etc. These elements must be implemented as part of the basic HASP. Procedures are found in Part II of this Standard Plan.

All contacts and telephone numbers are listed in Section 7.0.

SECTION 11.0

HEALTH AND SAFETY PLAN APPROVAL/SIGN OFF FORM

Site Name: Rocky Mountain Arsenal WO#: 5300-01-03-0070

Work Location Address: 72nd and Quebec Street, Commerce City, Colorado 80022

I have read, understood, and agreed with the information set forth in this Health and Safety Plan (and attachments) and discussed in the Personnel Health and Safety briefing.

Site Safety Coordinator	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
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APPENDIX F

HEALTH & SAFETY PLAN

FOR MANHOLE CLOSURE IN THE SOUTH PLANTS AND SECTION 36

INTRODUCTION

This Health and Safety Plan provides guidance and establishes procedures for manhole closure in the South Plant and Section 36 related activities at the Rocky Mountain Arsenal, Denver, Colorado. The intention of the plan is to establish a safety policy and general standards, and to provide the framework for more specific safety requirements to be employed. This plan applies to all prime and subcontractor personnel working on this assignment and to visitors at project work locations. All affected personnel will be required to sign a statement to the effect that this document has been reviewed and understood prior to commencement of on-site activities and/or visits to the work location.

SECTION 1.0

PROJECT BACKGROUND

An existing sewer line in Section 35 and 36 of the RMA has been identified as being a source for migration of contaminants from previous South Plants operations. The South Plants from the early 1940's until the 1970's produced military and industrial chlorinated chemical products such as mustard gas and organo-chloride pesticides. Product compounds, intermediates, and by-products have been leached into the South Plants ground water and may have entered the sewer line through infiltration during periods of high ground water. The existing sewer line will be plugged and grouted after construction of a new sewer line serving the same area. This HASP defines the hazards and risks associated with the manhole closures in the South Plants. It also establishes specific health and safety requirements and procedures for this activity. This plan is designed to comply with OSHA regulations 29 CFR 1910.120, Environmental Protection Agency (EPA) Orders 1420.2 and 1440.3, and State Requirements. All activities must also meet OSHA construction standards 29 CFR 1910.26.

SECTION 2.0

SCOPE OF WORK

Once the new sanitary sewer line has been completed, the old South Plants sewer line is scheduled to be abandoned. The South Plants sewer line has been identified as a potential contributing source to the migration of contaminants around the arsenal. A past survey conducted by Black and Vetch indicated that the South Plant sewer system was in poor condition and contaminated ground-water infiltration was documented. To prevent further migration, concrete will be placed into manholes along the line. In addition, sheet piles will be driven on the downgradient side of the line to reduce the migration potential in the pipe trench.

Three steps pertaining to the manhole closure activities have been developed. These steps include:

- Plugging the ends of the manhole sewer line
- Sheet Pile installation
- Concreting the manhole

In order to plug the end of the manhole, it is necessary for an individual to enter the manhole and manually install the plug into the end of the sewer line. While in the manhole, a potential threat of chemical exposure is quite high due to contaminated ground-water infiltration combined with sewer by-products. Therefore, those individuals entering manholes must be in a minimum personal protection level of Level B. Level B personal protection includes the use of compressed air with a pressure demand regulator-airline, saranex, inner latex-gloves, outer butyl gloves, latex overboots, steel toe boots, and hard-hat. Monitoring prior to entry into the manhole shall be performed using several instruments which include a Combustible Gas Indicator (CGI), Oxygen Meter (O_2M), Hydrogen Sulfide Meter, and Organic Vapor Monitor (OVM). The monitoring results will be documented by the site safety coordinator or responsible individual using a field book or proper recording sheets. Entry into the manhole will not take place if vapor levels exceed 25 percent of the Lower Explosive

Limit, if OVA readings exceed 5 units, or if the oxygen concentration is less than 18.0 percent. If this situation does occur, notification of site safety coordinator is required and manhole ventilation will be required until acceptable entry levels are obtained.

Once the plug is in place, sheet piles will be driven on the downgradient side of the manhole. Sheet pile weighs in excess of 400 pounds. Sheet pile installation procedures include the use of heavy machinery such as backhoes, cranes and drivers. Physical injury is the main concern of this activity. Pinch points, accidental contact with objects, and falls should be brought up by the site safety coordinator on a daily basis. The level of personal protection for this activity has been determined as modified level D, with periodic organic vapor monitoring using an OVM such as a OVA or Hnu. If vapors exceed background at any time when monitoring, upgrade to level C is required until additional monitoring indicates a downgrade is appropriate.

The third step to the closure of the manhole sewer line is placing concrete into the manhole. In order for the concrete to penetrate into cracks and crevices, a vibrating stinger will be used. A fall in hazard exists when using the stinger in the hole. A barriers will be used to provide protection against fall in.

During installation of the plugs, the possibility of exposure to volatile organic compounds and pesticide residual from surface soils exists. Consequently, the activity will require the use of a direct reading instrument such as an Organic Vapor Analyzer (OVA) or a Hnu to detect the presence of volatile-organic compounds. Modified level D personal protection will be required for this phase of the project. Modified level D requires the use of tyvek, safety boots, hard hat, safety glasses, and latex inner and nitrile outer gloves. All holes shall be approached using a direct reading instrument. Each hole shall be checked with the instrument for the presence of volatile organic vapors. Any reading on the instrument above the background level, while approaching or at the hole, shall cause work to cease and require an upgrade in personal protection to Level C. Level C personal protection requires the addition of a full face respirator to modified level D described above.

When leaving the exclusion zone, decontamination is required by all personnel working on this task. A decontamination area will be designed prior to the activity by the Site Safety Coordinator. Decontamination shall include boot washing, glove and tyvek disposal, and hand washing. The use of alconox and rinse water is enough to remove soil residue from boots and gloves.

SECTION 3.0

HAZARD IDENTIFICATION AND RISK ASSESSMENT

The hazards associated with the manhole closure in the South Plants and Section 36 can be identified as physical, chemical, and biological.

3.1 PHYSICAL HAZARDS ASSESSMENT

3.1.1 Heavy Equipment Operation

Driving sheet piles downgradient of the plugged manhole will involve heavy equipment operation including crane/lighting equipment.

Before any machinery or mechanized equipment is placed in use, it will be inspected and tested by a competent mechanic and certified to be in safe operating condition.

The employer will designate a competent person to be responsible for the inspection of all machinery and equipment daily and during use to make sure it is in safe operating condition. Test will be made at the beginning of each shift during which the equipment is to be used to determine that the brakes and operating systems are in proper working condition.

Preventative maintenance procedures recommended by the manufacturer will be followed.

Any machinery or equipment found to be unsafe will be deadlined and its use prohibited until unsafe conditions have been corrected.

Inspections or determinations of road conditions and structures will be made in advance to assure that clearances and load capacities are surface for the passing or placing of any machinery or equipment.

Machinery and mechanized equipment will be operated only by designated personnel. Equipment deficiencies observed at any time that affect their safe operation will be corrected before continuing operation.

Seats or equal protection will be provided for each person required to ride on equipment.

Getting off or on any equipment while it is in motion is prohibited.

Machinery or equipment requiring an operator will not be permitted to run unattended.

Machinery or equipment will not be operated in a manner that will endanger persons or property nor will unsafe operating speeds or loads be exceeded.

Equipment used for lifting sheet piles or personnel shall be used and maintained in strict accordance with manufacturers directions and applicable OSHA regulations.

Load limits will be visibly posted on all lifting devices.

Only operators will demonstrated competence shall be permitted to operate lifting devices.

Lifting machinery and all elements of equipment involved in lifting or supporting loads must be inspected prior to use and at a minimum monthly. Inspections must be performed by a competent persons and must be documented.

3.1.2 Noise

Sheet pile driving equipment generated noise will exceed the OSHA action level. Noise can cause sudden traumatic hearing loss, long term more slowly occurring sensory-neural hearing loss which is irreversible, disruption of communication, masking of warning devices and alarms, increased stress levels, and effects on the cardio-vascular and nervous systems. These latter two effects may occur at levels below that which cause damage to hearing and in situations where the conditions are more or less constant and daily.

OSHA regulations generally apply to 8 hour exposures and consider 85 dBA as an action level for a Hearing Conservation Program.

During sheet pile driving activity high noise levels will be encountered. Hearing protection will be afforded by either disposable ear plugs or ear muffs. Administrative time control is not an acceptable method for preventing noise exposure since extreme noise for a short duration can cause severe, permanent hearing loss.

3.1.3 Confined Space Entry

A confined space is any space having a limited means of egress, which is subject to the accumulation of toxic or flammable contaminants or has an oxygen deficient atmosphere. The sewer line plugging and manhole closure activity will require entry through the manhole into a confined space. A confined space entry permit (CSEP) will be initiated by the supervisor of personnel who are to enter into or work a confined space. The CSEP will be completed by the personnel involved in the entry and approved by the SHSC before personnel will be permitted to enter the confined space. The CSEP shall be valid only for the performance of the work identified and for the location and time specified. The beginning of a new shift with change of personnel will require the issuance of a new CSEP.

3.1.4 Inclement Weather

Heat, rain, cold, snow, ice, and lightning are natural phenomena which complicate work activities and add or increase risk. Much of the responsibility for protection from inclement weather hazards falls upon the Site Health and Safety Coordinator (SHSC). The SHSC must recognize the inclement weather hazards affecting site for which he is responsible and complete the pre-site activity risk assessment when inclement weather occurs. The SHSC must recognize which weather conditions affect instrument and Personal Protective Equipment function and constantly remind site workers of the effects and need for more careful attention to check-out, donning and doffing and monitoring of function and integrity. The SHSC must make decisions on the proper safety procedures to use if work must continue or to stop work if the risk is too great.

3.1.4.1 Heat Stress Prevention and Monitoring

Heat stress may occur at any time work is being performed at elevated temperatures. Wearing of chemical protective clothing, which may result in decreasing natural body ventilation, increases the risk of heat stress.

If the body's physiological processes fail to maintain a normal body temperature because of excessive heat, a number of physical reactions can occur, ranging from mild (such as fatigue, irritability, anxiety, and decreased concentration, dexterity, or movement) to fatal. Because heat stress is one of the most common and potentially serious illnesses at hazardous waste sites, regular monitoring and other preventative measures are vital.

Site workers must learn to recognize and treat the various forms of heat stress. The best approach is preventative heat stress management. In general:

- Have workers drink 16 ounces of water before beginning work, such as in the morning or after lunch. Provide disposable 4- ounce cups, and water that is maintained at 50 - 60°F. Urge workers to drink 1 to 2 of these cups of water every 20 minutes for a total of 1 to 2 gallons per day. Provide a cool area for rest breaks. Discourage the intake of coffee during working hours. Monitor for signs of heat stress.
- Acclimate workers to site work conditions by slowly increasing workloads, i.e., do not begin site work activities with extremely demanding activities.
- Provide cooling devices to aid natural body ventilation. These devices, however, add weight and their use should be balanced against worker efficiency. An example of a cooling aid is long cotton underwear which acts as a wick to absorb moisture and protect the skin from direct contact with heat-absorbing protective clothing.
- In extremely hot weather, conduct field activities in the early morning and evening.

- Ensure that adequate shelter is available to protect personnel against heat as well as cold, rain, snow, etc. which can decrease physical efficiency and increase the probability of both heat and cold stress. If possible, set up the command post in the shade.
- In hot weather, rotate shifts of workers wearing impervious clothing.
- Good hygienic standards must be maintained by frequent changes of clothing and showering. Clothing should be permitted to dry during rest periods. Persons who notice skin problems should immediately consult medical personnel.

The following is a discussion of specific results of heat stress:

3.1.4.2 Heat Stroke

Heat stroke is an acute and dangerous reaction to heat stress caused by a failure of heat regulating mechanisms of the body; the individual's temperature control system that causes sweating stops working correctly. Body temperature rises so high that brain damage and death will result if the person is not cooled quickly.

- Symptoms - Red, hot, dry skin, although person may have been sweating earlier; nausea; dizziness; confusion; extremely high body temperature; rapid respiratory and pulse rate; unconsciousness or coma.
- Treatment - Cool the victim quickly. If the body temperature is not brought down fast, permanent brain damage or death will result. Soak the victim in cool, but not cold water; sponge the body with cool water or pour water on the body to reduce the temperature a safe level (102°F). Observe the victim and obtain medical help. Do not give coffee, tea, or alcoholic beverages.

3.1.4.3 Heat Exhaustion

Heat exhaustion is a state of very definite weakness or exhaustion caused by the loss of fluids from the body. The condition is much less dangerous than heat stroke, but it nonetheless must be treated.

- Symptoms - Pale, clammy, moist skin; profuse perspiration and extreme weakness. Body temperature is normal, pulse is weak and rapid, breathing is shallow. The person may have a headache, may vomit, and may be dizzy.
- Treatment - Remove the person to a cool, air conditioned place, loosen clothing, place in a head-low position and provide bed rest. Consult physician, especially in severe cases. The normal thirst mechanism is not sensitive enough to ensure body fluid replacement. Have patient drink 1 to 2 cups of water immediately, and every 20 minutes there after until symptoms subside. Total water

consumption should be about 1 to 2 gallons per day.

3.1.4.4 Heat Cramps

Heat cramps are caused by perspiration that is not balanced by adequate fluid intake. Heat cramps are often the first sign of a condition that can lead to heat stroke.

- o Symptoms - Acute painful spasms of voluntary muscles, e.g., abdomen and extremities.
- o Treatment - Remove victim to a cool area and loosen clothing. Have patient drink 1 to 2 cups of water immediately, and every 20 minutes thereafter until symptoms subside. Total water consumption should be 1 to 2 gallons per day.

3.1.4.5 Heat Rash

Heat Rash is caused by continuous exposure to heat and humid air and aggravated chafing clothes. The condition decreases ability to tolerate heat.

- o Symptoms - Mild red rash, especially in areas of the body that come into contact with protective gear.
- o Treatment - Decrease amount of time in protective gear and provide powder to help absorb moisture and decrease chafing.

3.1.4.6 Heat Stress Monitoring and Work Cycle Management

For strenuous field activities that are part of on-going site work activities in hot weather, the following procedures shall be used to monitor the body's physiological response to heat, and to manage the work cycle, even if workers are not wearing impervious clothing. These procedures are to be instituted when the temperature exceeds 70°F.

Measure Heart Rate - Heart rate should be measured by the radial pulse for 30 seconds as early as possible in the resting period. The HR at the beginning of the rest period should not exceed 110 beats/minute. If the HR is higher, the next work period should be shortened by 33%, while the length of the rest period stays the same. If the pulse rate still exceeds 110 beat/minute at the beginning of the next rest period, the following work cycle should be further shortened by 33%. The procedure is continued until the rate is maintained below 110 beats/minute.

Measure Body Temperature - When ambient temperatures over 90°, body temperatures should be measured with a clinical thermometer as early as possible in the resting period. Oral temperature (OT) at the beginning of the rest period should be shortened by 33%, while the length of the rest period stays the same. If the OT exceeds 99.6°F at the beginning of the next rest period, the following work cycle should be further shortened by 33%. The procedure is continued until the body temperature is maintained below 99.6°F.

Physiological Monitoring Schedule - The following Suggested Frequency of Physiological Monitoring Schedule for Fit and Acclimated Workers shall be used as a guideline:

Temperature	(Level D)	(Level C)
90°F (32.2°C) or above	After each 45 minutes of work	After each 15 minutes of work
87.5°F (30.8° - 32.2°C)	After each 60 minutes of work	After each 30 minutes of work
82.5°-87.5°F (28.1° - 32.2°C)	After each 90 minutes of work	After each 60 minutes of work
77.5°-82.5°F (25.3° - 28.1°C)	After each 120 minutes of work	After each 90 minutes of work
72.5°-77.5°F (22.5° - 25.3°C)	After each 150 minutes of work	After each 120 minutes of work

Measure the air temperature with a standard thermometer. Estimate fraction of sunshine by judging what percent the sun is out.

100% sunshine = no cloud cover = 1.0

50% sunshine = 50% cloud cover = 0.5

0% sunshine = full cloud cover = 0.0

Adjusted temp. = actual temp. + 13 X (% sunshine factor).

The length of work period is governed by Frequency of Physiological Monitoring. The length of the rest period is governed by physiological parameters (heart rate and oral temperature). For example, if an individual's heart rate exceeds 110 beats/minute at the beginning of the rest period, that individual will remain on rest-time until his/her heart rate drops well below 110 beats/minute and their next work period (=duration of time before suggested physiological monitoring) is decreased by 33%.

3.1.5 Cold Stress

Persons working outdoors in low temperatures, especially at or below freezing are subject to cold stress. Exposure to extreme cold for a short time causes severe injury to the surface of the body, or results in profound generalized cooling, causing death. Areas of the body which have high surface area-to-volume ratio such as fingers, toes, and ears, are the most susceptible.

Chemical protective clothing generally does not afford protection against cold stress. In many instances, it increases susceptibility.

Chemical hazard site workers must learn to dress carefully to provide chemical protection and thermal insulation while not dressing so warmly that exercise or strenuous activity will result in heat stress.

Provisions must also be made for the fact that after physical activity and accumulation of body heat, sudden chilling during decontamination and rest breaks may increase susceptibility to colds, etc.

Two factors influence the development of a cold injury: ambient temperature and the velocity of the wind. Wind Chill Indices describe the chilling effect of moving air in combination with low temperature.

As a general rule, the greatest incremental increase in wind chill occurs when a wind of 5 mph increases to 10 mph. Additionally, water conducts heat 240 times faster than air; thus, the body cools suddenly when chemical-protective equipment is removed if the clothing underneath is perspiration-soaked.

3.1.5.1 Frostbite

Local injury resulting from cold is included in the generic term frostbite. Frostbite of the extremities can be categorized into:

- Frost nip or incipient frostbite is characterized by sudden blanching or whitening of skin.
- Superficial frostbite is characterized by skin with a waxy or white appearance and is firm to the touch, but tissue beneath is resilient.
- Deep frostbite is characterized by tissues that are cold, pale, and solid.

To administer first aid for frostbite: Take the victim indoors and rewarm the areas quickly in water that is between 39°C and 41°C (102°F- 105°F). Give a warm drink - water, or juices **not** coffee, tea or alcohol. The victim must not smoke. Keep the frozen parts in warm water or covered with warm clothes for 30 minutes, even though the tissue will be very painful as it thaws. Then elevate the injured area and protect it from injury. Do not allow blisters to be broken. Use sterile, soft, dry material to cover the injured areas. Keep victim warm and get immediate medical care.

After thawing, the victim should try to move the injured areas a little, but no more than can be done alone, without help. Seek medical attention as soon as possible.

NOTE:

- Do **not** rub the frostbitten part (this may cause gangrene).
- Do **not** use ice, snow, gasoline or anything cold on the frostbitten area.
- Do **not** use heat lamps or hot water bottles to rewarm the part.
- Do **not** place the part near a hot stove.

3.1.5.2 Hypothermia

Systemic hypothermia is caused by exposure to freezing or rapidly dropping temperature. Its symptoms are usually exhibited in five stages:

- Shivering
- Apathy, listlessness, sleepiness, and (sometimes) rapid cooling of the body to less than 95°F.
- Unconsciousness, glassy stare, slow pulse, slow respiration
- Death

If hypothermia is suspected in any field personnel, remove person to a warmer location until symptoms recede.

3.1.5.3 Wet Feet

Under both hot and cold conditions, wet feet can lead to serious problems. Trench Foot, Paddy Foot and Immersion Foot are foot ailments resulting from feet being wet for long periods of time and are similar in effect. In their more serious form, these ailments can result in pain, skin loss and incapacitation.

Workers in wet conditions or when conditions result in sweating and feet becoming and remaining wet, must dry their feet and change socks regularly to avoid these ailments.

3.1.6 Lightning

Lightning represents a hazard of electrical shock which is increased when working in flat open spaces, elevated work places are working near tall structures or equipment. Stopping work in open areas, around drill rigs or pile driver which may attract lightening, on or in water and in elevated work places when lightning strikes are sighted or thunder is heard near a work site.

3.2 CHEMICAL HAZARD ASSESSMENT

Chemical hazards which may be encountered during the sewer line plugging activity are directly related to the chemical and physical properties of the compounds that are present in the ground water that is infiltrating the sewer line and those compounds that are contained in the soil. The compound in Table 3.1 have been identified in ground water at the Rocky Mountain Arsenal. Attachment 2 provides compound specific information.

For these compounds to represent a hazard to workers, there must be contact through inhalation, skin, or ingestion at a concentration high enough to result in health effects. Chemical exposure will be controlled by eliminating worker contact through the use of personal protective equipment (PPE).

3.3 BIOLOGICAL HAZARD ASSESSMENT

The only known biological hazard to workers at the RMA is the plague. The Arsenal's prairie dog population carries fleas that are infected with the plague. Workers should avoid any contact with dead animals. By taping pants to the boots, the flea cannot come in contact with the worker's legs.

3.4 REGULATORY STATUS

The RMA must comply with both Federal and State regulatory requirements. The Federal regulatory requirements include CERCLA as amended by SARA, RCRA, OSHA, and DOD. State requirements for RCRA and OSHA are also included in the regulatory status of RMA. Since RMA is on the National Priorities List (NPL), and under CERCLA authority for clean-up and remediation, additional federal and state regulatory requirements may be applicable, or relevant and appropriate.

TABLE 3-1

POTENTIAL CONTAMINANTS

Aldrin/Dieldrin
Dicyclopentadiene (DCPD)
Dibromochloropropane (DBCP)
Diisopropylmethylphosphonate (DIMP)
Endrin
Chloroform
1,2-Dichloroethane
1,1-Dichloroethene
T-1,2-Dichloroethene
1,1-Dichloroethane
Benzene
Chlorobenzene
DDT
DDE
Carbon Tetrachloride
Methylene Chloride
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Isodrin
Toluene
Ethylbenzene
M-xylene
O&P-xylene
Trichloroethene
Tetrachloroethene
1,4-Oxathiane
1,4-Dithiane
Arsenic
Mercury
Lead
Cadmium
Zinc
Hydrazine
Nitrosodimethylamine

SECTION 4.0

KEY PERSONNEL/IDENTIFICATION OF HEALTH AND SAFETY PERSONNEL

4.1 KEY PERSONNEL

Listed below are personnel with RMA and WESTON which are key players regarding the activities at this site. Also identified are each key persons roles and responsibilities with site.

	RMA Representative	Address	Telephone
Tim Kilgannon	Environmental Energy	72nd & Quebec St. Commerce City, CO 80222	(303) 289-0289

Roles and Responsibilities: Shall be Task Manager and responsible for the interim response activities conducted at this site shall ensure all contractors complete and fulfill all contract requirements.

WESTON Representatives	Address	Telephone
Paul Warbington Senior Project Manager	215 Union Blvd., Suite 550 Lakewood, CO 80228	(303) 980-6800

Roles and Responsibilities: Shall manage manhole-sewer line closure activities. Shall assure proper health and safety programs which are functional according to the designed health and safety plans. Assure that all regulations and policies are being followed and that the potential hazards are presented before work begins.

WESTON Representatives	Address	Telephone
Frank Kabot Regional Safety Officer	215 Union Blvd., Suite 550 Lakewood, CO 80228	(303) 980-6800

Roles and Responsibilities: Shall audit the health and safety related activities at this site to ensure compliance with the approved HASP.

4.2 SITE SPECIFIC HEALTH AND SAFETY PERSONNEL

The Site Health and Safety Coordinator (SHSC) for activities to be conducted at this site is ________________________.

The Site Health and Safety Coordinator (SHSC) has total responsibility for ensuring that the provisions of this Site HASP are adequate and implemented in the field.

Changing field conditions may required decisions to be made concerning adequate protection programs. Therefore, the personnel assigned as SHSC's are experienced and meet the additional training requirements specified by OSHA in 29 CFR 1910.120.

SECTION 5.0

FIELD HEALTH AND SAFETY GUIDELINES

The three tasks associated with the sewer line abandonment project are described in terms of the likelihood of exposure to the hazards identified and the levels of personal protection to be used.

- Capping the ends of the manhole is the first step in manhole sewer line closure. This procedure requires an individual to enter the manhole and manually plug the ends of sewer line. Old sewer by-products such as methane and hydrogen sulfide may be present. In addition, infiltration of ground water contaminated with various volatile organic compounds, pesticides and inorganics may be present. Consequently, monitoring will be performed using a combustible gas indicator, O_2 meter, hydrogen sulfide indicator and an organic vapor monitor. This operation will be in Level B personal protection using pressure demand regulator-airlines.

- Task 2 - Sheet piles will be placed adjacent to the existing manhole sewer line to reduce contaminated ground-water infiltration into the line. Sheet piles weigh in excess of 400 pounds and pose a significant physical injury hazard. Construction safety (OSHA 1910.26) with regard to heavy machinery will be understood by all those involved with this activity. Periodic monitoring using an HNu or OVA will be required during sheet pile installation. A minimum level of protection has been determined to be modified Level D with an upgrade if VOCs are indicated while monitoring.

- Task 3 - The final step in manhole closure is pouring concrete into the hole. In order to allow the concrete to penetrate into the cracks and crevices, it is necessary to use a manually held vibrating stinger over the hole. Because of potential fall in, on-site training and worker awareness shall be required in the vicinity of the hole and manholes shall be barricaded. Periodic monitoring shall be performed while this activity is taking place. Modified Level D personal protection can be used during this activity however, if VOCs are detected while monitoring, upgrade to Level C is required.

Prior to initiating the tasks described above the Site Safety Coordinators will conduct a pre-task safety briefing of all project personnel. This briefing will include discussions of the following areas:

- Delegation of individual project staff responsibilities
- Review of physical, chemical and biological hazard assessment and health effects
- Discussion of applicable safety rules and protocols relevant to physical, chemical, and biological hazard assessment
- Review personal protection equipment and rationale for levels of protection and action levels.

- Decontamination protocols
- Emergency response procedures

5.1 PERSONAL PROTECTIVE EQUIPMENT

PPE REQUIRED FOR TASKS 2 AND 3

	LEVEL D (MODIFIED)
Head	(X) hard hat
Eye and Face	(X) safety glasses
Hearing	(X) ear plugs or muffs
Arms and Legs only	( )
Whole Body	(X) Tyvek
Hand - gloves	(X) latex inner
- gloves	(X) outer butyl/nitrile
Foot - Boots	(X) steel toe
- Boots	(X) latex outer

PPE REQUIRED FOR TASK 1

	LEVEL C	LEVEL B
Head	(X) hard hat	(X) hard hat
Hand - gloves	(X) latex inner	(X) latex inner
- gloves	(X) outer butyl	(X) outer butyl
Foot - Boots	(X) steel toe	
- Boots	(X) latex outer	
Full Face	(X)	( )
Cart./Canister	(X) GMC-H or equivalent	( )
Comb. Airline/SCBA	( )	(X)
Cascade System	( )	(X)
Compressor	( )	(X)2

5.2 FIELD MONITORING INSTRUMENTS

- Photoionization Organic Vapor Analyzer supplied with a 10.2 eV detector module
- Flame Ionization Detector Organic Vapor Analyzer
- Combustible Gas Analyzer
- Oxygen Analysis
- Hydrogen Sulfide Analyzer

5.3 PERSONAL PROTECTIVE EQUIPMENT ACTION LEVELS

Level D -	Organic Vapor Analyzer reading does not exceed background in breathing zone.
Level C -	Organic Vapor Analyzer reading exceeds background in breathing zone
Level B -	Organic Vapor Analyzer reading reaches 5 units in breathing zone.

5.4 ACTION LEVELS FOR COMBUSTIBLE/EXPLOSIVE ENVIRONMENTS

5.4.1 Explosive Atmosphere: Task 1

Action Level	Action
<10% LEL	Continue investigation.
10%-25% LEL	Continue on-site monitoring with extreme caution as higher levels are encountered.
>25% LEL	Explosion hazard. Withdraw from area immediately.

5.4.2 Oxygen Atmosphere: Task 1

Action Level	Action
<19.5%	Monitor wearing SCBA.

NOTE: Combustible gas readings may not be valid in atmospheres with <19.5% oxygen.

19.5%-25%	Continue investigation with caution, as Oxygen levels >21% require extreme caution. Other than normal level may be due to presence of other substances.
>25%	Fire hazard potential. Stop work and consult a fire safety specialist.

5.5 ANALYZER CALIBRATION

All survey instruments will be calibrated daily prior to use in the field.

5.6 AIR SAMPLING PROGRAM

An air sampling program will be initiated prior to the start of Task 1 of the manhole closure in the South Plants. A one day sampling program will test for various contaminants including volatile organic compounds and pesticides. These compounds are listed in Table 5-1. These contaminants were selected from Table 3-1 in Section 3.0. The objective of this program is to define concentrations of the VOCs and pesticides in the sewer manholes where workers in Level B will enter to plug the sewer line.

Sampling for volatile organic compounds will be performed following NIOSH Analytical Methods. The air sampling pumps will be lowered into the manhole and tethered at a distance above the manhole floor that would be representative of the breathing zone. This sampling program will be performed by an industrial hygienist and the samples will be analyzed by an accredited industrial hygiene laboratory.

TABLE 5-1

AIR SAMPLING PROGRAM

CONTAMINANT	MEDIA	FLOW RATE (L/MIN)	VOLUME (L)	GROUP
Trichloroethylene	Charcoal COC 100mg/50mg	0.2	15	A
Carbon Tetrachloride	Charcoal COC 100mg/50mg	0.2	15	A
Tetrachloroethylene	Charcoal COC 100mg/50mg	0.2	15	A
Chloroform	Charcoal COC 100mg/50mg	0.2	15	A
Chlorobenzene	Charcoal COC 100mg/50mg	0.2	15	A
Methyl Isobutyl Ketone	Charcoal COC 100mg/50mg	0.2	15	A
Methylene Chloride	2 Charcoal COC 100mg/50mg	0.2	1.5	B
Dibromochloropropane (DBCP)	Charcoal/Pet.	0.2	7	C
Benzene	Charcoal COC 100mg/50mg	0.2	20	D
Xylene	Charcoal COC 100mg/50mg	0.2	20	D
Ethylbenzene	Charcoal COC 100mg/50mg	0.2	20	D
Chlorodane	PUF	3	1,000	G
Aldrin	PUF	3	1,000	G
Dieldrin	PUF	3	1,000	G
Endrin	PUF	3	1,000	G
DDT	PUF	3	1,000	G

SECTION 6.0

MEDICAL SURVEILLANCE REQUIREMENTS

All project staff and subcontractors who will be performing field work in areas either suspected or known to be contaminated will be required to participate in a medical surveillance program. For all site personnel, a release for work will be verified by the Site Health and Safety Coordinator (SHSC) before an employee or subcontractor can begin on-site activities.

The physical exam will be administered prior to the onset of any field work and upon termination of employment or field involvement. Episodic examinations may also be administered, at the discretion of the SHSC.

6.1 OBJECTIVES

The medical surveillance program has been designed specifically to address those activities associated with invasive operations conducted at the Rocky Mountain Arsenal. All physical examinations falling under the program will be administered by a licensed physician.

In general, the principal objectives of the medical surveillance program are to:

- Provide respirator certification as required under 29 CFR 1910.134.
- Determine an individual's ability to perform work while wearing protective equipment.
- Assist in evaluating the adequacy of the personal protective equipment prescribed.
- Establish a physiological baseline necessary to assess the degree and/or effects of exposure to hazardous materials.
- Provide data for future epidemiological studies and evaluations.

6.2 MEDICAL INFORMATION DISCLOSURE AND CONFIDENTIALITY

The personal medical information obtained through the medical surveillance program shall be treated as strictly confidential, and may be released only through adherence to the corporate guidelines.

Consistent with this policy, all personnel will be requested to complete a "Medical Record Release Authorization" form and submit it to the examining physician with a completed medical history questionnaire at the time of the exam. With this release, the examining physician will be able to inform each employe and project management of an individual's physical status and ability to perform work on the project site with or without any specified work restrictions.

6.3 SITE PERSONNEL AND CERTIFICATION STATUS

A. WESTON

Name	Title	Task(s)	Medical Current a.	Fit Test Current Qual. b.	Fit Test Current Quant. b.	Training Current c.	Certification Level or Description
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

C. Subcontractor

	Name	Title	Task(s)	Medical Current a.	Fit Test Current Qual. b.	Fit Test Current Quant. b.	Training Current c.	Certification Level or Description
1.								
2.								
3.								
4.								
5.								
6.								

SECTION 7.0

EMERGENCY CONTACTS AND PHONE NUMBERS

Agency	Contact	Phone Number
Local Medical Emergency Facility		(303) 363-7200
WESTON Medical Emergency Contact	AGATHA	(513) 421-3063
WESTON Health and Safety	Frank Kabot	(303) 980-6800
Fire Department	RMA - on site	(303) 289-0187
Police Department	Post Security	(303) 289-0369
On Site Coordinator		
Site Telephone	WSI	(303) 287-6884
Nearest Telephone	WESTON	(303) 980-6800

LOCAL MEDICAL EMERGENCY FACILITY(S)

Name of Hospital: Aurora Presbyterian

Address: 700 Potomac Street Phone No.: (303) 363-7200

Type of Service: Physical Trauma & Chemical Exposure and Available 24 Hours

Route to Hospital: (Attach Map) Exit RMA through West Gate to Quebec Street; South to I-70 East; I-70 to I-225 South to 6th Avenue. Right on 6th Avenue West to Potomac Street. Potomac North to Aurora Presbyterian.

Travel Time From Site (Minutes):	20
Distance to Hospital (Miles):	15
Name/No. of 24 Hr. Ambulance Service:	(303) 289-0187

SECTION 8.0

SITE PERSONNEL TRAINING AND CERTIFICATION REQUIREMENTS

Access to project areas, within the scope of WESTON's control and the Site Health and Safety Plan (HASP), is limited to those persons who met WESTON Certification Requirements. All persons to whom this HASP applies must be informed of site hazards, Standard Procedures and site specific requirements for personnel protection.

Access to this site shall be limited to those WESTON persons and Subcontractors certified by training, medical evaluation and Fit Testing per the Standard Practices and Subcontractor Services Agreements.

a)	Training (General):	All personnel, including visitors, entering the exclusion or contamination reduction zones must have certification of current training status in accordance with OSHA 29 CFR 1910, 1926 or 1910.120. Appendix A defines the WESTON Training Program and requirements for maintaining current status.
b)	Training and Qualifications:	Site manager and Site Health and Safety Coordinators (SHSC) must meet experience criteria and have additional training prior to being assigned to these positions. In addition to an 8-Hour Certification Course, Site Managers and SHSC's must have current First Aid and CPR status.
c)	Medical Monitoring Requirements:	All personnel, including visitors, entering the exclusion or contamination reduction zones must be currently certified as medically fit to work, and to wear a respirator, if required, in accordance with 29 CFR 1910, 1926 or 1910.120.
d)	Respirator Fit Testing:	All persons, including visitors, entering any area requiring the use or potential use of any negative pressure respirator must have had as a minimum, a qualitative fit test, administered in accordance with OSHA 29 CFR 1910.134 or ANSI within the last 12 months. If site conditions require the use of a full face negative pressure, air purifying respirator, employees must have had a quantitative fit test, administered according to OSHA 29 CFR 1910.1002, .1018 or .1025 within the last six months.

SECTION 9.0

DECONTAMINATION OF PERSONNEL AND EQUIPMENT

Personnel contact with contaminants will be minimized as far as can be reasonably achieved. Personnel and equipment that have been in contact with contaminated materials may carry residual contamination. Despite protective clothing, equipment, and good work practices, decontamination is necessary to prevent personnel exposure and migration of contaminants. Decontamination will be done under the direction of the Site Safety Coordinator. The work location will be divided into three distinct work zones. The work zones are as follows:

Zone 1:	Exclusion Zone -- The zone where contamination does or could exist. All personnel entering this one must wear the level of protective clothing specified for that work area.
Zone 2:	Contamination Reduction Zone -- Provides a transition zone between the Exclusion Zone and the Support Zone to prevent the spread of contaminants from the Exclusion Zone. Decontamination is performed in this zone.
Zone 3:	Support Zone -- Area of work site considered to be non-contaminated located upwind of the Exclusion Zone. This is a storage area for support equipment and provides a point of personnel access and traffic control to the Exclusion Zone.

The following general guidelines will be used in the development of decontamination procedures:

- The level of decontamination will depend on the nature and magnitude of contamination, and the type of protective clothing.
- Personnel assisting in the decontamination activities will be attired in clothing to protect them from contamination released during the decontamination process.
- Under emergency conditions, decontamination procedures will be omitted and lifesaving measures initiated without delay if:
  - decontamination activities could aggravate or cause more serious health effects, or if
  - prompt lifesaving first aid and/or medical treatment is required.

Personnel decontamination for Level D protection will consist of washing hands and face with soap and water after leaving the exclusion zone and before eating or drinking.

Personnel in Level B protection will wash their outer gloves and boots with a solution of trisodiumphosphate, Alconox, and water followed by a tap water rinse. Personnel will also wash their hands and face after removing all protective clothing.

All personnel working at the RMA will change from personal clothing to work clothing prior to performing any work. Prior to leaving RMA each evening, personnel will shower and change. Field work clothing is not to be worn off the RMA.

All disposal coveralls, gloves, booties, etc. will be placed in drums, labeled, and given to the hazardous waste contractor at RMA. All waste from the exclusion zone will be considered hazardous waste and kept separate form other waste.

Heavy equipment will be decontaminated by moving equipment to the decontamination pad and cleaning with high pressure hot water. Liquid is to be transferred to the tank at the decontamination pad. Personnel performing the decontamination will be dressed in Level C attire with a face shield to protect from splashback.

SECTION 10.0

EMERGENCY RESPONSE

10.0 CONTINGENCY PLAN

The contingency plan identifies for the project staff the actions to be taken in the event of medical emergencies, fires, and explosions.

10.1 MEDICAL EMERGENCIES

Emergency medical treatment must be available and provided as quickly as possible when needed. This requires careful planning and a pre-determined sequence of events, a contingency plan, if it is to be effective, and meet regulatory requirements.

There must be at least one person on every site who has current certification in First Aid and CPR. If field teams are more than five minutes apart, each team must have a member current in First Aid and CPR.

There must be at least one approved First Aid Kit on every site. If work crews are out of line of sight with each other, each crew must have a First Aid Kit.

When work involves potential eye contact or exposure to chemical hazards, either contaminants, process materials or laboratory reagents, eye washes must be immediately available with minimum clean water flow duration of 15 minutes.

When the potential for chemical splash exists, safety showers with a minimum flow duration of 15 minutes must be immediately available.

There must be provisions for transportation of an ill or injured worker to the emergency medical facility if an ambulance service is unable to respond within ten minutes.

10.2 FIRES AND EXPLOSIONS

Fires and explosions must be responded to quickly and efficiently if control and minimization of risk is to be accomplished. The key to fire and explosion response is identification of risk, fire and explosion prevention plans, having a pre-designed response plan and training.

10.2.1 Fire and Explosion Risk Assessment

Fire and explosion potential exists when ignition sources are used in the vicinity of explosive, flammable or combustible materials and when chemicals interact. The Site HASP risk assessment must identify the potential for fires or explosions occurring on site, and appropriate Prevention and Response Plans must be implemented.

10.2.2 Fire and Explosion Prevention

Preventing fires and explosions is an integral part of a contingency plan. Prevention programs, if not totally successful, minimize the chance of occurrence, reduce the magnitude of a fire or explosion and allow quicker response. Fire prevention procedures include use of the "Hot Work" Permitting System, safe welding procedures, safe storage/use of flammable and explosive materials, smoking restriction policies, fire watches, vapor freeing/tank inerting, etc. These elements must be implemented as part of the basic HASP. Procedures are found in Part II of this Standard Plan.

All contacts and telephone numbers are listed in Section 7.0.

SECTION 11.0

HEALTH AND SAFETY PLAN APPROVAL/SIGN OFF FORM

Site Name: Rocky Mountain Arsenal WO#: 5300-01-03-0070

Work Location Address: 72nd and Quebec Street, Commerce City, Colorado 80022

I have read, understood, and agreed with the information set forth in this Health and Safety Plan (and attachments) and discussed in the Personnel Health and Safety briefing.

Site Safety Coordinator	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date
Name	Signature	Date

ATTACHMENT 1

CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES OF RMA CONTAMINANTS

ALDRIN/DIELDRIN

Summary

Aldrin degrades to dieldrin, which is very persistent in the environment. Both pesticides are carcinogenic in rats and mice and are teratogenic and reproductive toxicants. Aldrin and dieldrin cause liver toxicity and central nervous system abnormalities following chronic exposure. Both are also acutely toxic, with oral LD_{50} values of about 50 mg/kg. Both pesticides are very toxic to aquatic organisms and have been associated with large-scale kills of terrestrial wildlife in treated areas.

Background Information

Dieldrin is the 6,7-epoxide of aldrin and is readily obtained from aldrin under normal environmental conditions and by metabolism in animals.

CAS Number: Aldrin: 309-00-2
Dieldrin: 60-57-1

Chemical Formula: Aldrin: $C_{12}H_8Cl_6$
Dieldrin: $C_{12}H_8Cl_6O$

IUPAC Name: Aldrin: 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-exo-dimethanonaphthalene
Dieldrin: 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-endo,exo-1,4:5,8-dimethanonaphthalene

Chemical and Physical Properties

Molecular Weight: Aldrin: 365
Dieldrin: 381

Melting Point: Aldrin: 104°C
Dieldrin: 176 °C

Solubility in Water: Aldrin: 20/ ug/liter at 25°C
Dieldrin: 200 ug/liter at 25°C

Solubility in Organics: Soluble in most organic solvents

Log Octanol/Water Partition Coefficient: No data found; probably greater than 5 for both chemicals

Vapor Pressure: Aldrin: 2.31×10^{-5} mm at 20°C
Dieldrin: 2.8×10^{-6} mm at 20°C

Transport and Fate

Aldrin evaporates rapidly from aquatic environments and also probably from soil. Photolysis probably occurs in the atmosphere after volatilization. Adsorption, especially by organic materials, is also an important fate process for this chemical. Aldrin is bioconcentrated by aquatic organisms by a factor of 10^3 to 10^4. Biotransformation by aquatic organisms and biodegradation are also important fate processes.

The primary product of aldrin degradation is its epoxide, dieldrin. Photolysis of aldrin also produces small amounts of photoaldrin, photodieldrin, and a polymerization product. Dieldrin is considered to be at least as toxic as aldrin and is quite persistent in the environment. Therefore, transformation of aldrin represents only a change of state and not detoxification of the chemical.

Dieldrin is one of the most persistent of the chlorinated hydrocarbons. Volatilization and possibly subsequent photolysis to photodieldrin are important transport and fate processes from surface water and probably from soil. Adsorption to sediments, especially organic materials, and bioaccumulation are also important in removing dieldrin from water. Biotransformation and biodegradation of dieldrin occur very slowly but may be the final fate processes in sediment.

Health Effects

Both aldrin and dieldrin are carcinogens, causing increases in a variety of tumors in rats at low but not at high doses and producing a higher incidence of liver tumors in mice. the reason for this reversed dose-response relationship is unclear. Neither appears to be mutagenic when tested in a number of systems. Aldrin and dieldrin are both toxic to the reproductive system and teratogenic. Reproductive effects include decreased fertility, increased fetal death, and effects on gestation; while teratogenic effects include cleft palate, webbed foot, and skeletal anomalies. Chronic effects attributed to aldrin and dieldrin include liver toxicity and central nervous system abnormalities. Both chemicals are acutely toxic; the oral LD_{50} is around 50 mg/kg, and the dermal LD_{50} is about 100 mg/kg.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

Freshwater

Acute toxicity:	Aldrin: 3.0 ug/liter Dieldrin: 2.5 ug/liter
Chronic toxicity:	Aldrin: No available data Dieldrin: 0.0019 ug/liter

Saltwater

Acute toxicity: Aldrin: 1.3 ug/liter
Dieldrin: 0.71 ug/liter

Chronic toxicity: Aldrin: No available data
Dieldrin: 0.0019 ug/liter

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations in water are:

Risk	Aldrin Concentration	Dieldrin Concentration
10^{-5}	0.74 ng/liter	0.71 ng/liter
10^{-6}	0.074 ng/liter	0.071 ng/liter
10^{-7}	0.0074 ng/liter	0.0071 ng/liter

CAG Unite Risk (U.S. EPA): Aldrin: 11.4 $(mg/kg/day)^{-1}$
Dieldrin: 30.4 $(mg/kg/day)^{-1}$

ACGIH Threshold Limit Value:* 0.25 mg/m3 TWA
0.75 mg/m^3 STEL

OSHA Standard (air):* 250 ug/m^3 TWA

* Applies to both aldrin and dieldrin.

ARSENIC

Summary

Arsenic is a metal that is present in the environment as a constituent of organic and inorganic compounds; it also occurs in a number of valence states. Arsenic is generally rather mobile in the natural environment, with the degree of mobility dependent on its chemical form and the properties of the surrounding medium. Arsenic is a human carcinogen; it causes skin tumors when it is ingested and lung tumors when it is inhaled. Arsenic compounds are teratogenic and have adverse reproductive effects in animals. Chronic exposure to arsenic is associated with polyneuropathy and skin lesions. It is acutely toxic to some early life stages of aquatic organisms at levels as low as 40 ug/liter.

Background Information

Arsenic can be found in the environment in any of four valence states (-3, 0, +3 and +5) depending on the pH, Eh, and other factors. It can exist as either inorganic or organic compounds and often will change forms as it moves through the various media. The chemical and physical properties depend on the state of the metalloid. Only the properties of metallic arsenic have been listed; properties of other arsenic compounds are often quite different.

CAS Number: 7440-38-2

Chemical Formula: As

IUPAC Name: Arsenic

Chemical and Physical Properties

Atomic Weight: 74.91

Boiling Point: 613°C

Melting Point: 817°C

Specific Gravity: 5.72 at 20°C

Solubility in Water: Insoluble; some salts are soluble.

Transport and Fate

In the natural environment, arsenic has four different oxidation states, and chemical speciation is important in determining arsenic's distribution and mobility. Interconversions of the +3 and +5 states as well as organic complexation, are the most important. Arsenic is generally quite mobile in the environment. In the aquatic environment, volatilization is important when biological activity or highly reducing conditions is an important fate for the chemical. Arsenic is metabolized to organic arsenicals by a number of organisms: this increases arsenic's mobility in the environment. Because of its general mobility, arsenic tends to cycle through the environment. Its ultimate fate is probably the deep ocean, but it may pass through numerous stages before finally reaching the sea.

Health Effects

Arsenic has been implicated in the production of skin cancer in humans. There is also extensive evidence that inhalation of arsenic compounds causes lung cancer in workers. Arsenic compounds cause chromosome damage in animals, and humans exposed to arsenic compounds have been reported to have an elevated incidence of chromosome aberrations. Arsenic compounds have been reported to be teratogenic, fetotoxic, and embryotoxic in several animal species, and an increased incidence of multiple malformations among children born to women occupationally exposed to arsenic has been reported. Arsenic compounds also cause noncancerous, possibly precancerous, skin changes in exposed individuals. Several cases of progressive polyneuropathy involving motor and sensory nerves and particularly affecting the extremities and myelinated long-axon neurons have been reported in individuals occupationally exposed to inorganic arsenic. Polyneuropathies have also been reported after the ingestion of arsenic-contaminated foods.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

Freshwater

Acute toxicity: 440 ug/liter
Chronic toxicity: No available data

Saltwater

Acute toxicity: 508 ug/liter
Chronic toxicity: No available data

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of arsenic in water are:

Risk	Concentration
10^{-5}	22 ng/liter
10^{-6}	2.2 ng/liter
10^{-7}	0.22 ng/liter

CAG Unit Risk (U.S. EPA): 15 $(mg/kg/day)^{-1}$

National Interim Primary Drinking Water Standard (U.S. EPA): 50 ug/liter

NIOSH Recommended Standard (air): 2 ug/m^3 TWA

OSHA Standard (air): 500 ug/m^3 TWA

ACGIH Threshold Limit Value: 200 ug/m^3 (soluble compounds, as As).

BENZENE

Summary

Benzene is an important industrial solvent and chemical intermediate. It is rather volatile, and atmospheric photooxidation is probably an important fate process. Benzene is a known human carcinogen, causing leukemia in exposed individuals. It also adversely affects the hematopoietic system. Benzene has been shown to be fetotoxic and to cause embryolethality in experimental animals. Exposure to high concentrations of benzene in the air causes central nervous system depression and cardiovascular effects, and dermal exposure may cause dermatitis.

CAS Number: 71-43-2

IUPAC Name: Benzene

Chemical Formula: C_6H_6

Chemical and Physical Properties

Molecular Weight: 78.12

Boiling Point: 80.1°C

Melting Point: 5.56°C

Specific Gravity: 0.879 at 20°C

Solubility in Water: 1,780 mg/liter at 25°C

Solubility in Organics: Miscible with ethanol, ether, acetic acid, acetone, chloroform, carbon disulfide, and carbon tetrachloride

Log Octanol/Water Partition Coefficient: 1.95-2.13

Vapor Pressure: 75 mm Hg at 20°C

Vapor Density: 2.77

Flash Point: -11.1°C

Transport and Fate

Volatilization appears to be the major transport process of benzene from surface waters to the ambient air, and atmospheric transport of benzene occurs readily (U.S. EPA 1979). Although direct oxidation of benzene in environmental waters is unlikely, cloud chamber data indicate that it may be photooxidized rapidly in the atmosphere. Inasmuch as volatilization is likely to be the main transport process accounting for the removal of benzene from water, the atmospheric destruction of benzene is probably the most likely fate process. Values for benzene's log octanol/water partition coefficient indicate that adsorption onto organic material may be significant under conditions of constant exposure. Sorption processes are likely removal mechanisms in both surface water and groundwater. Although the bioaccumulation potential for benzene appears to be low, gradual biodegradation by a variety of microorganisms probably occurs. The rate of benzene biodegradation may be enhanced by the presence of other hydrocarbons.

Health Effects

Benzene is a recognized human carcinogen. Several epidemiological studies provide sufficient evidence of a causal relationship between benzene exposure and leukemia in humans. Benzene is a known inducer of aplastic anemia in humans, with a latent period of up to 10 years. It produces leukopenia and thrombocytopenia, which may progress to pancytopenia. Similar adverse effects on the blood-cell-producing system occur in animals exposed to benzene. In both humans and animals, benzene exposure is associated with chromosomal damage, although it is not mutagenic in microorganisms. Benzene was fetotoxic and caused embryolethality in experimental animals.

Exposure to very high concentrations of benzene [about 20,000 ppm (66,000 mg/m^3) in air] can be fatal within minutes. The prominent signs are central nervous system depression and convulsions, with death usually following as a consequence of cardiovascular collapse. Milder exposures can produce vertigo, drowsiness, headache, nausea, and eventually unconsciousness if exposure continues. Deaths from cardiac sensitization and cardiac arrhythmias have also been reported after exposure to unknown concentrations. Although most benzene hazards are associated with inhalation exposure, dermal absorption of liquid benzene may occur, and prolonged or repeated skin contact may produce blistering, erythema, and a dry, scaly dermatitis.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

The available data are not adequate for establishing criteria. However, EPA did report the lowest concentrations of benzene known to cause toxic effects in aquatic organisms.

Freshwater

Acute toxicity: 5,300 ug/liter
Chronic toxicity: No available data

Saltwater

Acute toxicity: 5,100 ug/liter
Chronic toxicity: No available data

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of benzene in water are:

Risk	Concentration
10^{-5}	6.6 ug/liter
10^{-6}	0.66 ug/liter
10^{-7}	0.066 ug/liter

CAG Unit Risk (U.S. EPA): 2.0×10^{-2} $(mg/kg/day)^{-1}$

OSHA Standard (air):
30 mg/m^3 TWA
75 mg/m^3 Ceiling Level
150 mg/m^3 10-min Peak Level

ACGIH Threshold Limit Value:
Suspected human carcinogen
30 mg/m^3 TWA
75 mg/m^3 STEL

CADMIUM

Summary

Cadmium is a metal that can be present in a variety of chemical forms in wastes or in the environment. Some forms are insoluble in water, but cadmium is relatively mobile in the aquatic environment. Cadmium is carcinogenic in animals exposed by inhalation and may also be in humans. It is uncertain whether it is carcinogenic in animals or humans exposed via ingestion. Cadmium is a known animal teratogen and reproductive toxin. It has chronic effects on the kidney, and background levels of human exposure are thought to provide only a relatively small margin of safety for these effects.

Background Information

Cadmium is a soft, bluish white metal that is obtained as a by-product from the treatment of the ores of copper, lead, and iron. Cadmium has a valence of +2 and has properties similar to those of zinc. Cadmium forms both organic and inorganic compounds. Cadmium sulfate is the most common salt.

CAS Number: 7440-43-9

Chemical Formula: Cd

IUPAC Name: Cadmium

Chemical and Physical Properties

Atomic Weight: 112.41

Boiling Point: 765°C

Melting Point: 321°C

Specific Gravity: 8.642

Solubility in Water: Salts are water soluble; metal is insoluble

Solubility in Organics: Variable, based on compound

Vapor Pressure: 1 mm Hg at 394°C

Transport and Fate

Cadmium is relatively mobile in the aquatic environment compared to other heavy metals. It is removed from aqueous media by complexing with organic materials and subsequently being adsorbed to the sediment. It appears that cadmium moves slowly through soil, but only limited information on soil transport is available. Cadmium uptake by plants is not a significant mechanism for depletion of soil accumulations but may be significant for human exposure.

Health Effects

There is suggestive evidence linking cadmium with cancer of the prostate in humans. In animal studies, exposure to cadmium by inhalation caused lung tumors in rats, and exposure by injection produced injection-site sarcomas and/or Leydig-cell tumors. An increased incidence of tumors has not been seen in animals exposed to cadmium orally, but four of the five available studies were inadequate by current standards.

The evidence from a large number of studies on the mutagenicity of cadmium is equivocal, and it has been hypothesized that cadmium is not directly mutagenic but impedes repair. Cadmium is a known animal teratogen and reproductive toxin. It has been shown to cause renal dysfunction in both humans and animals. Other toxic effects attributed to cadmium include immunosuppression (in animals), anemia (in humans), pulmonary disease (in humans), possible effects on the endocrine system, defects in sensory function, and bone damage. The oral LD_{50} in the rat was 225 mg/kg.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life (Proposed 1984)

Freshwater

Acute toxicity: $e^{\{1.30[\ln(\text{hardness})] - 3.92\}}$ ug/liter
Chronic toxicity: $e^{\{1.30[\ln(\text{hardness})] - 3.92\}}$ ug/liter

Saltwater

Acute toxicity: 38 ug/liter
Chronic toxicity: 12 ug/liter

Human Health

Criterion: 10 ug/liter

CAG Unit Risk for inhalation exposure (U.S. EPA): 6.1 (mg/kg/day)$^{-1}$

Interim Primary Drinking Water Standard (U.S. EPA): 10 ug/liter

NIOSH Recommended Standards: 40 ug/m^3 TWA
200 ug/m^3 15 min Ceiling Level

OSHA Standard (air): 200 ug/m^3 TWA
600 ug/m^3 Ceiling Level

ACGIH Threshold Limit Value: 50 ug/m^3 TWA

CARBON TETRACHLORIDE

Summary

Carbon tetrachloride is used as a industrial solvent and chemical intermediate. It is an animal carcinogen, causing liver tumors in mice, rats, and hamsters. Carbon tetrachloride also causes liver and kidney damage in animals and humans.

Chemical Formula: CCl_4

IUPAC Name: Tetrachloromethane

Important Synonyms and Trade Names: Tetrachoromethane, perchloromethane

Chemical and Physical Properties

Molecular Weight: 153.8

Boiling Point: 76.7°C

Melting Point: 22.9°C

Specific Gravity: 1.59 at 20°C (liquid)
5.3 vapor (gas) specific gravity

Solubility in Water: 800 mg/liter

Solubility in Organics: Miscible with alcohol, benzene, chloroform, ether, and carbon disulfide

Log Octanol/Water Partition Coefficient: 2.64

Vapor Pressure: 90 mm Hg at 20°C

Vapor Density: 5.32

Transport and Fate

Carbon tetrachloride has a high vapor pressure and therefore volatilizes rapidly into the atmosphere from surface water and probably from soil. It is relatively soluble in water and therefore would be expected to be transported in groundwater. Because of its high specific gravity, it may move independently from the groundwater as a nonaqueous phase liquid.

Health Effects

Carbon tetrachloride was carcinogenic in mice, rats, and hamsters; in all cases liver tumors were induced. In addition, mice also displayed a high incidence of tumors of the adrenal gland. Studies discussed by EPA (1980) on the mutagenic and teratogenic effects of carbon tetrachloride and its impact on reproduction are inconclusive. Carbon tetrachloride also causes both liver and kidney damage in animals and humans. One study in which guinea pigs were repeatedly exposed to carbon tetrachloride vapor for several months provided evidence of damage to the optic nerve and degeneration of the myelin sheath of the sciatic nerve.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

The available data are not adequate for establishing criteria. However, EPA did report the lowest values known to cause toxicity in aquatic organisms.

Freshwater

Acute toxicity: 35,200 ug/liter
Chronic toxicity: No available data

Saltwater

Acute toxicity: 50,000 ug/liter
Chronic toxicity: No available data

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to carbon tetrachloride at various concentrations in water are:

Risk	Concentration
10^{-5}	4.0 ug/liter
10^{-6}	0.4 ug/liter
10^{-7}	0.04 ug/liter

CAG Unit Risk (U.S. EPA): 1.3×10^{-1} $(mg/kg/day)^{-1}$

OSHA Standard (air): 10 ppm TWA
25 ppm Ceiling Level

ACGIH Threshold Limit Value: 5 ppm Skin.

CHLOROBENZENE

Summary

Chlorobenzene is used as a solvent and as a raw material in chemical manufacturing. It is persistent in the environment and can be adsorbed to organic material in soil. Chlorobenzene may cause liver tumors in male mice. Animals exposed to chlorobenzene have exhibited liver and kidney damage. Chlorobenzene is not very toxic to aquatic organisms; none of the LC_{50} values are less than 10 mg/liter.

CAS Number: 108-90-7

Chemical Formula: C_6H_5Cl

IUPAC Name: Chlorobenzene

Important Synonyms and Trade Names: Monochlorobenzene, benzene chloride, phenyl chloride

Chemical and Physical Properties

Molecular Weight: 112.6

Boiling Point: 131°C

Melting Point: -46°C

Specific Gravity: 1.11 at 20°C (liquid)

Solubility in Water: 500 mg/liter

Solubility in Organics: soluble in alcohol, benzene, chloroform, ether, and carbon tetrachloride

Log Octanol/Water Partition Coefficient: 2.83

Vapor Pressure: 8.8 mm Hg at 20°C

Vapor Density: 3.88

Henry's Law Constant: 3.56×10^{-3} atm m^3/mole at 25°C

Flash Point: 28°C

Transport and Fate

Chlorobenzene is probably removed from surface water primarily by volatilization, although adsorption and bioaccumulation may also be factors. Monochlorobenzene would be expected to move slowly in soil because of its high octanol/water partition coefficient and consequent adsorption to soil organic material.

Health Effects

A study of the carcinogenicity of chlorobenzene was recently completed by the National Toxicology Program and preliminary results show that chlorobenzene caused neoplastic nodules in the liver of male rats but was not carcinogenic in female rats or in mice.

Occupational studies suggest that chronic exposure to monochlorobenzene vapor may cause blood dyscrasia, hyperlipidemia, and cardiac dysfunction in humans. Like many organic solvents, monochlorobenzene is a central nervous system depressant in overexposed humans, but no chronic neurotoxic effects have been reported. animals exposed to chlorobenzene have exhibited liver and kidney damage and atrophy of the seminiferous tubules in the testes. The oral LD_{50} value for rats was 2910 mg/kg.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

The available data are not adequate for establishing criteria.

Human Health

Health criterion: 488 ug/liter
Organoleptic criterion: 20 ug/liter

OSHA Standard (air): 350 mg/m^3 TWA

ACGIH Threshold Limit Value: 350 mg/m^3 TWA - 75 ppm.

CHLOROFORM

Summary

Chloroform (trichloromethane) is often produced during the chlorination of drinking water and thus is a common drinking water contaminant. It is volatile in surface waters and is not likely to be persistent in the environment. Chloroform caused an increase in kidney epithelial tumors in rats and in hepatocellular carcinomas in mice. In addition, there is suggestive evidence from epidemiological studies that exposure to chloroform and other trihalomethanes is associated with an increased incidence of bladder tumors in humans. Other toxic effects of chloroform include central nervous system depression; eye, skin, and gastrointestinal irritation; and damage to the liver, heart, and kidney.

CAS Number: 67-66-3

Chemical Formula: $CHCl_3$

IUPAC Name: Trichloromethane

Chemical and Physical Properties

Molecular Weight: 119.38

Boiling Point: 61.7°C

Melting Point: -63.5°C

Specific Gravity: 1.4832 at 20°C (liquid)

Solubility in Water: 8,200 mg/liter at 20°C

Solubility in Organics: soluble in acetone; miscible with alcohol, ether, benzene, and ligroin

Log Octanol/Water Partition Coefficient: 1.97

Vapor Pressure: 150.5 mm Hg at 20°C

Vapor Density: 4.12

Transport and Fate

Volatilization into the atmosphere is the major transport process for removal of chloroform from aquatic systems. Once in the troposphere, chloroform is attacked by hydroxyl radicals with the subsequent formation of phosgene ($COCl_2$) and possibly chlorine oxide (ClO) radicals. Neither of these reaction products is likely to persist;

phosgene is readily hydrolyzed to hydrochloric acid and carbon dioxide. Reaction with hydroxy radicals is thought to be the primary environmental fate of chloroform. However, chloroform that remains in the troposphere may return to earth in precipitation or adsorbed on particulates, and a small amount may diffuse upward to the stratosphere where it photodissociates via interaction with ultraviolet light.

Photolysis, hydrolysis, and sorption do not appear to be significant environmental fate processes for chloroform. However, sorption processes may have some importance as a removal mechanism in groundwater and soil. The log octanol/water partition coefficient6 indicates that this compound may bioaccumulate under conditions of constant exposure. Studies with marine organisms provide evidence for only weak to moderate bioaccumulation. Although chloroform is somewhat lipophilic and tends to be found at higher concentrations in fatty tissues, there is no evidence for biomagnification in aquatic food chains.

Health Effects

Chronic administration of chloroform by gavage is reported to produce a dose-related increase in the incidence of kidney epithelial tumors in rats and a dose-related increase in the incidence of hepatocellular carcinomas in mice. Epidemiological studies suggest that higher concentrations of chloroform and other trihalomethanes in water supplies may be associated with an increased frequency of bladder cancer in humans. However, these results are not sufficient to establish causality. An increased incidence of fetal abnormalities was reported in offspring of pregnant rats exposed to chloroform by inhalation. Oral doses of chloroform that caused maternal toxicity produced relatively mild fetal toxicity in the form of reduced birth weights. There are limited data suggesting that chloroform has mutagenic activity in some test systems. However, negative results have been reported for bacterial mutagenesis assays.

Humans may be exposed to chloroform by inhalation, ingestion, or skin contact. Toxic effects include local irritation of the skin or eyes, central nervous system depression, gastrointestinal irritation, liver and kidney damage, cardiac arrhythmia, ventricular tachycardia, and bradycardia. Death from chloroform overdosing can occur and is attributed to ventricular fibrillation. Chloroform anesthesia can produce delayed death as a result of liver necrosis.

Exposure to chloroform by inhalation, intragastric administration, or intraperitoneal injection produces liver and kidney damage in laboratory animals. The oral LD_{50} and inhalation LC_{LO} values for the rat are 908 mg/kg and 39,000 mg/m^3 per 4 hours, respectively.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

The available data are not adequate for establishing criteria.

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of chloroform in water are:

Risk	Concentration
10^{-5}	1.90 ug/liter
10^{-6}	0.19 ug/liter
10^{-7}	0.019 ug/liter

CAG Unit Risk (U.S. EPA): 8.1×10^{-2} $(mg/kg/day)^{-1}$

DDT

Summary

DDT is an organochlorine pesticide, which together with its metabolites, is very persistent in the environment. DDT, DDE, and DDD have been shown to be carcinogenic in mice. They primarily cause liver tumors, but they also increase the incidence of lung tumors and lymphomas. In addition, DDT is a reproductive toxin. Chronic exposure can damage the central nervous system and liver. DDT and other organochlorine pesticides are highly toxic to aquatic organisms and are responsible for the decreased reproductive success of many bird species.

Background Information

Technical DDT is a mixture containing 65-89% p, p'-DDT, 15-20% o,p'-DDT, up to 4% p,p'-DDD, and traces of other materials. Metabolites of DDT include p,p'-DDE and o,p'-DDD. The DDT isomers and metabolites are usually found together and generally have similar properties; therefore, they will be considered together. Where differences occur the specific isomer will be identified.. DDT will be used to refer to the combination of technical material and metabolites. Specific DDT isomers will be identified as such.

CAS Number: p,p'-DDT: 50-29-3
o,p'-DDT: 789-02-6
p,p'-DDD: 72-54-8
o,p'-DDD: 53-19-0
p,p'-DDE: 72-55-9

Chemical Formula: p,p'- and o,p'-DDT: $C_{14}H_9Cl_5$
p,p'- and o,p'-DDD: $C_{13}H_{10}Cl_4$
p,p'- and o,p'-DDE: $C_{14}H_8Cl_4$

IUPAC Name: p,p'-DDT: 1,1,1-Trichloro-2,2-bis(4-chlorophenyl)ethane
o,p'-DDT: 1,1,1-Trichloro-2-(2-chlorophenyl)-2-(4-chlorophenyl)ethane
p,p'-DDD: 1,1-Dichloro-2,2-bis(4-chlorophenyl)-ethane
o,p'-DDE: 1,1-Dichloro-2,2-bis(4-chlorophenyl)-ethene

Important Synonyms and Trade Names:
DDT: Dichlorodiphenyltrichloroethane, dicophane, chlorophenothane, Gesarol, Neocid
p,p'-DDD: TDE, Rothane

Chemical and Physical Properties

Molecular Weight: o.p- and p.p'-DDT: 354.5
DDD: 320
DDE: 318

Boiling Point: DDT: 260°C

Melting Point: DDT: 109°C
DDD: 112°C
DDE: 90°C

Solubility in Water: p.p'-DDT: 5.5 ug/liter
o.p'-DDT: 26 ug/liter
p.p'-DDD: 20 ug/liter
DDE: 14 ug/liter

Solubility in Organics: DDT: soluble in acetone, benzene, cyclohexanane, morpholine, pyridine, and dioxane

Log Octanol/Water Partition Coefficient:

DDT: 4.98
p.p'-DDT: 3.98
p.p'-DDD: 5.99
o.p'-DDD: 6.08
DDE: 5.69

Vapor Pressure:

p.p'-DDT: 1.9 x 10^{-7} mm Hg at 25°C
p.p'-DDT: 7.3 x 10^{-7} mm Hg at 30°C
o.p'-DDT: 5.5 x 10^{-6} mm Hg at 30°C
p.p'-DDD: 1.0 x 10^{-6} mm Hg at 30°C
o.p'-DDD: 1.9 x 10^{-6} mm Hg at 30°C
-DDE: 6.5 x 10^{-6} mm Hg at 20°C

Transport and Fate

DDT and it metabolites are very persistent in the environment. Volatilization is probably the most important transport process from soil and water for p.p'-DDT and o.p'-DDT, as evidenced by the ubiquitous nature of DDT in the environment.

Sorption and bioaccumulation are the most important transport processes for the DDT isomers. Although it only occurs slowly, the ultimate fate process for p.p'-DDT, o.p'-DDT, and DDD is biotransformation to form bis (2-chlorophenyl)methanone (DDCO). Indirect photolysis may also be important for p.p'-DDT and o.p'-DDT in aquatic environments. For DDE, direct photolysis is the most important ultimate fate process in the environment although biotransformation may also be important.

Health Effects

DDT, DDE, and DDD have been shown to be carcinogenic to mice, primarily causing liver tumors, but also causing lung tumors and lymphomas. DDT does not appear to be mutagenic; but it has caused chromosomal damage. There is no evidence that DDT is a teratogen; but it is a reproductive toxin, causing reduced fertility, reduced growth of offspring, and fetal mortality.

Chronic exposure to DDT causes a number of adverse effects, especially to the liver and central nervous system (CNS). DDT induces various microsomal enzymes and therefore probably affects the metabolism of steroid hormones and exogenous chemicals. Other effects on the liver include hypertrophy of the parenchymal cells and increased fat deposition. In the CNS, exposure to DDT cause behavioral effects such as decreased aggression and decreased conditional reflexes. Acute exposure to large doses or chronic exposure to lower doses causes seizures. The oral LD_{50} is between 113 and 450 mg/kg for the rat and is generally higher for other animals.

DDT, DDD, and DDE are bioconcentrated and stored in the adipose tissues of most animals.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

DDT: Freshwater

Acute toxicity: 1.1 ug/liter
Chronic toxicity: 0.001 ug/liter

Saltwater

Acute toxicity: 0.13 ug/liter
Chronic toxicity: 0.001 ug/liter

DDD and DDE:

The available data are not adequate for establishing criteria. However, EPA did report the lowest values known to be toxic in aquatic organisms.

Freshwater

Acute toxicity: DDD: 0.6 ug/liter
DDE: 1050 ug/liter
Chronic toxicity: DDD & DDE: No available data

Saltwater

Acute toxicity: DDD: 3.6 µg/liter
DDE: 14 µg/liter

Chronic toxicity: DDD & DDE: No available data

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of DDT in water are:

Risk	Concentration
10^{-5}	0.24 ng/liter
10^{-6}	0.024 ng/liter
10^{-7}	0.0024 ng/liter

CAG Unit Risk (U.S. EPA): 0.34 $(mg/kg/day)^{-1}$

OSHA Standard (air): 1 mg/m^3 TWA

ACGIH Threshold Limit Value: 1 mg/m^3 TWA

DIBROMOCHLOROPROPANE

Summary

Dibromochloropropane (DBCP) was formerly used as a soil fumigant and nematocide. It has been found to be carcinogenic in mice and rats. It causes mammary tumors (in female rats only) and forestomach tumors when administered orally, and nasal, tongue, and lung tumors when given by inhalation. Men occupationally exposed to DBCP had abnormally low sperm counts. Animals studies have shown that dibromochloropropane has adverse effects on the liver, kidneys, and blood cells.

CAS Number: 96-12-8

Chemical Formula: $C_3H_5Br_2Cl$

IUPAC Name: 1,2-Dibromo-3-chloropropane

Important Synonyms and Trade Names: DBCP, Fumazone, Nemagon

Chemical and Physical Properties

Molecular Weight: 236.36

Boiling Point: 196°C

Melting Point: 6°C

Specific Gravity: 2.093 at 14°C

Solubility in Water: Slightly soluble (probably 5-10 g/liter)

Solubility in Organics: Miscible with oils, dichloropropane, and isopropyl alcohol

Vapor Pressure: 0.8 mm Hg at 21°C

Transport and Fate

There was no information available on the transport and fate of 1,2-dribromo-3-chloropropane (DBCP) at the time of this review. However, there is some information on the transport and fate of structurally similar compounds that may be relevant to the environmental fate of DBCP.

1,2,3-Trichloropropane was found to have a half-life of 51 minutes in stirred water, suggesting volatilization of DBCP from water could be significant. However, DBCP is considerably heavier than 1,2,3-trichloropropane and thus somewhat less likely to volatilize. The log octanol/water partition coefficient, 2.28 of 1,2-dichloropropane[4] suggests that it will readily adsorb to organic components of soils and sediments and, therefore, be transported in dust and suspended solids. The tendency of brominated aliphatics to have higher log octanol/water portion coefficients than chlorinated aliphatics suggest DBCP will adsorb to a greater degree than 1,2-dichloropropane. Because of its water solubility, density, and low vapor pressure, DBCP is a likely groundwater contaminant. Its high density suggests that it would settle to the bottom of a contaminant plume and ultimately to the bottom of the aquifer.

Based on information of one and two carbon aliphatics, DBCP may be oxidized in the troposphere by hydroxyl radicals and hydrolyzed in an aqueous environment. Biodegradation of 1,2-dichloropropane does occur by soil microorganisms. However, the amount and speed of biodegradation and chemical degradation of DBCP is unknown.

Health Effects

DBCP has been found to be carcinogenic in two animal bioassays and mutagenic in the Ames assay system. In a gavage study, DBCP was found to produce significantly increased incidences of squamous-cell carcinomas of the forestomach of mice and rats and of mammary adenocarcinomas in female rats. In an inhalation study, rats had increased incidences of nasal cavity tumors and tumors of the tongue, while mice had increased incidences of nasal cavity tumors and lung tumors.

Men occupationally exposed to DBCP during its manufacture were found to have abnormally low sperm counts. Male rats exposed to DBCP during subchronic toxicity studies were also found to have abnormally low sperm cells as well as degenerative changes in the seminiferous tubules, decreased weight of the testes, and an increased proportion of abnormal sperm cells. Liver and kidney effects have also been noted in animal studies. Effects range from dilatation of the sinusoids and centrilobular congestion to cirrhosis and necrosis in the liver. Cloudy swelling of the epithelium of the proximal convoluted tubules and increased amounts of interstitial tissue have been found in the kidneys. Effects on blood cells were also noted in several studies. These effects include severe leukopenias and anemias in exposed monkeys and decreased activity of phagocytic cells in exposed rats.

Regulations and Standards

NIOSH Recommended Standard: 10 ppb (0.1 mg/m^3)

OSHA Standard (air): 1 ppb (9.6 ug/m^3) TWA

1.1-DICHLOROETHANE

Summary

1.1-Dichloroethane is quite volatile and probably is not very persistent in aquatic environments. Inhalation exposure to high doses causes central nervous system depression in humans and may cause hepatotoxicity. In animals, high doses cause liver and kidney damage and retard fetal development.

CAS Number: 75-34-3

Chemical Formula: CH_3CHCl_2

IUPAC Name: 1.1-Dichloroethane

Important Synonyms and Trade names: Ethylidene chloride, ethylidene dichloride

Chemical and Physical Properties

Molecular Weight: 98.96

Boiling Point: 57.3°C

Melting Point: -97.0°C

Specific Gravity: 1.1776 at 20°C

Solubility in Water: 5 g/liter

Solubility in Organics: Miscible in alcohol

Log Octanol/Water Partition Coefficient: 1.79

Vapor Pressure: 180 mm Hg at 20°C

Transport and Fate

1.1-Dichloroethane disperses from surface water primarily by volatilization into the troposphere, where it is subsequently broken down by hydroxylation. No studies on adsorption were found in the literature reviewed, but because of its water solubility and relatively low log octanol/water partition coefficient, 1.1-dichloroethane potentially could move through soil and enter the groundwater.

Health Effects

Limited toxicological testing of 1.1-dichloroethane has been conducted, although the literature indicates that 1.1-dichloroethane is one of the least toxic of the chlorinated ethanes. An NCI bioassay on 1.1-dichloroethane was limited by poor survival of test animals, but some marginal tumorigenic effects were seen. Inhalation exposure to high doses of 1.1-dichloroethane (over 16.000 mg/m^3) caused retarded fetal development in rats. 1.1-Dichloroethane was not found to be mutagenic using the Ames assay. 1.1-Dichloroethane causes central nervous system depression when inhaled at high concentrations, and evidence suggests that the compound is hepatotoxic in humans. Kidney and liver damage was seen in animals exposed to high levels of 1.1-dichloroethane. The oral LD_{50} value in the rat is 725 mg/kg.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

The available data were inadequate for establishing criteria.

OSHA Standard (air): 400 mg/m^3 TWA

ACGIH Threshold Limit Value: 810 mg/m^3 TWA - 200 ppm

1,2-DICHLOROETHANE

Summary

1,2-Dichloroethane (ethylene dichloride) is a volatile organic solvent, and volatilization and percolation into groundwater may be significant routes of transport. It has a low solubility in water and may be a component in nonaqueous-phase liquids. 1,2-Dichloroethane is carcinogenic in animals and mutagenic in bacterial test systems; it is a suspected human carcinogen.

CAS Number: 107-06-02

Chemical Formula: CH_2ClCH_2Cl

IUPAC Name: 1,2-Dichloroethane

Important Synonyms and Trade Names: Ethylene dichloride, glycol dichloride.

Chemical and Physical Properties

Molecular Weight: 98.96

Boiling Point: 83-84°C

Melting Point: -35.4°C

Specific Gravity: 1.253 at 20°C

Solubility in Water: 8 g/liter

Solubility in Organics: Miscible with alcohol, chloroform, and ether

Log Octanol/Water Partition Coefficient: 1.48

Vapor Pressure: 61 mm Hg at 20°C

Flash Point: 15°C (closed cup)

Transport and Fate

The primary method of dispersion from surface water for 1,2-dichloroethane is volatilization. In the atmosphere, 1,2-dichloroethane is rapidly broken down by hydroxylation, although some may be absorbed by atmospheric water and return to the earth by precipitation. No studies on the adsorption of 1,2-dichloroethane onto soil were reported in the literature examined. However, 1,2-dichloroethane has a low octanol/water partition coefficient, is slightly soluble in water, and therefore leaching through the soil into the groundwater is an expected route of dispersal.

Health Effects

1,2-Dichloroethane is carcinogenic in rats and mice, producing a variety of tumors. When administered by gavage, it produced carcinomas of the forestomach and hemangiosarcomas of the circulatory system in male rats; adenocarcinomas of the mammary gland in female rats; lung adenomas in male mice; and lung adenomas, mammary adenocarcinomas, and endometrial tumors in female mice. It is mutagenic when tested using bacterial test systems. Human exposure by inhalation to 1,2-dichloroethane has been shown to cause headache, dizziness, nausea, and liver and kidney dysfunction. Dermatitis may be produced by skin contact. In severe cases, leukocytosis (an excess of white blood cells) may be diagnosed; and internal hemorrhaging and pulmonary edema leading to death may occur. Similar effects are produced in experimental animals.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

The available data are not adequate for establishing criteria. However, EPA did report the lowest values known to be toxic in aquatic organisms.

Freshwater

Acute toxicity: 118 mg/liter
Chronic toxicity: 20 mg/liter

Saltwater

Acute toxicity: 113 mg/liter
Chronic toxicity: No available data

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of 1,2-dichloroethane in water are:

Risk	Concentration
10^{-5}	9.4 ug/liter
10^{-6}	0.94 ug/liter
10^{-7}	0.094 ug/liter

1,1-DICHLOROETHYLENE

Summary

1,1-Dichloroethylene (VDC, vinylidene chloride) caused kidney tumors (in males only) and leukemia in one study of mice exposed by inhalation, but the results of other studies were equivocal or negative. 1,1-Dichloroethylene is mutagenic, and it caused adverse reproductive effects when administered to rats and rabbits by inhalation. Chronic exposure causes liver damage, and acute exposure to high doses produces nervous system damage.

CAS Number: 75-35-4

Chemical Formula: CH_2CCl_2

IUPAC Name: 1,1-Dichloroethene

Important Synonyms and Trade Names: Vinylidene chloride, VDC, 1,1-dichloroethene, 1,1-DCE

Chemical and Physical Properties

Atomic Weight: 96.94

Boiling Point: 37°C

Melting Point: -122.1°C

Specific Gravity: 1.218 at 20°C

Solubility in Water: 400 mg/liter at 20°C

Solubility in Organics: Sparingly soluble in alcohol, ether, acetone, benzene, and chloroform

Log Octanol/Water Partition Coefficient: 1.48

Vapor Pressure: 500 mm Hg at 20°C

Vapor Density: 3.25

Transport and Fate

Volatilization appears to be the primary transport process for 1,1-dichloroethylene (VDC), and its subsequent photooxidation in the atmosphere by reaction with hydroxyl radicals is apparently the predominant fate process. Information on other transport and fate mechanisms was generally lacking for 1,1-dichloroethylene. However, by inference from related compounds, hydrolysis, sorption, bioaccumulation, biotransformation, and biodegradation probably all occur but at rates too slow to be of much significance.

Health Effects

1,1-Dichloroethylene caused kidney tumors in males and leukemia in males and females in one study of mice exposed by inhalation, gave equivocal results in other inhalation studies, and gave negative results in rats and mice following oral exposure and in hamsters following inhalation exposure. VDC was mutagenic in several bacterial assays. 1,1-Dichloroethylene did not appear to be teratogenic but did cause embryotoxicity and fetotoxicity when administered to rats and rabbits by inhalation. Chronic exposure to oral doses of VDC as low as 5 mg/kg/day caused liver changes in rats. Acute exposure to high doses causes central nervous system depression, but neurotoxicity has not been associated with low-level chronic exposure. The oral LD_{50} value for the rat is 1,500 mg/kg, and for the mouse it is 200 mg/kg.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

The available data are inadequate for establishing criteria. However, EPA did report the lowest values known to cause toxicity in aquatic organisms.

Freshwater

Acute toxicity: 11,600 ug/liter
Chronic toxicity: No available data

Saltwater

Acute toxicity: 224,000 ug/liter
Chronic toxicity: No available data

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of 1,2-dichloroethane in water are:

Risk	Concentration
10^{-5}	0.33 ug/liter
10^{-6}	0.033 ug/liter
10^{-7}	0.0033 ug/liter

CAG Unit Risk (U.S. EPA): 1.16 $(mg/kg/day)^{-1}$

ACGIH Threshold Limit Value: 5 ppm TWA
20 mg/m^3 TWA
485 mg/m^3 STEL

1,2-TRANS-DICHLOROETHYLENE

Summary

Chronic inhalation exposure to 1,2-trans-dichloroethylene (1,2-trans-DCE) causes liver degeneration, and acute exposure to high levels has adverse effects on the central nervous system.

CAS Number: 540-59-0

Chemical Formula: $C_2H_2Cl_2$

IUPAC Name: 1,2-trans-Dichloroethene

Important Synonyms and Trade Names: trans-Acetylene dichloride, dioform

Chemical and Physical Properties

Molecular Weight: 96.94

Boiling Point: 47.5°C

Melting Point: -50°C

Specific Gravity: 1.2565 at 20°C

Solubility in Water: 600 mg/liter

Solubility in Organics: Miscible with alcohol, ether, and acetone; very soluble in benzene and chloroform

Log Octanol/Water Partition Coefficient: 1.48 (calculated)

Vapor Pressure: 200 mm Hg at 14°C

Flash Point: 3°C (undefined isomers)

Transport and Fate

Due to the relatively high vapor pressure of 1,2-trans-dichloroethylene (1,2-trans-DCE), volatilization from aquatic systems to the atmosphere is quite rapid and appears to be the primary transport process. Aerial transport of this compound can occur and is partly responsible for its relatively wide environmental distribution. Although little applicable information is available, adsorption is probably an insignificant environmental fate process for 1,2-trans-DCE. The relatively low log octanol/water partition coefficient of 1,2-trans-DCE suggests that bioaccumulation also is a relatively insignificant process. Although no information pertaining specifically to biodegradation of 1,2-trans-DCE is available, results with similar compounds suggest that this process probably occurs but at a very slow rate.

Photooxidation in the troposphere appears to be the dominant environmental fate of 1,2-trans-DCE. Once in the troposphere, the compound is attacked at the double bond by hydroxyl radicals, resulting in the formation of formic acid, hydrochloric acid, carbon monoxide, and formaldehyde. The half-life of 1,2-trans-DCE in the troposphere is estimated to be less than one day. Given the properties of similar compounds, photolysis of 1,2-trans-DCE in aquatic systems and photodissociation in the terrestrial environment are probably insignificant.

Health Effects

Very little information concerning exposure only to 1,2-trans-DCE is available. There are no reports of carcinogenic or teratogenic activity by 1,2-trans-DCE in animals or humans. It is reportedly nonmutagenic in a variety of test systems. Like other members of the chlorinated ethylene series, 1,2-trans-DCE has anesthetic properties. Exposure to high vapor concentrations has been found to cause nausea, vomiting, weakness, tremor, and cramps in humans. Repeated exposure via inhalation of 800 mg/m^3 (8 hours/day, 5 days/week, for 16 weeks) was reported to produce fatty degeneration of the liver in rats. The intraperitoneal injection LD_{50} value for the rat is 7,536 mg/kg.

Although nephrotoxic and cardiac sensitizing effects are associated with exposure to 1,1-dichloroethylene, the 1,2-DCE isomers have not been investigated with respect to this type of effects. 1,2-trans-Dichloroethylene can inhibit aminopyrine demethylation in rat liver microsomes in vitro, and it may thus interact with the hepatic drug-metabolizing monooxygenase system.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

The available data are not adequate for establishing criteria.

OSHA Standard: 790 mg/m^3 TWA

ACGIH Threshold Limit Value: 790 mg/m^3 TWA
1,000 mg/m^3 STEL.

ENDRIN

Summary

Endrin is a cyclodiene insecticide that is an isomer of dieldrin. It is probably retained in soils and sediments and is persistent in the environment. It is strongly bioaccumulated by aquatic organisms. Endrin is highly toxic to mammals, aquatic organisms, and terrestrial wildlife4 after acute exposure. It has not been shown to be carcinogenic or mutagenic, but it is a potent teratogen and reproductive toxin.

CAS Number: 72-20-8

Chemical Formula: $C_{12}H_8Cl_6O$

IUPAC Name: 1,2,3,4,10,10-Hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a
octahydro-endo-1,4:5,8-dimethanonaphthalene

Important Synonyms and Trade Names: Endrex, hexadrin, mendrin

Chemical and Physical Properties

Molecular Weight: 380.9

Melting Point: Decomposes at 235°C

Specific Gravity: 1.65 at 25°C

Solubility in Water: 250 ug/liter at 25°C

Solubility in Organics: Soluble in acetone, benzene, carbon tetrachloride, hexane, and xylene

Log Octanol/Water Partition Coefficient: 5.6

Vapor Pressure: 2.7×10^{-7} mm Hg at 25°C

Transport and Fate

Endrin is quite persistent in the environment. Volatilization from soil surfaces and probably from surface water is an important transport process. Subsequent photolysis to delta-keto endrin and endrin aldehyde are apparently important fate processes. No information on the ability of endrin to adsorb to soils and sediments was found in the literature reviewed, but the physical properties of the chemical suggest that sorption would be an important fate process. Endrin is readily bioconcentrated by aquatic organisms, with concentration factors of 10^3 to 10^4. Biotransformation and biodegradation may also be important fate processes for endrin.

Health Effects

Endrin has not been shown to be carcinogenic or mutagenic. However, it is a potent reproductive toxin and teratogen in experimental animals. Reproductive effects included fetal mortality and growth retardation, while teratogenic effects included cleft palate, open eye, clubbed foot, meningoencephales, and fused ribs. Chronic exposure to low levels of endrin primarily results in nervous system damage but also has adverse effects on the heart, lungs, liver, and kidneys. The acute toxicity of endrin is due to its effects on the central nervous system. The acute oral and dermal LD_{50} values for endrin to the rat were both approximately 15 mg/kg.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

Freshwater

Acute toxicity: 0.18 ug/liter
Chronic toxicity: 0.0023 ug/liter

Saltwater

Acute toxicity: 0.037 ug/liter
Chronic toxicity: 0.0023 ug/liter

Human Health

Criterion: 1.0 ug/liter

Primary Drinking Water Standard: 1.0 ug/liter

OSHA Standard: 100 ug/m^3 TWA

ETHYLBENZENE

Summary

There is some evidence suggesting that ethylbenzene causes adverse reproductive effects in animals. Oral and inhalation exposure caused minor liver and kidney changes in rats. Ethylbenzene is a skin and eye irritant.

CAS Number: 100-41-4

Chemical Formula: $C_6H_5C_2H_5$

IUPAC Name: Ethylbenzene

Important Synonyms and Trade Names: Phenylethane, EB, ethylbenzol

Chemical and Physical Properties

Molecular Weight: 106.2

Boiling Point: 136.2°C

Melting Point: -95°C

Specific Gravity: 0.867 at 20°C (liquid)

Solubility in Water: 161 mg/liter at 25°C

Solubility in Organics: Freely soluble in organic solvents

Log Octanol/Water Partition Coefficient: 3.15

Vapor Pressure: 7 mm Hg at 20°C

Vapor Density: 3.66

Henry's Law constant: 6.44 atm. m^3/mole

Flash Point: 17.2°C

Transport and Fate

Only limited data are available on the transport and fate of ethylbenzene. Volatilization is probably the major route of elimination from surface water. Subsequent atmospheric reactions, especially photooxidation, are responsible for its fate. However, its high log octanol/water partition coefficient suggests that a significant amount of ethylbenzene may be adsorbed by organic material in the sediment. Some soil bacteria are capable of using ethylbenzene as a source of carbon. However, the relative importance of this potential route of ethylbenzene elimination has not been determined.

Health Effects

Ethylbenzene has been selected by the National Toxicology Program to be tested for possible carcinogenicity, although negative results were obtained in mutagenicity assays in *Salmonella typhimurium* and *Saccharomyces cerevisiae*. There is recent animal evidence that ethylbenzene causes adverse reproductive effects. Ethylbenzene is a skin irritant, and its vapor is irritating to the eyes at a concentration of 200 ppm (870 mg/m^3) and above. When experimental animals were exposed to ethylbenzene by inhalation, 7 hours/day for 6 months, adverse effects were produced at concentrations of 600 ppm (2,610 mg/m^3) and above, but not at 400 ppm (1,740 mg/m^3). At 600 ppm rats and guinea pigs showed slight changes in liver and kidney weights, monkeys had slight changes in liver weight, and monkeys and rabbits experienced histopathologic changes in the testes. Similar effects on the liver and kidney were observed in rats fed ethylbenzene at 408 and 680 mg/kg/day for 6 months.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

The available data are not adequate for establishing criteria. However, EPA did report the lowest values known to have toxic effects in aquatic organisms.

Freshwater

Acute toxicity: 32,000 ug/liter
Chronic toxicity: No available data

Saltwater

Acute toxicity: 430 ug/liter
Chronic toxicity: No available data

Human Health

Criterion: 1.4 mg/liter

OSHA Standard (skin): 435 mg/m^3 TWA

ACGIH Threshold Limit Values: 435 mg/m^3 TWA
100 ppm TWA
545 mg/m^3 STEL
125 ppm STEL

LEAD

Summary

Lead is a heavy metal that exists in one of three oxidation states, 0, +2, and +4. There is suggestive evidence that some lead salts are carcinogenic, inducing kidney tumors in mice and rats. Lead is also a reproductive hazard, and it can adversely affect the brain and central nervous system by causing encephalopathy and peripheral neuropathy. Chronic exposure to low levels of lead can cause subtle learning disabilities in children. Exposure to lead can also cause kidney damage and anemia, and it may have adverse effects on the immune system.

CAS Number: 7439-92-1

Chemical Formula: Pb

IUPAC Name: Lead

Chemical and Physical Properties

Atomic Weight: 207.19

Boiling Point: 1,740°C

Melting Point: 327.502°C

Specific Gravity: 11.35 at 20°C

Solubility in Water: Insoluble; some organic compounds are soluble

Solubility in Organics: Soluble in HNO_3 and hot, concentrated H_2SO_4

Transport and Fate

Some industrially produced lead compounds are readily soluble in water. However, metallic lead and the common lead minerals are insoluble in water. Natural compounds of lead are not usually mobile in normal surface or groundwater because the lead leached from ores is adsorbed by ferric hydroxide or combines with carbonate or sulfate ions to form insoluble compounds.

Movement of lead and its inorganic and organolead compounds as particulates in the atmosphere is a major environmental transport process. Lead carried in the atmosphere can be removed by either wet or dry deposition. Although little evidence is available concerning the photolysis of lead compounds in natural waters, photolysis in the atmosphere occurs readily. These atmospheric processes are important in determining the form of lead entering aquatic and terrestrial systems.

The transport of lead in the aquatic environment is influenced by the speciation of the ion. Lead exists mainly as the divalent cation in most unpolluted waters and becomes adsorbed into particulate phases. However, in polluted waters organic complexation is most important. Volatilization of lead compounds probably is not important in most aquatic environments.

Sorption processes appear to exert a dominant effect on the distribution of lead in the environment. Adsorption to inorganic solids, organic materials, and hydrous iron and manganese oxides usually controls the mobility of lead and results in a strong partitioning of lead to the bed sediments in aquatic systems. The sorption mechanism most important in a particular system varies with geological setting, pH, Eh, availability of ligands, dissolved and particulate ion concentrations, salinity, and chemical composition. The equilibrium solubility of lead with carbonate, sulfate, and sulfide is low. Over most of the normal pH range, lead carbonate, and lead sulfate control solubility of lead in aerobic conditions, and lead sulfide and the metal control solubility in anaerobic conditions. Lead is strongly complexed to organic materials present in aquatic systems and soil. Lead in soil is not easily taken up by plants, and therefore its availability to terrestrial organisms is somewhat limited.

Bioaccumulation of lead has been demonstrated for a variety of organisms, and bioconcentration factors are within the range of 100-1,000. Microcosm studies indicate that lead is not biomagnified through the food chain. Biomethylation of lead by microorganisms can remobilize lead to the environment. The ultimate sink of lead is probably the deep oceans.

Health Effects

There is evidence that several lead salts are carcinogenic in mice or rats, causing tumors of the kidneys after either oral or parenteral administration. Data concerning the carcinogenicity of lead in humans are inconclusive. The available data are not sufficient to evaluate the carcinogenicity of organic lead compounds or metallic lead. There is equivocal evidence that exposure to lead causes genotoxicity in humans and animals. The available evidence indicates that lead presents a hazard to reproduction and exerts a toxic effect on conception, pregnancy, and the fetus in humans and experimental animals.

Many lead compounds are sufficiently soluble in body fluids to be toxic. Exposure of humans or experimental animals to lead can result in toxic effects in the brain and central nervous system, the peripheral nervous system, the kidneys, and the hematopoietic system. Chronic exposure to inorganic lead by ingestion or inhalation can cause lead encephalopathy, and severe cases can result in permanent brain damage. Lead poisoning may cause peripheral neuropathy in adults and children, and permanent learning disabilities that are clinically undetectable in children may be caused by exposure to relatively low levels. Short-term exposure to lead can cause reversible kidney damage, but prolonged exposure at high concentrations may result in progressive kidney damage and possibly kidney failure. Anemia, due to inhibition of hemoglobin synthesis and a reduction in the life span of circulating red blood cells, is an early manifestation of lead poisoning. Several studies with experimental animals suggest that lead may interfere with various aspects of the immune response.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life (Proposed Criteria)

The concentrations below are for active lead, which is defined as the lead that passes through a 0.45-um membrane filter after the sample is acidified to pH 4 with nitric acid.

Freshwater

Acute toxicity: $e^{\{1.34[\ln(\text{hardness})] - 2.014\}}$ ug/liter

Chronic toxicity: $e^{\{1.34[\ln(\text{hardness})] - 5.245\}}$ ug/liter

Saltwater

Acute toxicity: 220 ug/liter
Chronic toxicity: 8.6 ug/liter

Human Health

Criterion: 50 ug/liter

Primary Drinking Water Standard: 50 ug/liter

NIOSH Recommended Standard: 0.10 mg/m^3 TWA (inorganic lead)

OSHA Standard: 50 ug/m^3 TWA

ACGIH Threshold Limit Values:

0.15 mg/m^3 TWA (inorganic dusts and fumes)
0.45 mg/m^3 STEL (inorganic dusts and fumes)

MERCURY

Summary

Both organic and inorganic forms of mercury are reported to be teratogenic and embryotoxic in experimental animals. In humans, prenatal exposure to methylmercury has been associated with brain damage. Other major target organs for organic mercury compounds in humans are the central and peripheral nervous system and the kidney. In animals, toxic effects also occur in the liver, heart, gonads, pancreas, and gastrointestinal tract. Inorganic mercury is generally less acutely toxic than organic mercury compounds, but it does affect the central nervous system adversely.

Background Information

Several forms of mercury, including insoluble elemental mercury, inorganic species, and organic species, can exist in the environment. In general, the mercurous (+1) salts are such less soluble than the more commonly found mercuric (+2) slats. Mercury also forms many stable organic complexes that are generally much more soluble in organic liquids than in water. The nature and solubility of the chemical species that occur in an environmental system depend on the redox potential and the pH of the environment.

CAS Number: 7439-97-6

Chemical Formula: Hg

IUPAC Name: Mercury

Chemical and Physical Properties

Atomic Weight: 200.59

Boiling Point: 356.58°C

Melting Point: -38.87°C

Specific Gravity: 13.5939 at 20°C

Solubility in Water: 81.3 ug/liter at 30°C; some salts and organic compounds are soluble.

Solubility in Organics: Depends on chemical species

Vapor Pressure: 0.0012 mm Hg at 20°C

Transport and Fate

Mercury and certain of its compounds, including several inorganic species and dimethyl mercury, can volatilize to the atmosphere from aquatic and terrestrial sources. Volatilization is reduced by conversion of metallic mercury to complexed species and by deposition of HgS in reducing sediments, but even so atmospheric transport is the major environmental distribution pathway for mercury. Precipitation is the primary mechanism for removal of mercury from the atmosphere. Photolysis is important in the breakdown of airborne mercurials and may be important in some aquatic systems. Adsorption onto suspended and bed sediments is probably the most important process determinating the fate of mercury in the aquatic environment. Sorption is strongest into organic materials. Mercury in soils is generally complexed to organic compounds.

Virtually any mercury compound can be remobilized in aquatic systems by microbial conversion to methyl and dimethyl forms. Conditions reported to enhance biomethylation include large amounts of available mercury, large numbers of bacteria, the absence of strong complexing agents, near neutral pH, high temperatures, and moderately aerobic environments. Mercury is strongly bioaccumulated by numerous mechanisms. Methylmercury is the most readily accumulated and retained form of mercury in aquatic biota, and once it enters a biological system it is very difficult to eliminate.

Health Effects

When administered by intraperitoneal injection, metallic mercury produces implantation site sarcomas in rats. No other studies were found connecting mercury exposure with carcinogenic effects in animals or humans. Several mercury compounds exhibit a variety of genotoxic effects in eukaryotes. In general, organic mercury compounds are more toxic than inorganic compounds. Although brain damage due to prenatal exposure to methylmercury has occurred in human populations, no conclusive evidence is available to suggest that mercury causes anatomical defects in humans. Embryotoxicity and teratogenicity of methylmercury has been reported for a variety of experimental animals. Mercuric chloride is reported to be teratogenic in experimental animals. No conclusive results concerning the teratogenic effects of mercury vapor are available.

In humans, alkyl mercury compounds pass through the blood brain barrier and the placenta very rapidly, in contrast to inorganic mercury compounds. Major target organs are the central and peripheral nervous systems, and the kidney. Methylmercury is particularly hazardous because of the difficulty of eliminating it from the body. In experimental animals, organic mercury compounds can produce toxic effects in the gastrointestinal tract, pancreas, liver, heart, and gonads, with involvement of the endocrine, immunocompetent, and central nervous systems.

Elemental mercury is not highly toxic as an acute poison. However, inhalation of high concentrations of mercury vapor can cause pneumonitis, bronchitis, chest pains, dyspnea, coughing, stomatitis, gingivitis, salivation, and diarrhea. Soluble mercuric salts are highly poisonous on ingestion, with oral LD_{50} values of 20 to 60 mg/kg reported. Mercurous compounds are less toxic when administered orally. Acute exposure to mercury compounds at high concentrations causes a variety of gastrointestinal symptoms and severe anuria with uremia. Signs and symptoms associated with chronic exposure involve the central nervous system and include behavioral and neurological disturbances.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life (Proposed Criteria)

Freshwater

Acute toxicity: 1.1 ug/liter
Chronic toxicity: 0.20 ug/liter

Saltwater

Acute toxicity: 1.9 ug/liter
Chronic toxicity: 0.10 ug/liter

Human Health

Criterion: 144 ng/liter

Primary Drinking Water Standard: 0.002 mg/liter

NIOSH Recommended Standard: 0.05 mg/m^3) TWA (inorganic mercury)

OSHA Standard: 0.1 mg/m^3) Ceiling Level

ACGIH Threshold Limit Values:

0.01 mg/m^3 TWA (alkyl compounds)
0.03 mg/m^3 STEL (alkyl compounds)
0.05 mg/m^3 TWA (vapor)
0.1 mg/m^3 TWA (aryl and inorganic compounds)

METHYLENE CHLORIDE

Summary

Methylene chloride increased the incidence of lung and liver tumors and sarcomas in rats and mice. It was found to be mutagenic in bacterial test systems. In humans, methylene chloride irritates the eyes, mucous membranes, and skin. Exposure to high levels adversely affects the central and peripheral nervous systems and the heart. In experimental animals, methylene chloride is reported to cause kidney and liver damage, convulsions, and paresis.

CAS Number: 75-09-2

Chemical Formula: CH_2Cl_2

IUPAC Name: Dichloromethane

Important Synonyms and Trade names: Methylene dichloride, methane dichloride

Chemical and Physical Properties

Molecular Weight: 84.93

Boiling Point: 40°C

Melting Point: -95.1°C

Specific Gravity: 1.3266 at 20°C

Solubility in Water: 13,200-20,000 mg/liter at 25°C

Solubility in Organics: Miscible with alcohol and ether

Log Octanol/Water Partition Coefficient: 1.25

Vapor Pressure: 362.4 mm Hg at 20°C

Vapor Density: 2.93

Transport and Fate

Volatilization to the atmosphere appears to be the major mechanism for removal of methylene chloride from aquatic systems and its primary environmental transport process. Photooxidation in the troposphere appears to be the dominant environmental fate of methylene chloride Once in the troposphere, the compound is attacked by hydroxyl radicals, resulting in the formation of carbon dioxide, and to a lesser extent, carbon monoxide and phosgene. Phosgene is readily hydrolyzed to HCl and CO_2. About one percent of tropospheric methylene chloride would be expected to reach the stratosphere where it would probably undergo photodissociation resulting from interaction with high energy ultraviolet radiation. Aerial transport of methylene chloride is partly responsible for its relatively wide environmental distribution. Atmospheric methylene chloride may be returned to the earth in precipitation.

Photolysis, oxidation, and hydrolysis do not appear to be significant environmental fate processes for methylene chloride, and there is no evidence to suggest that either adsorption or bioaccumulation are important fate processes for this chemical. Although methylene chloride is potentially biodegradable, especially by acclimatized microorganisms, biodegradation probably only occurs at a very slow rate.

Health Effects

Methylene chloride is currently under review by the National Toxicology Program. Preliminary results indicate that it produced an increased incidence of lung and liver tumors in mice and mammary tumors in female and male rats. In a chronic inhalation study, male rats exhibited an increased incidence of sarcomas in the ventral neck region. However, the authors suggested that the relevance and toxicological significance of this finding were uncertain in light of available toxicity data. Methylene chloride is reported to be mutagenic in bacterial test systems. It also has produced positive results in the Fisher rat embryo cell transformation test. However, it has been suggested that the observed cell-transforming capability may have been due to impurities in the test material. There is no conclusive evidence that methylene chloride can produce teratogenic effects.

In humans, direct contact with methylene chloride produces eye, respiratory passage, and skin irritation. Mild poisoning due to inhalation exposure produce somnolence, lassitude, numbness and tingling of the limbs, anorexia, and lightheadedness, followed by rapid and complete recovery. More severe poisoning generally involve correspondingly greater disturbances of the central and peripheral nervous systems. Methylene chloride also has acute toxic effects on the heart, including the induction of arrhythmia. Fatalities reportedly due to methylene chloride exposure have been attributed to cardiac injury and heart failure. Methylene chloride is metabolized to carbon monoxide in vivo, and levels of carboxyhemoglobin in the blood are elevated after acute exposures. In experimental animals, methylene chloride is reported to cause kidney and liver damage, convulsions, and distal paresis. An oral LD_{50} value of 2,136 mg/kg, and an inhalation LC_{50} value of 88,000 mg/m^3/30 min are reported for the rat.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

The available data are not adequate for establishing criteria.

Human Health

Criterion: 12.4 mg/liter (for protection against the noncarcinogenic effects of methylene chloride)

CAG Unit Risk (U.S. EPA): 1.4 x 10^{-2} $(mg/kg/day)^{-1}$

NIOSH Recommended Standards:

261 mg/m^3 TWA in the presence of no more than 9.9 mg/m^3 of CO
1,737 mg/m^3/15 min Peak Concentration

OSHA Standard:
1,737 mg/m^3 TWA
3,474 mg/m^3 Ceiling Level
6,948 mg/m^3 Peak Concentration (5 min in any 3 hr)

ACGISH Threshold Limit Value:
350 mg/m^3 TWA
100 ppm TWA
1,740 mg/m^3 STEL
500 ppm STEL

TETRACHLOROETHYLENE

Summary

Tetrachloroethylene (PCE, perchloroethylene) induced liver tumors when administered orally to mice and was found to be mutagenic using a microbial assay system. Reproduction toxicity was observed in pregnant rats and mice exposed to high concentrations. Animals exposed by inhalation to tetrachloroethylene exhibited liver, kidney, and central nervous system damage.

CAS Number: 127-18-4

Chemical Formula: C_2Cl_4

IUPAC Name: Tetrachloroethene

Important Synonyms and Trade Names: Perchloroethylene, PCE

Chemical and Physical Properties

Molecular Weight: 165.83

Boiling Point: 121°C

Melting Point: -22.7°C

Specific Gravity: 1.63

Solubility in Water: 150 to 200 mg/liter at 20°C

Solubility in Organics: Soluble in alcohol, ether, and benzene

Log Octanol/Water Partition Coefficient: 2.88

Vapor Pressure: 14 mm Hg at 20°C

Transport and Fate

Tetrachloroethylene (PCE) rapidly volatilizes into the atmosphere where it reacts with hydroxyl radicals to produce HCl, CO, CO_2, and carboxylic acid. This is probably the most important transport and fate process for tetrachloroethylene in the environment. PCE will leach into the groundwater, especially in soils of low organic content. In soils with high levels of organics, PCE adsorbs to these materials and can be bioaccumulated to some degree. However, it is unclear if tetrachloroethylene bound to organic material can be degraded by microorganisms or must be desorbed to be destroyed. There is some evidence that higher organisms can metabolize PCE.

Health Effects

Tetrachloroethylene was found to produce liver cancer in male and female mice when administered orally by gavage. Unpublished gavage studies in rats and mice performed by the National Toxicology Program (NTP) showed hepatocellular carcinomas in mice and a slight, statistically insignificant increase in a rare type of kidney tumor. NTP is also conducting an inhalation carcinogenicity study. Elevated mutagenic activity was found in Salmonella strains treated with tetrachloroethylene. Delayed ossification of skull bones and sternebrae were reported in offspring of pregnant mice exposed to 2,000 mg/m^3 of tetrachloroethylene for 7 hours/day on days 6-15 of gestation. Increased fetal resorptions were observed after exposure of rats to tetrachloroethylene. Renal toxicity and hepatotoxicity have been noted following chronic inhalation exposure of rats to tetrachloroethylene. Renal toxicity and hepatotoxicity have been noted following chronic inhalation exposure of rats to tetrachloroethylene levels of 1,356 mg/m^3. During the firs 2 weeks of a subchronic inhalation study, exposure to concentrations of 1,6222 ppm (10,867 mg/m^3) of tetrachloroethylene produced signs of central nervous system depression, and chlolinergic stimulation was observed among rabbits, monkeys, rats, and guinea pigs.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

The available data are not adequate for establishing criteria. However, EPA did report the lowest values known to be toxic in aquatic organisms.

Freshwater

Acute toxicity: 5,280 ug/liter
Chronic toxicity: 840 ug/liter

Saltwater

Acute toxicity: 10,200 ug/liter
Chronic toxicity: 450 ug/liter

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of tetrachloroethylene in water are:

Risk	Concentration
10^{-5}	8.0 ug/liter
10^{-6}	0.8 ug/liter
10^{-7}	0.08 ug/liter

CAG Unit Risk (U.S. EPA): 5.1 x 10^{-2} $(mg/kg/day)^{-1}$

NIOSH Recommended Standards (air):

335 mg/m^3 TWA
670 mg/m^3 15-min Ceiling Level

OSHA Standard (air):

670 mg/m^3 TWA
1,340 mg/m^3 Ceiling Level
2,010 mg/m^3 for 5 min every 3 hr. Peak Concentration

ACGIH Threshold Limit Value:

50 ppm TWA
335 mg/m^3 TWA
200 ppm STEL
1,340 mg/m^3 STEL

TOLUENE

Summary

Toluene has been shown to be embryotoxic in experimental animals, and the incidence of cleft palate increased in the offspring of dosed mice. Chronic inhalation exposure to high levels of toluene caused cerebellar degeneration and an irreversible encephalopathy in animals. In humans, acute exposure depressed the central nervous system and caused narcosis.

CAS Number: 108-88-3

Chemical Formula: $C_6H_5CH_3$

IUPAC Name: Methylbenzene

Important Synonyms and Trade Names: Toluol, phenylmethane

Chemical and Physical Properties

Molecular Weight: 92.13

Boiling Point: 110.6°C

Melting Point: -95°C

Specific Gravity: 0.8669 at 20°C

Solubility in Water: 534.8 mg/liter

Solubility in Organics: Soluble in acetone, ligroin, and carbon disulfide; miscible with alcohol, ether, benzene, chloroform, glacial acetic acid, and other organic solvents

Log Octanol/Water Partition Coefficient: 2.69

Vapor Pressure: 28.7 mm Hg at 25°C

Vapor Density: 3.14

Flash Point: 4.4°C

Transport and Fate

Volatilization appears to be the major route of removal of toluene from aquatic environments, and atmospheric reactions of toluene probably subordinate all other fate processes. Photooxidation is the primary atmospheric fate process for toluene, and benzaldehyde is reported to be the principal organic product. Subsequent precipitation or dry deposition can deposit toluene and its oxidation products into aquatic and terrestrial systems. Direct photolytic cleavage of toluene is energetically improbable in the troposphere, and oxidation and hydrolysis are probably not important as aquatic fates.

The log octanol/water partition coefficient of toluene indicates that sorption processes may be significant. However, no specific environmental sorption studies are available, and the extent to which adsorption by sedimentary and suspended organic material may interfere with volatilization is unknown. Bioaccumulation is probably not an important environmental fate process. Although toluene is known to be degraded by microorganisms and can be detoxified and excreted by mammals, the available data do not allow estimation of the relative importance of biodegradation/biotransformation processes. Almost all toluene discharged to the environment by industry is in the form of atmospheric emissions.

Health Effects

There is no conclusive evidence that toluene is carcinogenic or mutagenic in animals or humans. The National Toxicological Program is currently conducting an inhalation carcinogenicity bioassay in rats and mice.

Oral administration of toluene at doses as low as 260 mg/kg produced a significant increase in embryonic lethality in mice. Decreased fetal weight was observed at doses as low as 434 mg/kg, and an increased incidence of cleft palate was seen at doses as low as 867 mg/kg. However, other researches have reported that toluene is embryotoxic but not teratogenic in laboratory animals. There are no accounts of a teratogenic effect in humans after exposure to toluene.

Acute exposure to toluene at concentrations of 375-1,500 mg/kg produces central nervous system depression and narcosis in humans. However, even exposure to quantities sufficient to produce unconsciousness fail to produce residual organ damage. The rat oral LD_{50} value and inhalation LC_{LO} value are 5,000 mg/kg and 15,000 mg/m^3, respectively. Chronic inhalation exposure to toluene at relatively high concentrations produces cerebellar degeneration and an irreversible encephalopat in mammals.

Toluene in sufficient amounts appears to have the potential to alter significantly the metabolism and resulting bioactivity of certain chemicals. For example, coadministration of toluene along with benzene or styrene has been shown to suppress the metabolism of benzene or styrene in rats.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

The available data are not adequate for establishing criteria. However, EPA did report the lowest values known to cause toxicity in aquatic organisms.

Freshwater

Acute toxicity: 17,500 ug/liter
Chronic toxicity: No available data

Saltwater

Acute toxicity: 6,300 ug/liter
Chronic toxicity: 5,000 ug/liter

Human Health

Criterion: 14.3 mg/liter

NIOSH Recommended Standards:	375 mg/m^3 TWA 560 mg/m^3 STEL
OSHA Standards:	750 mg/m^3 TWA 1,120 mg/m^3 Ceiling Level
ACGIH Threshold Limit Value:	100 ppm TWA 375 mg/m^3 TWA 150 ppm STEL 560 mg/m^3 STEL

1,1,1-TRICHLOROETHANE

Summary

Preliminary results suggest that 1,1,1-trichloroethane (1,1,1-TCA) induces liver tumors in female mice. It was shown to be mutagenic using the Ames assay, and it causes transformation in cultured rat embryo cells. Inhalation exposure to high concentrations of 1,1,1-TCA depressed the central nervous system; affected cardiovascular function; and damaged the lungs, liver, and kidneys in animals and humans. Irritation of the skin and mucous membranes has also been associated with human exposure to 1,1,1-trichloroethane.

CAS Number: 71-55-6

Chemical Formula: CH_3CCl_3

IUPAC Name: 1,1,1-Trichloroethane

Important Synonyms and Trade Names: Methyl chloroform, chlorothene, 1,1,1-TCA

Chemical and Physical Properties

Molecular Weight: 133.4

Boiling Point: 74.1°C

Melting Point: -30.4°C

Specific Gravity: 1.34 at 20°C (liquid)

Solubility in Water: 480-4,400 mg/liter at 20°C (several divergent values were reported in the literature)

Solubility in Organics: Soluble in acetone, benzene, carbon tetrachloride, methanol, ether, alcohol, and chlorinated solvents

Log Octanol/Water Partition Coefficient: 2.17

Vapor Pressure: 123 mm Hg at 20°C

Vapor Density: 4.63

Transport and Fate

1,1,1-Trichloroethane (1,1,1-TCA) disperses from surface water primarily by volatilization. Several studies have indicated that 1,1,1-trichloroethane may be adsorbed onto organic materials in the sediment, but this is probably not an important route of elimination from surface water. 1,1,1-Trichloroethane can be transported in the groundwater, but the speed of transport depends on the composition of the soil.

Photooxidation by reaction with hydroxyl radicals in the atmosphere is probably the principal fate process for this chemical.

Health Effects

1,1,1-Trichloroethane was retested for carcinogenicity because in a previous study by NCI, early lethality precluded assessment of carcinogenicity. Preliminary results indicate that 1,1,1-TCA increased the incidence of combined hepatocellular carcinomas and adenomas in female mice when administered by gavage. There is evidence that 1,1,1-trichloroethane is mutagenic in Salmonella typhimurium and causes transformation in cultured rat embryo cells. These data suggest that the chemical may be carcinogenic.

Other effects of 1,1,1-TCA are seen only at concentrations well above those likely in an open environment. The most notable toxic effects of 1,1,1-trichloroethane in humans and animals are central nervous system depression, including anesthesia at very high concentrations and impairment of coordination, equilibrium, and judgment at lower concentrations (350 ppm and above); cardiovascular effects, including premature ventricular contractions, decreased blood pressure, and sensitization to epinephrine-induced arrhythmia; and adverse effects on the lungs, liver, and kidneys. Irritation of the skin and mucous membranes resulting from exposure to 1,1,1-trichloroethane has also been reported. The oral LD_{50} value of 1,1,1-trichloroethane in rats is about 11,000 mg/kg.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

The available data are not adequate for establishing criteria. However, EPA did report, the lowest values of the two trichloroethanes (1,1,1 and 1,1,2) known to be toxic in aquatic organisms.

Freshwater

Acute toxicity: 18 mg/liter
Chronic toxicity: 8.4 mg/liter

Saltwater

Acute toxicity: 31.2 mg/liter
Chronic toxicity: No available data

<u>Human Health</u>

Criterion: 18.4 mg/liter

NIOSH Recommended Standard: 350 ppm (1,910 mg/m^3)/15 min Ceiling Level

OSHA Standard: 350 ppm (1,910 mg/m^3) TWA

ACGIH Threshold Limit Value:	350 ppm TWA 1,400 mg/m^3 TWA 450 ppm STEL 2,450 mg/m^3 STEL.

1,1,2-TRICHLOROETHANE

Summary

1,1,2-Trichloroethane induced liver tumors and pheochromocytomas in mice. It caused liver and kidney damage in dogs.

CAS Number: 79-00-5

Chemical Formula: $CH_2ClCHCl_2$

IUPAC Name: 1,1,2-Trichloroethane

Important Synonyms and Trade Names: Vinyl trichloride, ethane trichloride

Chemical and Physical Properties

Molecular Weight: 133.41

Boiling Point: 133.8°C

Melting Point: -36.5°C

Specific Gravity: 1.4397 at 25°C

Solubility in Water: 4,500 mg/liter at 20°C

Solubility in Organics: Soluble in alcohol, ether, and chloroform

Log Octanol/Water Partition Coefficient: 2.17

Vapor Pressure: 19 mm Hg at 20°C

Vapor Density: 4.63

Transport and Fate

Volatilization and subsequent photooxidation in the troposphere are probably the primary transport and fate processes for 1,1,2-trichloroethane. Some sorption, bioaccumulation, and biodegradation may occur, but these processes are probably not very important processes for trichloroethane transport or fate.

1,1,2-Trichloroethane induced heptacellular carcinomas and pheochromocytoma of the adrenal gland in male and female mice but did not produce a significant increase in tumor incidence in male or female rats. It was not mutagenic when tested using the Ames assay. No information was found concerning the reproductive toxicity or teratogenicity of 1,1,2-trichloroethane. No chronic studies were found on the toxicity of 1,1,2-trichloroethane but single doses as low as 400 mg/kg caused liver and kidney damage in dogs. The oral LD_{50} value for 1,1,2-trichloroethane in rats is 835 mg/kg.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

The available data are not sufficient for establishing criteria. However, EPA did report the lowest values known to be toxic in aquatic organisms.

Freshwater

Acute toxicity: 18,000 ug/liter
Chronic toxicity: 9,400 ug/liter

Saltwater

Acute toxicity: No available data
Chronic toxicity: No available data

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of 1,1,2-trichloroethane in water are:

Risk	Concentration
10^{-5}	6.0 ug/liter
10^{-6}	0.6 ug/liter
10^{-7}	0.06 ug/liter

CAG Unit Risk (U.S. EPA): 5.7×10^{-2} $(mg/kg/day)^{-1}$

ACGIH Threshold Limit Value: 10 ppm TWA (skin)
45 mg/m^3 TWA (skin)

TRICHLOROETHYLENE

Summary

Trichloroethylene (TCE) induced hepatocellular carcinomas in mice and was mutagenic when tested using several microbial assay systems. Chronic inhalation exposure to high concentrations caused liver, kidney, and neural damage and dermatological reactions in animals.

CAS Number: 79-01-06

Chemical Formula: C_2HCl_3

IUPAC Name: Trichloroethene

Important Synonyms and Trade Names: Trichloroethene, TCE, and ethylene trichloride

Chemical and Physical Properties

Molecular Weight: 131.5

Boiling Point: 87°C

Melting Point: -73°C

Specific Gravity: 1.4642 at 20°C

Solubility in Water: 1,000 mg/liter

Solubility in Organics: Soluble in alcohol, ether, acetone, and chloroform

Log Octanol/Water Partition Coefficient: 2.29

Vapor Pressure: 60 mm Hg at 20°C

Vapor Density: 4.53

Transport and Fate

Trichloroethylene (TCE) rapidly volatilizes into the atmosphere where it reacts with hydroxyl radicals to produce hydrochloric acid, carbon monoxide, carbon dioxide, and carboxylic acid. This is probably the most important transport and fate process for trichloroethylene in surface water and in the upper layer of soil. TCE adsorbs to organic materials and can be bioaccumulated to some degree. However, it is unclear whether trichloroethylene bound to organic materiaL can be degraded by microorganisms or must be desorbed to be destroyed. There is some evidence that higher organisms can metabolize TCE. Trichloroethylene leaches into the groundwater fairly readily, and it is a common contaminant of groundwater around hazardous waste sites.

Health Effects

Trichloroethylene is carcinogenic to mice after oral administration, producing hepatocellular carcinomas. It was found to be mutagenic using several microbial assay systems. Trichloroethylene does not appear to cause reproductive toxicity or teratogenicity. TCE has been shown to cause renal toxicity, hepatotoxicity, neurotoxicity, and dermatological reactions in animals following chronic exposure to levels greater than 2,000 mg/m^3 for 6 months. Trichloroethylene has low acute toxicity; the acute oral LD$_{50}$ value in several species ranged from 6,000 to 7,000 mg/kg.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

The available data are not adequate for establishing criteria. However, EPA did report the lowest values known to have toxic effects in aquatic organisms.

Freshwater

Acute toxicity: 45 mg/liter
Chronic toxicity: No available data

Saltwater

Acute toxicity: 2 mg/liter
Chronic toxicity: No available data

Human Health

Estimates of the carcinogenic risks associated with lifetime exposure to various concentrations of trichloroethylene in water are:

Risk	Concentration
10^{-5}	27 ug/liter
10^{-6}	2.7 ug/liter
10^{-7}	0.27 ug/liter

CAG Unit Risk (U.S. EPA): 1.1 x 10^{-2} $(mg/kg/day)^{-1}$

NIOSH Recommended Standards (air):
540 mg/m^3 TWA
760 mg/m^3 10-min Ceiling Level

OSHA Standard (skin):
540 mg/m^3 TWA
1,075 mg/m^3/15-min Ceiling Level
1,620 mg/m^3 for 5 min every 3 hr, Peak Concentration

ACGIH Threshold Limit Values:
50 ppm TWA
270 mg/m^3 TWA
200 ppm STEL
1,080 mg/m^3 STEL

XYLENES

Summary

Xylene has been shown to be fetotoxic in rats and mice. In humans, exposure to high concentrations of xylene adversely affects the central nervous system and irritates the mucous membranes.

Background Information

Xylene has three isomers, o-, m-, and p-xylene. These three generally have similar chemical and biological characteristics and therefore will be discussed together.

CAS Number:
Mixed: 1330-20-7
m-Xylene: 108-38-3
o-Xylene: 95-47-6
p-Xylene: 106-42-3

Chemical Formula: $C_6H_4(CH_3)_2$

IUPAC Name: Dimethylbenzene

Important Synonyms and Trade Names:
Mixed xylene: Dimethylbenzene, xylol
m-Xylene: 1,3-Dimethylbenzene, m-xylol
o-Xylene: 1,2-Dimethylbenzene, o-xylol
p-Xylene: 1,4-Dimethylbenzene, p-xylol

Chemical and Physical Properties

Molecular Weight: 106.17

Boiling Point:
Mixed: 137-140°C
m-Xylene: 139°C
o-Xylene: 144°C
p-Xylene: 138°C

Melting Point:
m-Xylene: -48°C
o-Xylene: -25°C
p-Xylene: 13°C

Specific Gravity: 0.86

Solubility in Water: 160 mg/liter at 25°C

Solubility in Organics: Soluble in alcohol, ether, and other organic solvents.

Log Octanol/Water Partition Coefficient: 3

Vapor Pressure: 10 mm Hg at 25°C

Vapor Density: 3.7

Flash Point: 25°C (closed cup)

Transport and Fate

Volatilization and subsequent photooxidation by reaction with hydroxyl radicals in the atmosphere are probably important transport and fate processes for xylene in the upper layer of soil and in aquatic environments. Products of the hydroxylation reaction include carbon dioxide, peroxyacetylnitrate (PAN), and cresol. Xylene binds to sediment in water and to organics in soils and undergoes microbial degradation. Biodegradation is probably the most important fate process in both soils and the aquatic environment. Xylenes have been shown to persist for up to 6 months in soil. Because of their low water solubility and rapid biodegradation, xylenes are unlikely to leach into groundwater in high concentrations.

Health Effects

The National Toxicology Program (NTP) is testing xylene for carcinogenicity by administering it orally to rats and mice. Although the results have not been finalized, it does not appear to be carcinogenic in rats. Results have not been reported for mice. Xylene was not found to be mutagenic in a battery of short-term assays. Xylene is not teratogenic but has caused fetotoxicity in rats and mice. Acute exposure to rather high levels of xylene affects the central nervous system and irritates the mucous membranes. There is limited evidence of effects on other organ systems, but it was not possible to attribute these effects solely to xylene as other solvents were present. The oral LD_{50} value of xylene in rats is 5,000 mg/kg.

Regulations and Standards

NIOSH Recommended Standard (air):
435 mg/m^3 TWA
870 mg/m^3 10-min Ceiling Level

OSHA Standard: 435 mg/m^3 TWA

ACGIH Threshold Limit Values:
100 ppm TWA
435 mg/m^3 TWA
150 ppm STEL
655 mg/m^3 STEL

ZINC

Summary

Ingestion of excessive amounts of zinc can cause fever, vomiting, and stomach cramps. Zinc oxide fumes can cause metal fume fever. Inhalation of mists or fumes may irritate the respiratory tract, and contact with zinc chloride may irritate the eyes and skin. High levels of zinc in the diet have been shown to retard growth and produce defective mineralization of bone.

Background Information

Zinc generally exists in nature as a salt with a valence of +2, although it is also found in four other stable valences.

CAS Number: 7440-66-6

Chemical Formula: Zn

IUPAC Name: Zinc

Chemical and Physical Properties

Atomic Weight: 65.38

Boiling Point: 907°C

Melting Point: 419.58°C

Specific Gravity: 7.133 at 25°C

Solubility in Water: Insoluble; some salts are soluble

Solubility in Organics: Soluble in acid and alkali

Vapor Pressure: 1 mm Hg at 487°C

Transport and Fate

Zinc can occur in both suspended and dissolved forms. Dissolved zinc may occur as the free (hydrated) zinc ion or as dissolved complexes and compounds with varying degrees of stability and toxicity. Suspended (undissolved) zinc may be dissolved following minor changes in water chemistry or may be sorbed to suspended matter. The predominant fate of zinc in aerobic aquatic systems is sorption of the divalent cation by hydrous iron and manganese oxides, clay minerals, and organic material. The efficiency of these materials in removing zinc from solution varies according to their compositions and concentrations; the pH and salinity of the water; the concentrations of complexing ligands; and the concentration of zinc. Concentrations of zinc in suspended and bed sediments always exceed concentrations in ambient water. In reducing environments, precipitation of zinc sulfide limits the mobility of zinc. However, under aerobic conditions, precipitation of zinc compounds is probably important only where zinc is present in high concentrations. Zinc tends to be more readily sorbed at higher pH than lower pH and tends to be desorbed from sediments as salinity increases. Compounds of zinc with the common ligands of surface waters are soluble in most neutral and acidic solutions, so that zinc is readily transported in most unpolluted, relatively organic-free waters.

The relative mobility of zinc in soil is determined by the same factors affecting its transport in aquatic systems. Atmospheric transport of zinc is also possible. However, except near sources such as smelters, zinc concentrations in air are relatively low and fairly constant.

Since it is an essential nutrient, zinc is strongly bioaccumulated even in the absence of abnormally high ambient concentrations. Zinc does not appear to be biomagnified. Although zinc is actively bioaccumulated in aquatic systems, the biota appear to represent a relatively minor sink compared to the sediments. Zinc is one of the most important metals in biological systems. Since it is actively bioaccumulated, the environmental concentrations of zinc probably exhibit seasonal fluctuations.

Health Effects

Testicular tumors have been produced in rats and chickens when zinc salts are injected intratesticularly, but not when other routes of administration are used. Zinc may be indirectly important with regard to cancer since its presence seems to be necessary for the growth of tumors. Laboratory studies suggest that although zinc-deficient animals may be more susceptible to chemical induction of cancer, tumor growth is slower in these animals. There is no evidence that zinc deficiency has any etiological role in human cancer. There are no data available to suggest that zinc is mutagenic or teratogenic in animals or humans.

Zinc is an essential trace element that is involved in enzyme functions, protein synthesis, and carbohydrate metabolism. Ingestion of excessive amounts of zinc may cause fever, vomiting, stomach craps, and diarrhea. Fumes of freshly formed zinc oxide can penetrate deep into the alveoli and cause metal fume fever. Zinc oxide dust does not produce this disorder. Contact with zinc chloride can cause skin and eye irritation. Inhalation of mists or fumes may irritate the respiratory and gastrointestinal tracts. Zinc in excess of 0.25% in the diet of rats causes growth retardation, hypochromic anemia, and defective mineralization of bone. No zinc toxicity is observed at dietary levels below 0.25%.

Studies with animals and humans indicate that metabolic changes may occur due to the interaction of zinc and other metals in the diet. Exposure to cadmium can cause changes in the distribution of zinc, with increases in the liver and kidneys, organs where cadmium also accumulates. Excessive intake of zinc may cause copper deficiencies and result in anemia. Interaction of zinc with iron or lead may also lead to changes that are not produced when the metals are ingested individually.

Regulations and Standards

Ambient Water Quality Criteria (U.S. EPA):

Aquatic Life

Freshwater

Acute toxicity: $e^{\{0.83[\ln(\text{hardness})] + 1.95\}}$ ug/liter
Chronic toxicity: 47 ug/liter

Saltwater

Acute toxicity: 170 ug/liter
Chronic toxicity: 58 ug/liter

Human Health

Organoleptic criterion: 5 mg/liter

Secondary Drinking Water Standard: 5 mg/liter

NIOSH Recommended Standard: 5 mg/m^3 (zinc oxide)

OSHA Standard: 5 mg/m^3 TWA (zinc oxide)

ACGIH Threshold Limit Values:

Zinc chloride fume:	1 mg/m^3 TWA
	2 mg/m^3 STEL
Zinc oxide fume:	5 mg/m^3 TWA
	10 mg/m^3 STEL
Zinc oxide dust:	10 mg/m^3 TWA (nuisance particulate)
Zinc stearate:	10 mg/m^3 TWA (nuisance particulate)
	20 mg/m^3 STEL