ANALYSIS OF CONSTRUCTION ALTERNATIVE TO MITIGATE POOR SOIL CONDITION ALONG THE ROOSEVELT IRRIGATION DISTRICT CANAL NEAR THE AGUA FRIA RIVER

FLOOD CONTROL DISTRICT
RECEIVED

DEC 03 '85

5	CH ENG		HYDRO
4	ASST		LMgt
	ADMIN		SUSP
3	C & O	6	FILE
2	ENGR		DESTROY
	FINANCE	1	RGP

REMARKS

3A ~~WGA~~ ~~2114~~
3B ~~LCE~~ ~~PE~~.
~~3C~~ ~~EOK~~

~~Fcd~~ LH 3.1

sla

ENGINEERING DIVISION
LIBRARY

Property of
Flood Control District of MC Library
Please Return to
2801 W. Durango
Phoenix, AZ 85009

ANALYSIS OF CONSTRUCTION ALTERNATIVE TO MITIGATE POOR SOIL CONDITION ALONG THE ROOSEVELT IRRIGATION DISTRICT CANAL NEAR THE AGUA FRIA RIVER

For

Flood Control District of Maricopa County
3335 West Durango
Phoenix, Arizona 85009

By

Simons, Li & Associates, Inc.
3555 Stanford Road
P.O. Box 1816
Fort Collins, Colorado 80522

SLA Project Number AZ-MC-08 - Phase IV
R577/RDF249

December 2, 1985

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

As a result of encountering an unknown poor soil condition on the new RID canal alignment between Stations 20+50 and 24+00, the Flood Control District of Maricopa County (FCDMC) authorized Simons, Li & Associates, Inc. (SLA) to make an analysis of the problem area and recommend the most efficient construction method to solve the problem. In addition, a previous construction problem with dewatering an existing gravel wash pond had given rise to a realignment of the canal to avoid construction within the pond area, FCDMC also wanted to reevaluate the realignment in this western area. The wash pond extends from Stations 10+50 to 17+00. FCDMC desires to have a solution which best combines the possible solutions to the problems and constraints of both locations.

The most significant constraint on the design solution to the current situation is the time available to remove the existing Roosevelt Irrigation District (RID) facilities from service while new facilities are constructed and placed into service. The RID has stated that, contrary to the initial indications, the RID canal will be dryed up from the middle of November through the first week in December 1985. The time necessary to effect any proposed modifications will certainly exceed the time of the RID planned dry-up period this year. Two scenarios are therefore possible. First, the existing flume can be left in service until the next scheduled dry-up period in 1986. Second, the construction process can be made to accommodate the required flow in the RID canal either by utilizing an alternative source of water west of the Agua Fria River or by providing a diversion of the RID flows around construction.

If the existing flume is to remain in service for another year, the amount of realignment possible to avoid problem areas is severely limited. Also, construction of all facilities is complicated since some facilities (e.g., canal wasteway, river bank protection) would have to be constructed for an interim period and the final facilities would also have to be built under a different contract at a later date. The cost of the interim facilities and any additional costs of the final facilities are the additional cost of leaving the flume in service an additional year.

If the construction is forced to provide for RID demands, no interim facilities will be constructed and construction can continue under the present contract. RID historical demands are less than 6,000 ac-ft per month through

February, after which they increase dramatically (Appendix A). A constant flow of approximately 100 cfs will provide 6,000 ac-ft per month. A construction diversion of 100 cfs should be feasible. The decision on which scenario to implement should probably be based on the costs attached to the various items. A change order can be submitted to Ball, Ball, and Brossamer to evaluate the charges for many, if not all, of the construction items.

Based on our initial conversations with the FCDMC, several construction alternatives are presented for consideration. These alternatives are:

1. Realignment to avoid the deep clay deposit.
2. Removal of clay material using original design alignment.
3. Realignment of the south of the original alignment using a retaining wall (or two walls) to limit the width of the embankment in order to avoid the majority of the deep clay deposit.
4. Provide measures to mitigate and stabilize the clay soil beneath original alignment.
5. Construct elevated flume with pier foundation over poor soil area.
6. Construct a bridging canal section with pier foundation over poor soil areas.

The overall configuration of the canal from approximately Station 10+50 to the siphon inlet will be dependent on the alternative selected in the Stations 20+50 to 24+00 (western) segment. For example, if a realignment of the western segment is selected, realignment of the eastern segment (Stations 10+50 to 20+50) could be desirable depending on the construction constraints imposed by the existing flume and the existing gravel waste pits. This is given flexibility by providing preliminary estimates of the construction costs of the eastern segment separate from the western segment. Therefore, east and west alternatives can be combined in various ways.

The analysis of these various alternatives is reviewed in the following sections. Each alternative is presented with a brief discussion of the construction considerations and a cost summary. The preliminary costs presented in this analysis are based on the bid prices in the current Ball, Ball & Brossamer contract, where applicable, and based on SLA engineering estimates in the area where no suitable unit is bid in that contract. Preliminary quantities were calculated based on conceptual designs of the facilities. It must be emphasized that these cost estimates are preliminary in nature and are not based on a final design of the facilities and can therefore not be expected to be exactly equal to the actual construction costs. They are intended to reflect the relative costs between various alternatives to select the most desirable construction alternative.

II. ALTERNATIVE EVALUATION

2.1 Realignment of Western Segment to Avoid Clay Deposit - Alternative 1

2.1.1 Alternative 1 Construction Considerations

Based on the proximity of the siphon inlet, conveyor crossing, canal wasteway, and existing flume to the area of the clay deposit, it is not physically possible to realign the canal to entirely avoid the clay deposit. Even utilizing retaining walls on both sides of the canal embankment, the northern edge of the canal construction is within the clay area. This causes the consideration of alternatives which combine mitigation and realignment.

2.1.2 Alternative 1 Cost Summary

No cost summary is possible since the alternative is not constructable.

2.2 Removal of Clay Material for Western Segment Along the Original Alignment - Alternative 2

2.2.1 Alternative 2 Construction Considerations

Due to the nature of the clay in the problem area (Appendix B), many construction problems are associated with the removal of the clay. These problems are categorized as follows:

- Difficult equipment access on weak saturated clay.
- Stable slopes in excavation may require at least 4:1 slopes causing large volumes of back slope to be removed for open excavation for any length of time.
- Clay depths of 30 to 35 feet require large excavation slopes or benching in order to remove entire deposit.

Various methods to address the above problems during removal are addressed. To provide construction equipment access, a geofabric membrane on the clay surface covered to a 2 or 3 feet depth with native sand could be used. If only tracked equipment was used in the clay soil area, it appears the geofabric membrane could be omitted. However, wheeled equipment (e.g., trucks) would require the membrane.

Excavation slope stability can be addressed in at least three ways:

1. Provide slopes no steeper than approximately 4:1. Shallow excavation slopes greatly increase the volume of clay material which must be removed. Based on preliminary quantities, 4:1 slopes would require in excess of 80,000 cubic yards of removal. This quantity is not feasible when the cost are examined.

2. Based on a phone conversation with Desert Earth Engineering, excavation slopes can be cut at approximately 1:1 with the understanding that excavations can not remain open for longer than a day without the danger of slope failure. Using appropriate construction methods, this is feasible and reduces removal quantity to approximately 50,000 cubic yards. Although significantly less than 80,000 cubic yards, this remains a large quantity of removal. A large hydraulic excavator or dragline would be required to perform this excavation and the spoil would have to be trucked to a waste area (potentially an abandoned gravel pit near the construction on the west bank of the Agua Fria).

3. A subsurface pile wall could be constructed at the shoulder of the canal maintenance road to limit the excavation quantities. This scenario is shown on Figure 2.1.

In terms of construction complexity, this alternative offers some advantage. It appears all items of construction can be accomplished using the current construction contract by adding quantities of excavation and fill, and geofabric placement. Construction is not complicated if a suitable method for clay removal is used. Finally, work could proceed almost immediately as very little design input for this construction would be needed.

2.2.2 Alternative 2 Cost Summary

Alternative 2 is subdivided into three methods of accomplishing the solutions.

2.2.2.1 Removal with 4:1 Slopes

	Quantity	Unit Cost	Total Cost
Removal of clay material	85,000 CY	$10/CY	$850,000
Replacement with native landfill	85,000 CY	$0.50/CY	42,500
Subtotal			$892,500
Contingency 10%			$ 89,200
TOTAL			$981,000

SIMONS, LI & ASSOCIATES, INC.

CLIENT Maricopa County FCD
JOB No. PAZ-MC-18
PAGE 2.3
PROJECT RID CANAL
DATE CHECKED
DATE 11-27-85
DETAIL PILE WALL ALT.
CHECKED BY
COMPUTED BY JKW

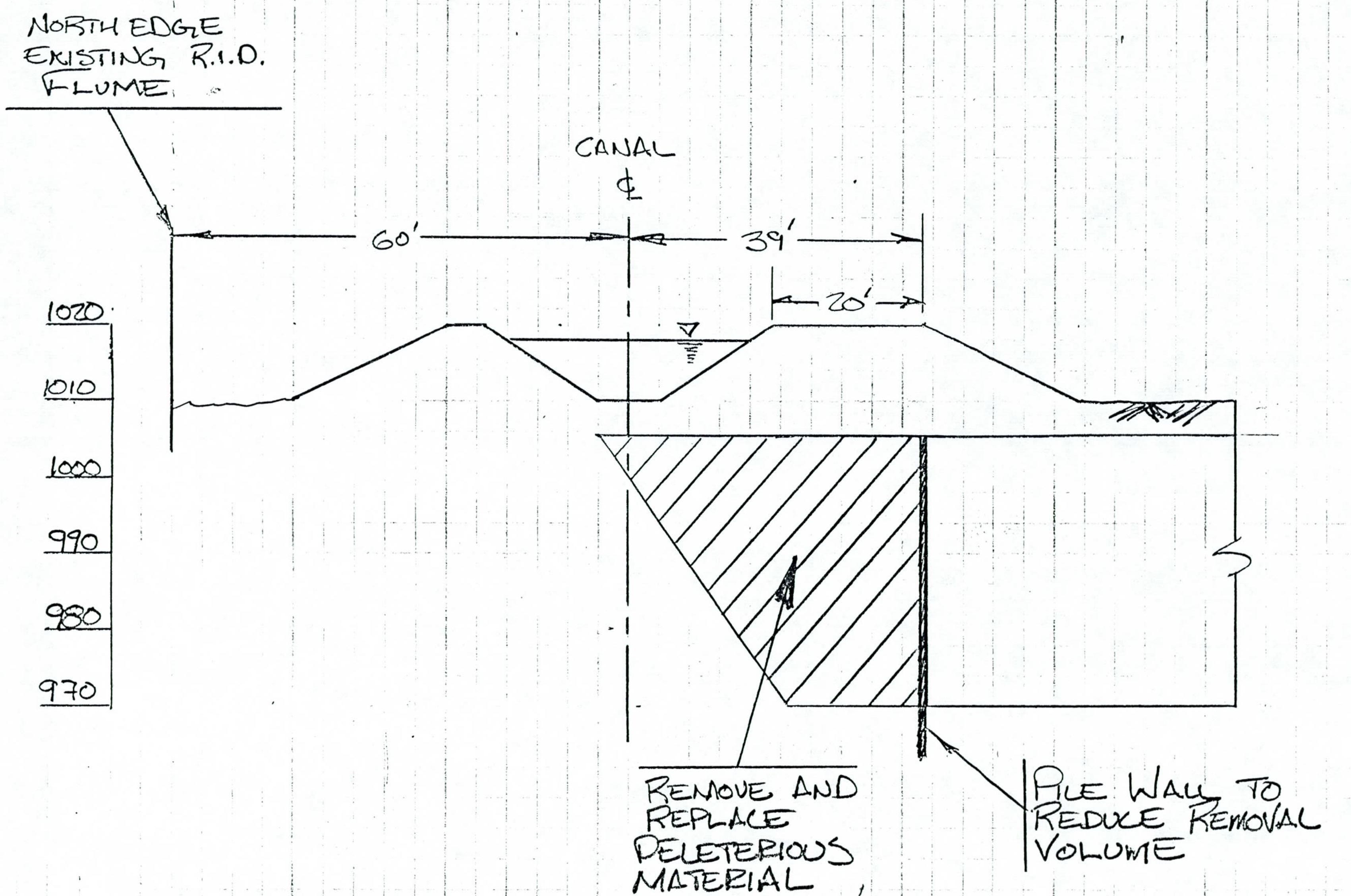


FIGURE 2.1 - PILE WALL TO LIMIT EXCAVATION

2.2.2.2 Removal with 1:1 Slopes

	Quantity	Unit Cost	Total Cost
Removal of clay material	50,000 CY	$10/CY	$500,000
Replacement with native landfill	50,000 CY	$0.50/CY	25,000
Subtotal			$525,000
Contingency 10%			$ 52,500
TOTAL			$577,500

2.2.2.3 Removal with Cutoff Wall

	Quantity	Unit Cost	Total Cost
Sheet pile wall, Stations 20+50 to 24+50	14,000 s.f.	$22/s.f.	$308,000
Removal of clay material	20,000 CY	$10/CY	$200,000
Replacement with native landfill	20,000 CY	$0.50/CY	10,000
Subtotal			$518,000
Contingency 10%			$ 51,800
TOTAL			$569,800

2.3 Realignment of Western Segment Using Retaining Walls to Limit Embankment Width - Alternative 3

2.3.1 Alternative 3 Construction Considerations

As a result of the location and proximity of the siphon inlet, side channel spillway, conveyor crossing, and wasteway to the clay deposit the realignment of the canal is limited to a southern offset of 26 feet. Canal curves with a centerline radius of 150 feet are used. One scenario would use a retaining wall on the south side of the embankment to avoid the majority of the clay deposit. Another scenario using an additional retaining wall on the north side of the embankment is also considered. Since the realignment does not entirely avoid the clay deposit, removal of clay material is required beneath a 1:1 slope from the limit of embankment on the north. Removal of the clay is assumed to use a 1:1 excavation slope implying the excavation can not remain open longer than a day. Overall, the construction complexity of this alternative is increased over that of Alternative 2 since clay removal is still required, retaining walls near the existing flume must be also constructed and less area is available for access.

2.3.2 Alternative 3 Cost Summary

Alternative 3 is subdivided into two methods of accomplishing this solution. These costs are shown in Tables 2.1a and 2.1b.

2.4 Clay Soil Mitigation Measures In Western Segment - Alternative 4

2.4.1 Alternative 4 Construction Considerations

Based on an interim, preliminary soil report by Desert Earth Engineering (which is to be finalized prior to final design stage), a feasible soil stabilization method would be placement of vertical sand drains. These sand drains would accelerate the natural consolidation of the clay soil. To obtain approximately 90 percent of the theoretical consolidation amount would limit long-term consolidation to 3 percent of clay volume. Long-term consolidation would occur over many years, and shotcrete lining damage in any given year should be well within acceptable, maintainable limits. Placement of sand drains on 10 feet center-to-center distance should provide 90 percent consolidation within a year (Appendix B). To provide a factor of safety, this analysis presents costs associated with placing sand drains on a center-to-center distance of 5 feet. By halving the spacing distance to drains, the time to reach a given consolidation should be reduced by a factor of 4. The embankment constructed over clay should have the consolidation monitored with the use of settlement surveys and perhaps a few soil samples. This cost is covered in the construction estimate. Since vertical drain will only work if the area treated is loaded with a surcharge, the canal embankment should be constructed as soon as possible to get the best effect. Additional height or width of embankment would enhance the effectiveness of this treatment. These design factors would be considered in the final design stage. The area to be treated in this manner is considered to include the entire clay deposit surface out to the north toe of embankment.

The recommended method of placement of these sand drains would be to utilize a hollow stem auger drilling rig so the augered hole would not collapse before sand could be placed into the hole. Alternatively, geofabric wick drains could be placed if a knowledgable contractor could be located in a timely manner. In order to facilitate drill rig access, a geofabric mat and a 2-foot sand cover would be placed over the clay deposit. A subsurface drain to collect water generated from the sand drains and convey water off-site would also be utilized. Clay excavation to place drains and for miscellaneous leveling prior to geofabric placement is included.

Table 2.1a. Alternative 3A Cost Summary.

Realign Canal 26 Feet South, Stations 20+50 to 23+24 Excavate at 1:1 Slope Beyond 1:1 Embankment Splay Slope Requires Retaining Wall on South Side of Canal.

Item	Quantity	Unit	Unit Cost ($)	Total
Remove Deleterious Material	42,000	C.Y.	10.00	420,000
Replace with Select Material	42,000	C.Y.	0.50	21,000
South Retaining Wall 20+50 to 23+24	2,120	S.F.	20.00	42,400
South Safety Railing	280	L.F.	30.00	8,400
South Material Saved	- 1,100	C.Y.	0.50	-550
Contingency (10 percent)				49,125
TOTAL				540,375

Table 2.1b. Alternative 3B Cost Summary.

Realign Canal 26 Feet South, Stations 20+50 to 23+24 Use North Wall to Limit Excavation Excavate at 1:1 Slope Beyond 1:1 Wall Splay Slope Requires Retaining Wall on South Side of Canal.

Item	Quantity	Unit	Unit Cost ($)	Total
Remove Deleterious Material	31,400	C.Y.	10.00	314,000
Replace with Select Material	31,400	C.Y.	0.50	15,700
South Retaining Wall 20+50 to 23+24	2,110	S.F.	20.00	42,200
South Safety Railing	280	L.F.	30.00	8,400
South Material Saved	- 1,100	C.Y.	0.50	-550
North Retaining Wall 20+50 to 24+00	5,290	S.F.	20.00	105,800
North Safety Railing	410	L.F.	30.00	12,300
North Material Saved	- 2,540	C.Y.	0.50	- 1,270
Contingency (10 percent)				49,658
TOTAL				546,238

This alternative has many attractive features in terms of construction complexity. It involves simple construction along the original alignment. Construction can and should be started almost immediately and significant cost saving may be realized. For an example of this type of construction, see Appendix C.

2.4.2 Alternative 4 Cost Summary

The cost summary for Alternative 4 is presented in Table 2.2.

2.5 Elevated Steel Flume Across Western Segment - Alternative 5

2.5.1 Alternative 5 Construction Considerations

To construct an elevated steel flume across the clay deposit area similar to the existing steel flume would allow construction without removing or treating the clay soil. Drilled piers would be used for the foundation of the flume. Construction of additional transitions from canal to flume at each end would be required. This alternative significantly increases the complexity of construction since the flume would require the use of steel workers, additional concrete structures, and drilled pier foundations. To provide maintenance access, a geofabric mat with a 2-foot road base cover will be required. At this time, this alternative is not considered favorable in any major respect.

2.5.2 Alternative 5 Cost Summary

The cost summary for Alternative 5 is presented in Table 2.3.

2.6 Reinforced Concrete Canal Supported on Piers Across Western Segment - Alternative 6

2.6.1 Alternative 6 Construction Considerations

Construction of a reinforced concrete canal section which would be supported on a drilled pier foundation would also not require any soil removal or soil treatment. However, the cost of structural concrete, additional transitions at each end, drilled piers, and geofabric supporting membrane will increase the construction complexity beyond Alternatives 3 and 4. Based on maintenance and construction considerations, this alternative is judged to be more desirable than Alternative 5, but less than Alternatives 2, 3, or 4.

Table 2.2. Alternative 4 Cost Summary.

Soil Stabilization Using Vertical Sand Drains, 45 Feet Deep on 5-Foot Centers Place Geotextile Fabric With 2-Foot Sand Layer to Permit Access.

Item	Quantity	Unit	Unit Cost ($)	Total
6-5/8" Sand Drains	82,130	L.F.	2.00	164,260
Geotextile Fabric	9,340	S.Y.	0.50	4,670
2' Sand Cover	3,100	C.Y.	0.50	1,550
6" ADS Drain Tubing with Fabric	580	L.F.	5.00	2,900
Excavation	2,000	C.Y.	10.00	20,000
Contingency (10 percent)				19,338
TOTAL				212,718

Table 2.3. Alternative 5 Cost Summary.

Steel Flume Section Supported by 3-Foot Piers, Stations 20+50 to 23+24 25-Foot Reinforced Concrete Transitions Access Adjacent to Flume.

Item	Quantity	Unit	Unit Cost ($)	Total
Steel Flume	350	L.F.	365.00	127,750
Reinforced Concrete (Transitions)	70	C.Y.	300.00	21,000
Reinforced Steel	18,400	LBS.	0.60	11,040
Structural Piers	1,575	L.F.	65.00	102,375
Access Road	each	L.S.	8,000	8,000
Contingency (10 percent)				27,000
TOTAL				297,165

2.6.2 Alternative 6 Cost Summary

The cost summary for Alternative 6 is presented in Table 2.4.

2.7. Realign Canal in Eastern Segment As Designed For WTI - Alternative 7 Eastern Segment

2.7.1 Eastern Segment Alternative 7 Construction Considerations

Construction of the canal along this alignment was suggested when difficulty arose in dewatering the pond adjacent to this area for construction. The canal was shifted as far to the south as possible without affecting an existing well south of the existing canal. This alignment will require the removal of the existing flume prior to construction. This will add to the amount of work which would need to be finished while the flume of out of service.

This alignment modification for WTI was undertaken to facilitate construction so the canal construction would not be delayed. Subsequent actions by the RID and the discovery of the clay deposit made completion of the project during the 1985 RID canal dry-up period impossible.

Based on current scheduling and the reevaluation of the alignment in this area, additional consideration of the dewatering problem should be made. Further investigation of dewatering methods for the pond or the provision of alternate water to the gravel washing plant could be used.

Construction of the WTI alignment would necessitate the use of a south retaining wall near the existing well, but would in turn remove the necessity of any significant dewatering in the pond.

2.7.2 Eastern Segment Alternative 7 Cost Summary

The cost summary for eastern segment Alternative 7 is presented in Table 2.5.

2.8 Realign Canal in Eastern Segment 26 Feet South - Alternative 8 Eastern Segment

2.8.1 Eastern Segment Alternative 8 Construction Considerations

This alignment considers shifting the canal approximately 26 feet south, using a retaining wall on the south embankment to allow the construction of the canal without the prior removal of the existing flume. An additional subdivision of this alternative is the addition of a north retaining wall to limit the width of the embankment into the existing pond. These alternatives

Table 2.4. Alternative 6 Cost Summary.

Reinforced Concrete Section Supported by 3-Foot Piers, Stations 20+50 to 24+07 Embankment Remains for Vehicle Access.

Item	Quantity	Unit	Unit Cost ($)	Total
Structural Concrete	570	C.Y.	300.00	171,000
Reinforced Steel	209,800	LBS.	0.60	125,880
Structural Piers	1,580	L.F.	65.00	102,700
Pier Caps	340	C.Y.	300.00	102,000
Contingency (10 percent)				50,158
TOTAL				551,738

Table 2.5. Eastern Segment Alternative 7 (WTI) Cost Summary.

Realign Canal 40 Feet South, Stations 10+50 to 17+00
Requires Retaining Wall on South Side of Canal to
Minimize Encroachment to Pump Station.

Item	Quantity	Unit	Unit Cost ($)	Total
South Retaining Wall	2,380	S.F.	20.00	47,600
South Safety Railing	240	L.F.	30.00	7,200
South Material Saved	- 1,200	C.Y.	0.50	- 600
North Material Saved	- 9,900	C.Y.	0.50	- 4,950
Contingency (10 percent)				4,950
TOTAL				54,175

allow the flume to remain in service, minimize construction in the existing gravel wash pond, but increase the complexity of construction since retaining walls must be built.

2.8.2 Eastern Segment Alternative 8 Cost Summary

The cost summary for eastern segment Alternative 8 is presented in Tables 2.6a and 2.6b.

Table 2.6a. Eastern Segment Alternative 8, Cost Summary.

Realign Canal 26 Feet South, Stations 10+50 to 17+00
Requires Retaining Wall on South Side of Canal.

Item	Quantity	Unit	Unit Cost ($)	Total
South Retaining Wall 11+00 to 16+50	5,600	S.F.	20.00	112,000
South Safety Railing	550	L.F.	30.00	16,500
South Material Saved	-2,900	C.Y.	0.50	- 1,450
Contingency (10 percent)				12,705
TOTAL				139,755

Table 2.6b. Eastern Segment Alternative 8, Cost Summary.

Realign Canal 26 Feet South, Stations 10+50 to 17+00
Use North Retaining Wall to Limit Excavation Also Requires
Retaining Wall on South Side of Canal.

Item	Quantity	Unit	Unit Cost ($)	Total
South Retaining Wall 10+90 to 16+50	5,570	S.F.	20.00	111,400
South Safety Railing	550	L.F.	30.00	16,500
South Material Saved	-2,900	C.Y.	0.50	- 1,450
North Retaining Wall 11+25 to 16+25	7,000	S.F.	20.00	140,000
North Safety Railing	50	L.F.	30.00	16,500
North Material Saved	-11,700	C.Y.	0.50	- 5,850
Contingency (10 percent)				27,710
TOTAL				304,810

III. SUMMARY AND RECOMMENDATIONS

Based on the construction considerations, cost summaries, and all physical design constraints, SLA would recommend Alternative 4, soil stabilization in the western segment. In the eastern segment, a judgment will have to be made in evaluating the construction problems of Alternative 7, the WTI realignment, and the option of leaving the alignment as originally designed. These alternatives are discussed below.

3.1 Construction Considerations

Construction of the soil consolidation measures will involve obtaining a change order from the current contractor for the vertical sand drains and a drainage collection system. This work is not complicated and should progress quickly. It is possible a subcontractor could be found to install geofabric wick drains as an alternative to vertical sand drains. Wick drains should be significantly cheaper and should be installed much more quickly if an experienced subcontractor can be used (see Appendix C).

Consolidation of the clay soil can be accelerated if the embankment is built larger than the final configuration. In any case, the construction of the drains and construction of the embankment should begin as soon as possible so that the amount of consolidation that occurs prior to the placement of the shotcrete lining is maximized.

An additional item can be suggested to minimize any undesirable effects of consolidation on the canal embankment, as follows. In the area of the clay soil the canal embankment could be built with a canal freeboard approximately 3 feet greater than the rest of the canal. In this segment, a flexible impervious liner similar to Hypalon, which is not degraded by sunlight, could be placed within the canal prism. Any settlement of the canal due to consolidation would not damage the liner and the increased embankment height would provide an adequate freeboard for the canal if settlement does occur. After the consolidation has occurred this portion of the canal could be lined with shotcrete. This method would allow the construction of canal facilities in 1985 if the RID canal water could be maintained during construction.

The cost of adding a flexible membrane liner to Alternative 5 is given below.

	Quantity	Unit Cost	Total Cost
30 mill Hypalon liner	2,200 SY	$5/SY	$ 10,880 11,000
3-foot embankment addition	3,000 CY	$0.50/CY	1,500
TOTAL FOR ADDITIONAL LINER			$ 12,388

In the eastern segment, two solutions are possible. First, if the necessary coordination between the contractor and the gravel pit operator can be accomplished, construction of the canal along the alignment originally designed would be possible. This option would cost the FCDMC only for the dewatering of the construction area. Discussions between the gravel pit operator, the contractor, the FCDMC, and the RID (as a potential source of water for the washing operation) should be quickly initiated to determine those dewatering costs.

The second solution in the eastern segment would be to utilize Alternative 7. This will necessitate more work while the RID flume is removed. However, conversation with Ball, Ball & Brossamer indicate they do not feel connections at each end and the additional work in Alternative 7 would take longer than 30 days of calendar time which is the normal RID dry-up period.

3.2 Cost Summary

The cost for providing a dewatering system for the existing gravel wash pond along original alignment should be developed from discussions mentioned above.

For reference purposes a summary of all alternatives is given below.

Alternative 2A	$ 981,000
Alternative 2B	$ 577,000
Alternative 2C	$ 569,800
Alternative 3A	$ 540,375
Alternative 3B	$ 546,238
Alternative 4	$ 212,718
Alternative 5	$ 297,165
Alternative 6	$ 551,738
Alternative 7	$ 54,175
Alternative 8A	$ 139,755
Alternative 8B	$ 304,810

APPENDIX A

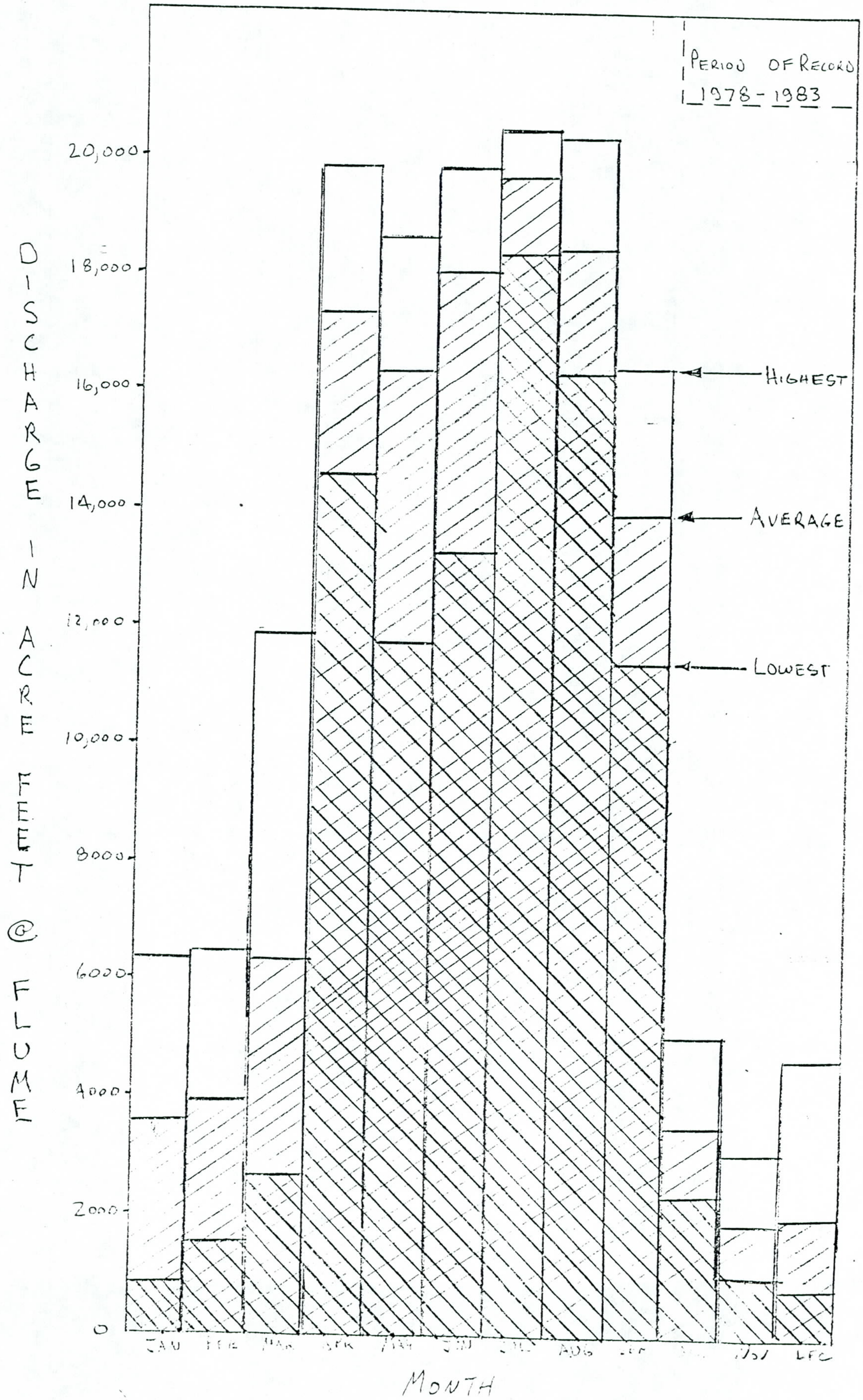
Historical Demand Hydrograph for
the RID canal

SIMONS, LI & ASSOCIATES, INC.

CLIENT ______ JOB NO. ______ PAGE ______

PROJECT ______ DATE CHECKED ______ DATE ______

DETAIL ______ CHECKED BY ______ COMPUTED BY ______



RECORDED MONTHLY DISCHARGE @ THE R.I.D. FLUME

Year	Monthly Discharge In Acre-Feet												
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL
1983	3,949	2,170	3,545	14,547	11,657	13,228	18,363	16,320	12,000	2,341	1,150	811	100,081
1982	4,465	5,526	6,637	17,742	16,187	17,915	20,006	18,730	11,358	2,606	1,029	252	122,453
1981	6,363	6,452	11,802	19,803	18,593	19,835	19,424	19,532	16,382	4,126	3,033	2,868	148,213
1980	4,433	2,682	6,530	18,746	16,868	19,204	19,980	20,301	16,215	5,092	2,378	4,669	137,098
1979	778	5,348	6,730	17,239	17,790	19,091	20,448	18,762	14,172	3,624	1,942	2,610	128,534
1978	1,549	1,521	2,642	16,146	17,181	18,976	19,664	17,088	13,200	3,362	1,589	1,000	113,918
AVERAGE	3,590	3,950	6,310	17,370	16,380	18,040	19,650	18,450	13,890	3,530	1,850	2,030	125,050
HIGH	6,363	6,452	11,802	19,803	18,593	19,835	20,448	20,301	16,382	5,092	3,033	4,669	148,213
LOW	778	1521	2,642	14,547	11,657	13,228	18,363	16,320	11,358	2,341	1,029	811	100,081

30 days Nov 1850 acre ft = 1850 acre ft

75 days Nov, Dec, and 1/2 Jan 1850 + 2030 + 1795 = 5675 acre ft

120 days Nov, Dec, Jan, Feb 1850 + 2030 + 3590 + 3950 = 11,420 acre ft

WYOMING CONCRETE PIPE
725 BRYAN STOCK TRAIL • CASPER, WYOMING 82609
PHONE: 307/265-3100

CARDER CONCRETE PRODUCTS
8311 WEST CARDER COURT • LITTLETON, COLORADO 80125
PHONE: 303/794-6303

Precast Concrete Box Culverts
Reinforced Concrete Elliptical Pipe (18" thr
Concrete Roof Tile
Precast Concrete Manholes
CONCRETE FOR PERMANENCE
Non Reinforced Concrete Sewer, Culvert & Irrigation Pipe
Reinforced Concrete Sewer, Culvert & Irrigation Pipe (12" thru 144")
Non Reinforced & Reinforced Rubber Joint Pipe
Reinforced Concrete, Steel & Rubber Joint Pipe

APPENDIX B

Iterim Soils Report

GEOTECHNICAL ENGINEERING INVESTIGATION

on

Roosevelt Irrigation District Canal
Station 20+50 to Station 24+00
Phoenix, Arizona

for

Simons, Li & Associates
120 West Broadway, Suite 170
Tucson, Arizona 85701

524 North Sixth Avenue
Tucson, Arizona 85705
(602) 623-7774

DESERT EARTH ENGINEERING

November 22, 1985
84-210B

Registered Professional Engineer (Civil)
CERTIFICATE NO.
10296
ROBERT L.
SOGGE
Date Signed 11/22
ARIZONA, U.S.A.

CONSULTING GEOTECHNICAL ENGINEERS

November 22, 1985
84-210B

Simons, Li & Associates
120 West Broadway, Suite 170
Tucson, Arizona 85701

ATTN: John Lynch

RE: Geotechnical Engineering Design Investigation Relating to Options for Roosevelt Irrigation District Canal Station 20+50 to Station 24+00 Phoenix, Arizona

Gentlemen:

At your request Desert Earth Engineering has reviewed several proposed solutions to the problem of placing the proposed Roosevelt Irrigation District canal over the clay filled waste pit near the Agua Fria River in Phoenix. The options reviewed include the following: 1) realigning the canal, 2) removal of the clay and replacing it with engineered fill, 3) a pier and grade beam system to support the canal, 4) a pier system to support an elevated flume over the stretch of the alignment affected by the waste pit, 5) stablizing the soil by use of geotechnical fabric or sand drains, 6) and a combination of partial realignment of the canal and the constructuion of a retaining wall to limit the width of the canal and the attendant removal of the clay material.

On November 20, 1985 Desert Earth Engineering drilled six boreholes on the site. These borings were used to establish the depth of the clay layer and the approximate configuration of the waste pit side slopes, as shown in Fig. 1. These boring confirm the findings of Western Technologies Inc. report #21555020-E. Boring logs and results of further lab testing will be supplied at a later date.

DESERT EARTH ENGINEERING

524 North Sixth Avenue
Tucson, Arizona 85705
(602) 623-7774

Based on the results of our borings and analysis, it is the opinion of our soils engineers that extreme difficulty may be anticipated for the proposed solutions which involve removal of the clay material from the pit area below the canal. This is the result of the extremely weak nature of the material, the depth of the deposit, and the large lateral extent of excavation required to produce stable conditions both during construction and afterwards. It will also be extremely difficult to operate heavy equipment in this weak, saturated material. Therefore, it is the recommendation of Desert Earth Engineering that the options which would allow the material to remain in place be given priority over those which would require removal of the clay.

It has been a pleasure being associated with you on this project. If we may be of further assistance to you, please call.

Submitted By:

Donald Tharp, B.S.C.E.

Ralph Pattison, B.S.C.E.

Registered Professional Engineer (Civil) CERTIFICATE NO. 10296 ROBERT L. SOGGE Date Signed 11/22 ARIZONA, U.S.A.

R. L. Sogge, P.E.

RLS/ajt

Copies: (2) Addressee

1. REALIGN CANAL

Due to the presence of the clay material in this pit, the canal may be realigned so as to avoid the area. Based upon the current configuration this alternative would require moving the centerline of the channel approximately 80 to 90 feet south of the currently envisioned alignment in the area of the clay-filled waste pit.

Due to the highly variable soil conditions encountered across this entire project, if the realignment option is selected, it would be inadvisable to generalize the soil conditions under any new alignment from those encountered in our test borings. Any new alignment which may be selected should be drilled prior to design and construction in order to accurately ascertain soil conditions prevalent along the route chosen.

2. REMOVE CLAY AND REPLACE WITH ENGINEERED FILL

A second alternative is to remove the saturated clay and replace it with engineered fill. If this alternative is selected extreme difficulty may be anticipated during excavation. Due to the extremely weak nature of the clay the angle of excavation should not exceed 1 vertical to 4 horizontal. The anticipated depth of excavation is in excess of 30 feet in some areas of this project. The splay angle below the toe of the slope will be dependent on the material selected as fill; however a 1 horizontal to 1 vertical splay slope may be used for preliminary design Based on these dimensions, and the currently proposed canal cross section and alignment the lateral extent of removal would be approximately 265 feet at the top and 145 feet at the bottom.

Our analysis of this option was based on an average value for cohesion obtained from unconfined compressive strength testing performed by Western Technologies Inc. The results of these tests also indicate that weaker spots are present in some areas of the pit. In these weaker areas even greater excavation difficulties may be anticipated. The stable excavation slope in these areas is 6 horizontal to 1 vertical which translates to a top width of excavation equal to 325 feet.

3. CONSTRUCT THE CANAL ALONG THE CURRENTLY PROPOSED ALIGNMENT WITH THE FLUME INDEPENDENTLY SUPPORTED

A third alternative is to construct the canal along the currently proposed alignment while supporting the flume independently on drilled, cast-in-place, concrete shafts. Assuming a system of two shafts per pier groups with each group spaced 10 feet on center, the required depth of embedment for a 2 foot diameter shaft would be 20 feet, (bottom elevation = 993) for the shafts on the south side of the flume and 23 feet, (bottom elevation = 969) for the shafts on the north side of the flume. These shafts could then be connected by a grade beam to support the flume (see Fig. 2A).

Alternatively a single 3-foot-diameter shaft may be used directly beneath the center of the flume. Assuming a 10-foot, on-center spacing, the required depth of embedment would be 22 feet, corresponding to a bottom elevation of 967 (see Fig. 2B). This alternative would not require a grade beam. All embedment depths are measured from the lowest adjacent granular material grade. The clay material is not to be used in determining embedment depth.

It should be noted that if alternative 3 is chosen the flume itself will need to be designed so as to be structurally sound without soil support since considerable settlement will occur in the clay material supporting the canal fill.

4. CONSTRUCT AN ELEVATED FLUME SUPPORTED BY SHAFTS ALONG THE CURRENTLY PROPOSED ALIGNMENT

A fourth alternative is to construct the flume along this stretch. This would result in an elevated flume along this section. The flume could then be supported on single, 3 foot diameter, drilled, cast-in-place, concrete shafts (see Fig. 3). Based upon 10-foot, on-center spacing for these shafts the required depth of embedment would be 24 feet which corresponds to a bottom elevation of approximately 969. Once again if alternative 4 is chosen the depth of embedment is to be measured from the lowest adjacent granular material grade. The depth of embedment for this option reflects vertical capacity only. A lateral load analysis should be performed prior to final design.

5. STABILIZATION OF SOIL USING GEOTEXTILE FABRIC OR SAND DRAINS

Geotextile fabric by itself will not be sufficient to stabilize the clay. This method was recommended for the portion of the alignment passing over the waste pits between Station 11+80 to Station 20+60 because it was beneficial to maintain separation between the embankment material and the quick-settling waste pit material. For the portion of the alignment from Station 20+60 to Station 24+00, the waste pit material is a slow settling clay; geotextile fabric will not prevent settlement of this clay. Nevertheless, fabric should be used with any alternative that involves placement of fill over the clay layer since it will be beneficial to maintain separation between the layers.

Geotextile reinforcement could also be used in soil below the embankment if the clay were removed. If clay removal is a preferred option, then use of reinforcing fabric can be analyzed further. However, for reasons given elsewhere in this report, clay removal is not recommended.

Stabilizing the soil through placement of sand drains is an alternative worthy of consideration. If these drains were constructed as soon as possible, and a sufficient overburden placed above the clay layer, 90% consolidation or better could be achieved within a year. This would enable construction of the embanked channel to proceed as originally intended, without modification of the cross-section or the alignment.

Tentatively, sand drains could be spaced 10 feet apart over that portion of the clay that will support the embanked channel. It would be feasible to use 1-foot-diameter or even 6 5/8-inch-diameter drilled shafts. The latter diameter has the advantage of being easily drilled using standard hollow-stem, continuous-flight auger, which would make drilling and placement of the sand easily manageable.

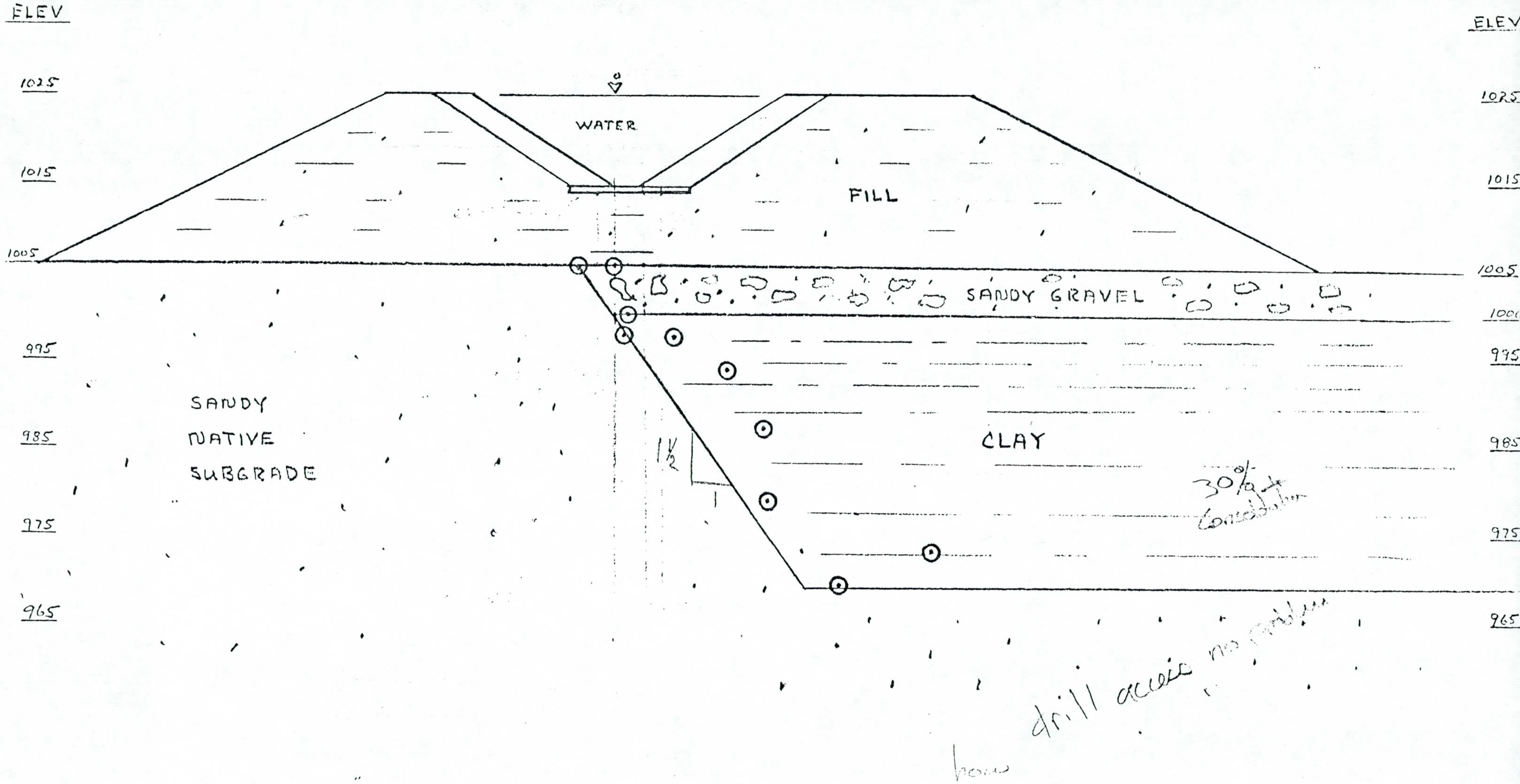
Actual spacing of sand drains would depend on measurable settlement taking place during early stages of the operation. If this settlement were occurring too slowly, it could be accelerated through placement of additional drains. These could be readily drilled with the overburden already in place.

6. PARTIALLY REALIGN CHANNEL AND CONSTRUCT RETAINING WALLS ALONG THE SIDES OF THE CANAL

A sixth alternative is to partially realign the channel by shifting the centerline approximately 26 feet to the south and construct retaining walls along the sides of the canal to restrict the canal width and subsequent need for clay removal.

The splay angle of the foundation for this retaining wall would depend on the material selected for fill but a 1:1 horizontal to vertical slope may be assumed for preliminary design. Due to the weak nature of the clay an excavation slope not to exceed 1 vertical to 4 horizontal is recommended during the clay removal. Based on an embedment depth of 5 feet for this wall and a 30 foot depth of excavation to remove the clay, this alternative would result in a top width of 33 feet.

It should be noted that if this alternative is chosen, the problems attendant with the removal of the clay material which have been outlined previously would also be encountered for this option.



⊙ BOTTOM OF CLAY LAYER
PER BORINGS & TRENCHES

FIGURE 1
LOCATION OF BOTTOM
OF CLAY LAYER ENCOUNTERED
IN BORINGS AND TRENCHES

Desert Earth Engineering consulting geotechnical engineers			
Drawn by: DT	Date 11/22/85	Checked by: [illegible]	Date 11/22/85
Sheet 1 of 1	Job No. 85-210b	Figure No. 1	

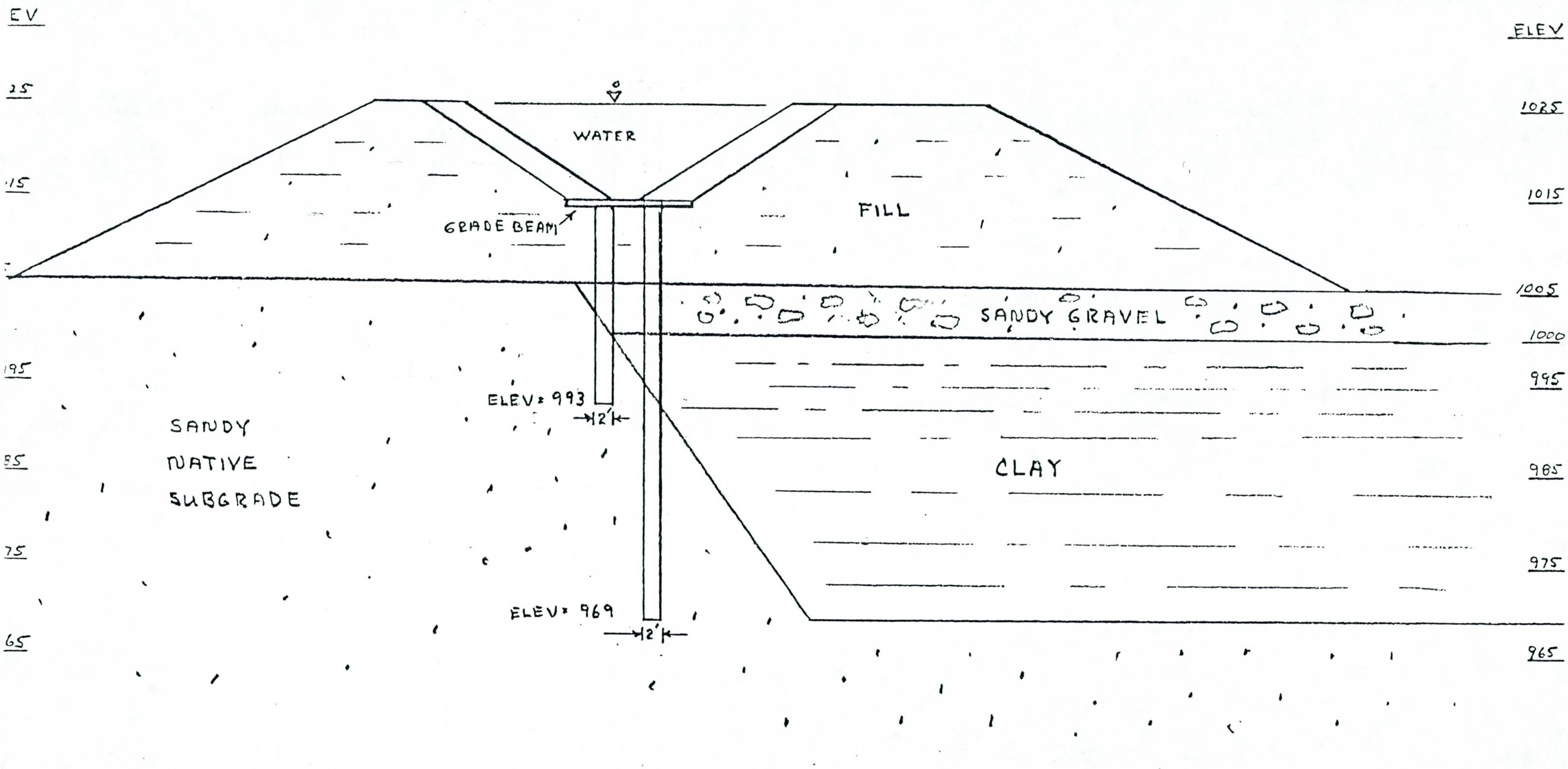


FIGURE 2A
(OPTION 3)
2 FOOT DIAMETER
CAST-IN-PLACE
SHAFTS w/ GRADE BEAM

Desert Earth Engineering consulting geotechnical engineers			
Drawn by: DT	Date 11/22/85	Checked by: RYJ	Date 11/22/85
Sheet 1 of 1	Job No. 85-210b	Figure No. 2A	

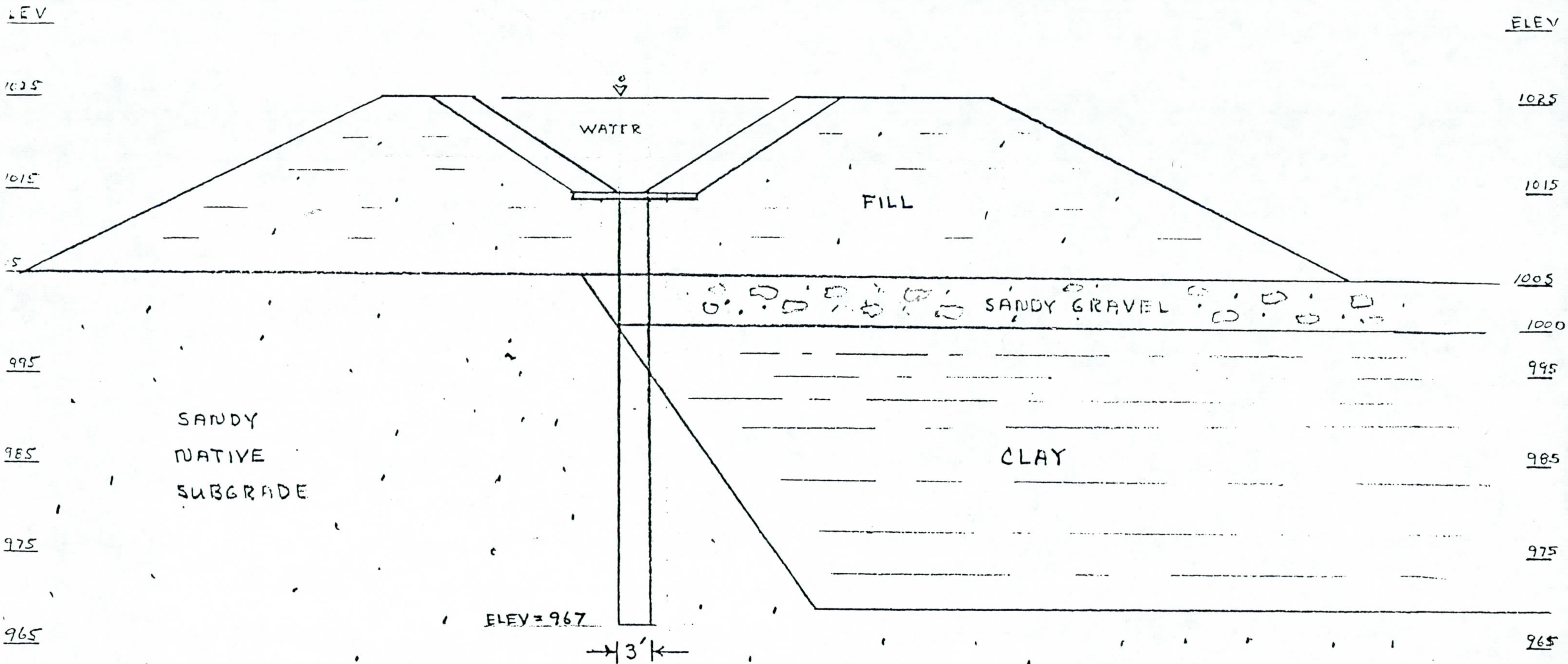


FIGURE 2 B
(OPTION 3)
3 FOOT DIAMETER
CAST-IN-PLACE
SHAFTS w/o GRADE BEAM

Desert Earth Engineering consulting geotechnical engineers			
Drawn by: DT	Date 11/22/85	Checked by: [illegible]	Date 11/22/85
Sheet 1 of 1	Job No. 85-210b	Figure No. 2B	

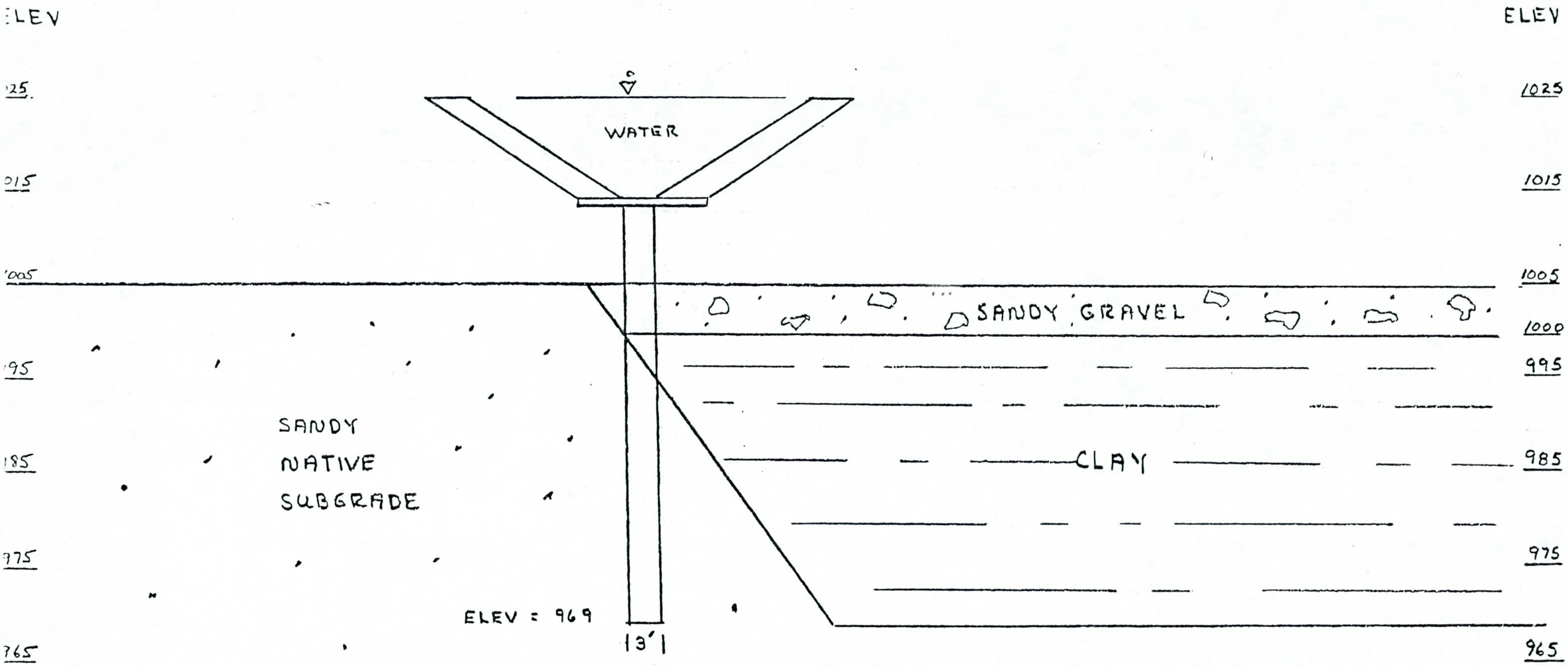


FIGURE 3:
(OPTION 4)
ELEVATED FLUME
SUPPORTED BY 3 FOOT
DIAMETER SHAFTS

Desert Earth Engineering consulting geotechnical engineers		
Drawn by: DT Date: 11/22/85	Checked by: [illegible] Date: [illegible]	
Sheet 1 of 1	Job No. [illegible]	Figure No. 3

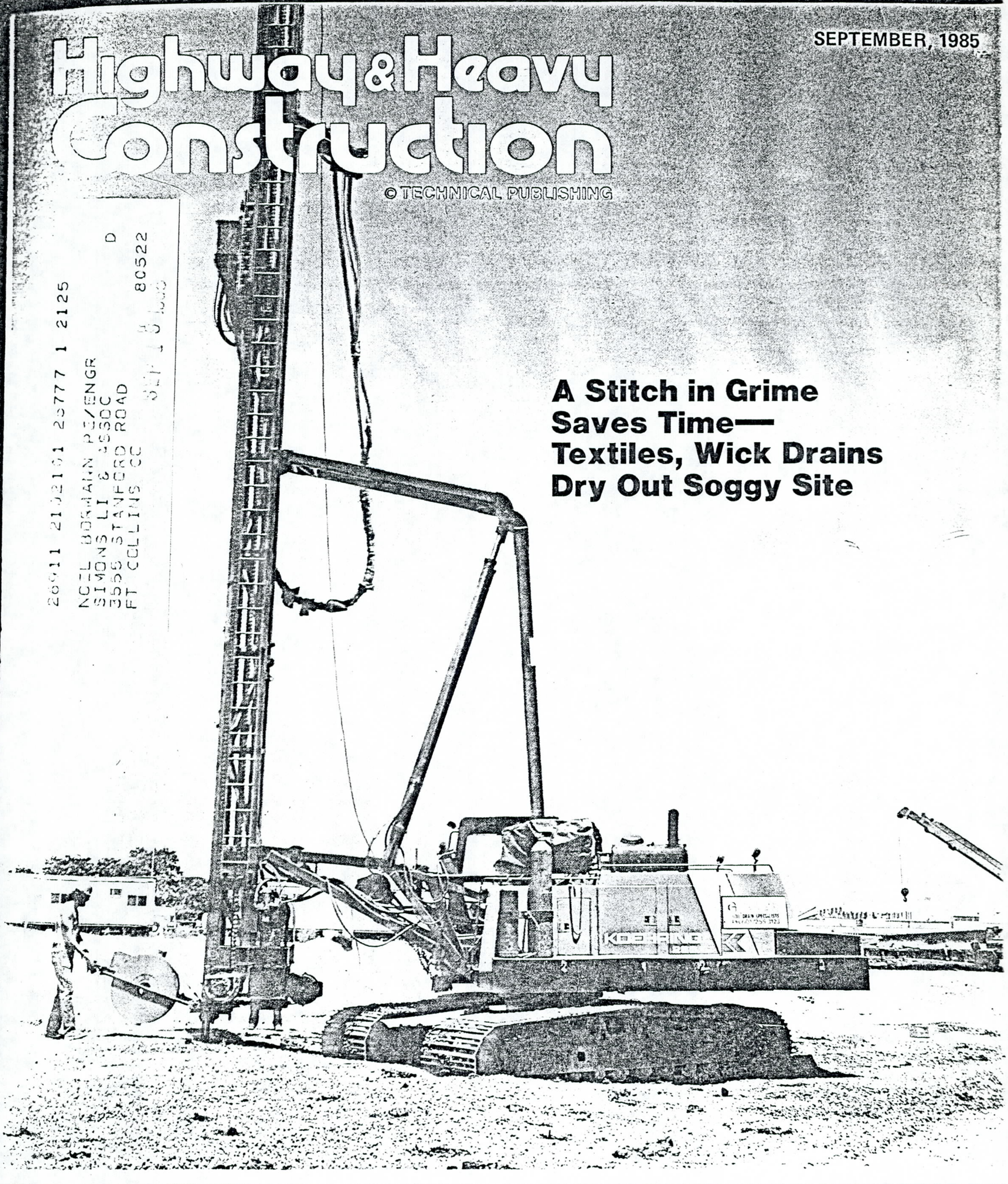
APPENDIX C

Wick Drain Construction Examples

SEPTEMBER, 1985

Highway & Heavy Construction

© TECHNICAL PUBLISHING



26911 2102101 25777 1 2125
NEIL BORMANN PE/ENGR D
SIMONS LI & ASSOC
3555 STANFORD ROAD
FT COLLINS CO 80522

A Stitch in Grime Saves Time— Textiles, Wick Drains Dry Out Soggy Site

Spotlight on Geotextiles

A tractor-supported sewing machine stitches seams along heavy, hand-spread geotextile used to support workers and equipment constructing new marine terminal on soft, wet dredgings in Baltimore Harbor.

Cover Story

A Stitch in Grime Saves Time

More than 3,000,000 l.f. of vertical wick drain—the largest such installation ever in this country—and 300,000 sq. yd. of an extra heavy geotextile field stitched in the grime are saving time on a new marine terminal in Baltimore.

The 113-acre disposal area for spoil from the I-95 tunnel under Baltimore harbor is now being consolidated for development as a container facility. C.J. Langenfelder & Son, Inc., Baltimore, is the general contractor on the $10.9-million, 600-calendar-day project for the Maryland Port Administration.

"It is all on a fast track schedule," said Ron Lange, project engineer for the Administration. "The heavy duty geotextile is essential to support the equipment installing the wicks. If we didn't use the wicks, the surcharge would have to remain for a settlement period of at least an additional year to adequately consolidate the spoil."

The pumped spoil is almost liquid. In most areas, the surface crust will support a man, but not construction machinery. Some areas will not even support a man, and equipment is safe only in a few areas along the old shoreline.

The extra heavy woven geotextile on top of the spoil distributes loads to the point that a man is safe, even in the softest areas, where movement feels like walking on a water bed. A 2½ ft. blanket of sand must be placed over the geotextile and capped with a six in. layer of crushed slag to provide barely adequate support for heavy equipment.

A 2½-ft. layer of sand and 6 in. of slag are spread over geotextile by wide-track dozers.

Equipment works on slag surface

Subcontractor Geotechnics, Inc., Bay St. Louis, Miss., works off the slag surface while installing the wicks with a modified Koehring 266 hydraulic excavator. It has 42-in.-wide crawler tracks to reduce its ground pressure to 6 psi, and its bucket and boom have been replaced with a 56-ft.-high mast. A mandrel in the mast, actually a fixed lead, acts like a needle while inserting the wick drain from 16 to 50 ft. down into the soft goo.

The toughest part is punching through the heavy geotextile, which is usually done with the rig's 15-ton static force. On occasions, a short burst of vibratory power helps. Once the pointed mandrel tip pierces the geotextile, the mandrel is pushed almost effortlessly to the bottom of the spoil and withdrawn leaving the wick behind.

After the mandrel is withdrawn, a laborer cuts the wick material with hand-held hedge trimmers, doubles the loose end back into the eye of the mandrel and inserts a 9-in. length of ½-in. rebar to hold the wick snuggly in position for the next insertion.

One wick every 30 seconds

John Singleman, the foreman for Geotechnic, regularly installs one wick every 30 seconds as the rig rotates from side to side inserting two or three rows of wicks from a single setting. The wicks are spaced about 5 ft. apart in a diamond-shaped pattern. Daily production, including downtime to change reels of wick material or for major movement of the machine, ranges from 10,000 to 18,000 l.f. installed per 10-hour day.

Another modification which Geotechnic's Russell Joiner made on the rig is an additional hydraulic system and cylinder to raise or lower the mast. By extending and pinning that cylinder to the mast, the entire 56-ft.-high fixed lead can be rotated to or from the horizontal position by the operator in the cab without the need for any support equipment.

With the mast lowered, the 70,000-lb., 11½-ft.-wide rig can be walked onto a special four-axle, hydraulic beam trailer, jacked up to provide 6-in. of clearance under its tracks, and moved over the highway as a 112,000-lb., special-permit load when moving from job to job.

The Amerdrain vertical wick drain used on the job is manufactured by ICE. Each reel consists of 1000 ft. of a flat, 4-in.-wide sleeve of nonwoven filter fabric surrounding a ribbon of longitudinally corrugated plastic.

Water is squeezed out

Once the wicks are installed and a heavy, 7- to 9-ft. earth surcharge is placed, water will be squeezed out of the spoil through the filter fabric and up the wicks for discharge into the sand blanket. An underdrain system in the sand blanket will collect that water and convey it to a sump for pumping into a settling basin prior to discharge in the bay.

The ADS underdrain is a 6-in. corrugated, perforated polypropylene pipe installed within the 2½-ft. sand blanket by one of Langenfelder's crews using a Vermeer V-430 trencher.

The extra heavy geotextile spread over the surface of the spoil is Nicolon's 62809 woven fabric consisting of cords of polypropylene in one direction and polyester in the other. The fabric weighs nearly two lb. per sq. yd. and has a tensile strength of more than 1000 lb. per lineal inch in each direction.

The fabric, which comes in 1200 lb. rolls about 16½-ft. wide and 270 ft. long, is towed to the site by wide track dozers, unrolled and hand-spread by laborers. Seaming is done with a special heavy duty electric sewing machine hung on a small Steiner farm tractor. The sewing machine is powered by a Homelite HG 1400 portable generator mounted on the rear of the tractor.

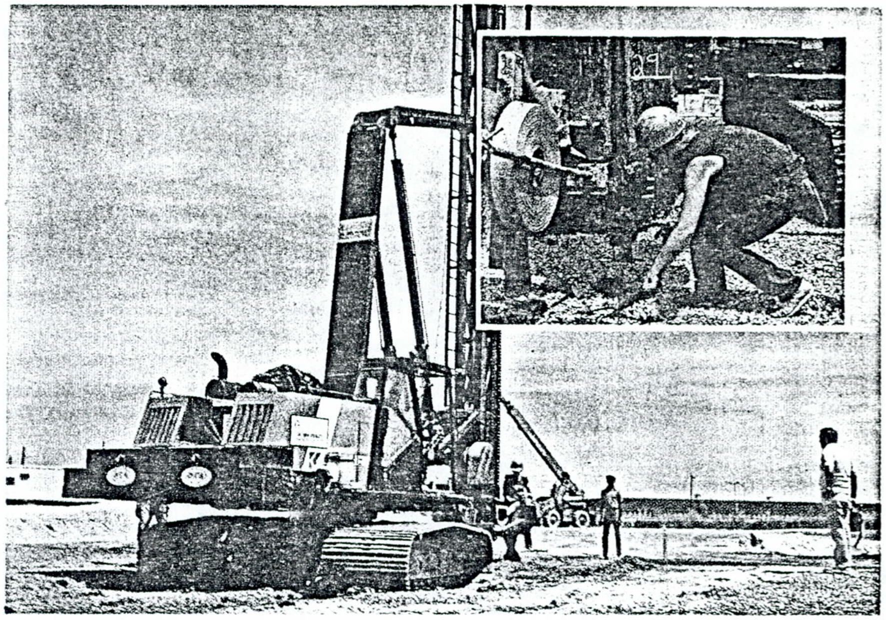
The longitudinal joints are double J-stitched in which two layers of geotextile are lapped, folded over, and the four thicknesses of material (about a third of an inch) stitched together with a heavy polyester "thread." In practice, this takes a crew of six to eight laborers to support and shape the fabric seams for the sewing machine operator.

Sand spread over geotextile

About 250,000 cu. yd. of sand is being spread over the seamed geotextile to a 2½ ft. depth. The sand is hauled in from off-site locations by Ingram Trucking, Co., Baltimore, and spread by two small Caterpillar D3B and one Komatsu D31P wide-track dozers.

Slag is placed in a similar manner after the sand course has been leveled by the small dozers dragging their blades. After the wicks and underdrains are installed, the 210,000 cu. yd. surcharge is built up in one ft. lifts to provide the load to squeeze water out of the subsoils.

"Sud" Cockey is project manager for Langenfelder coordinating a work force of 30 to 35, plus truck drivers, on the project. Crews typically work five 10-hour days a week. □



The modified wide-track excavator with 56 ft. mast still sinks into soft ground while installing more than three million l.f. of vertical wicks to drain the wet dredgings under new port site. Mandrel is withdrawn from soft goo and top of wick is cut from reel with hand shears (inset). Loose end from reel is then doubled back into tip of mandrel around a piece of rebar, and pulled snug by laborer at left before next wick is installed.

Horizontal drains are installed in 2½-ft. sand blanket to collect water to be discharged from vertical wicks after a heavy, earth surcharge is placed.

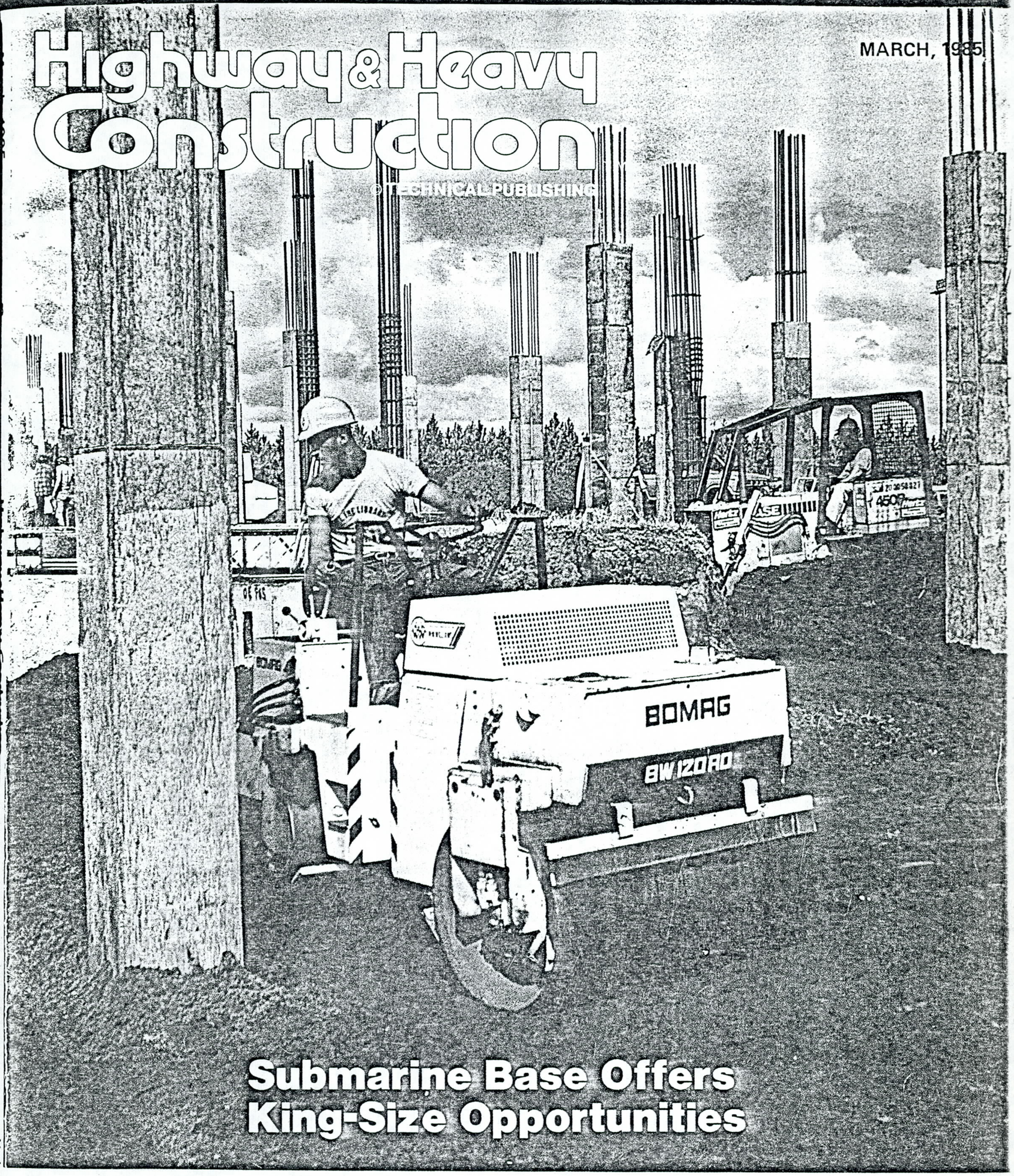
More information on equipment used is available by circling the appropriate Reader Service Numbers in this issue.

176 Hydraulic excavator
177 Vertical wick drains
178 Perforated underdrains
179 Trencher
180 Extra heavy woven geotextile
181 Farm tractor
182 Portable generator
183 Small dozers

MARCH, 1985

Highway & Heavy Construction

© TECHNICAL PUBLISHING



Submarine Base Offers King-Size Opportunities

New Horizons — Drainage

New Horizons In Drainage

What's new and different in drainage . . . for foundations . . . for surface runoff . . . for area drainage . . . and for construction sites.

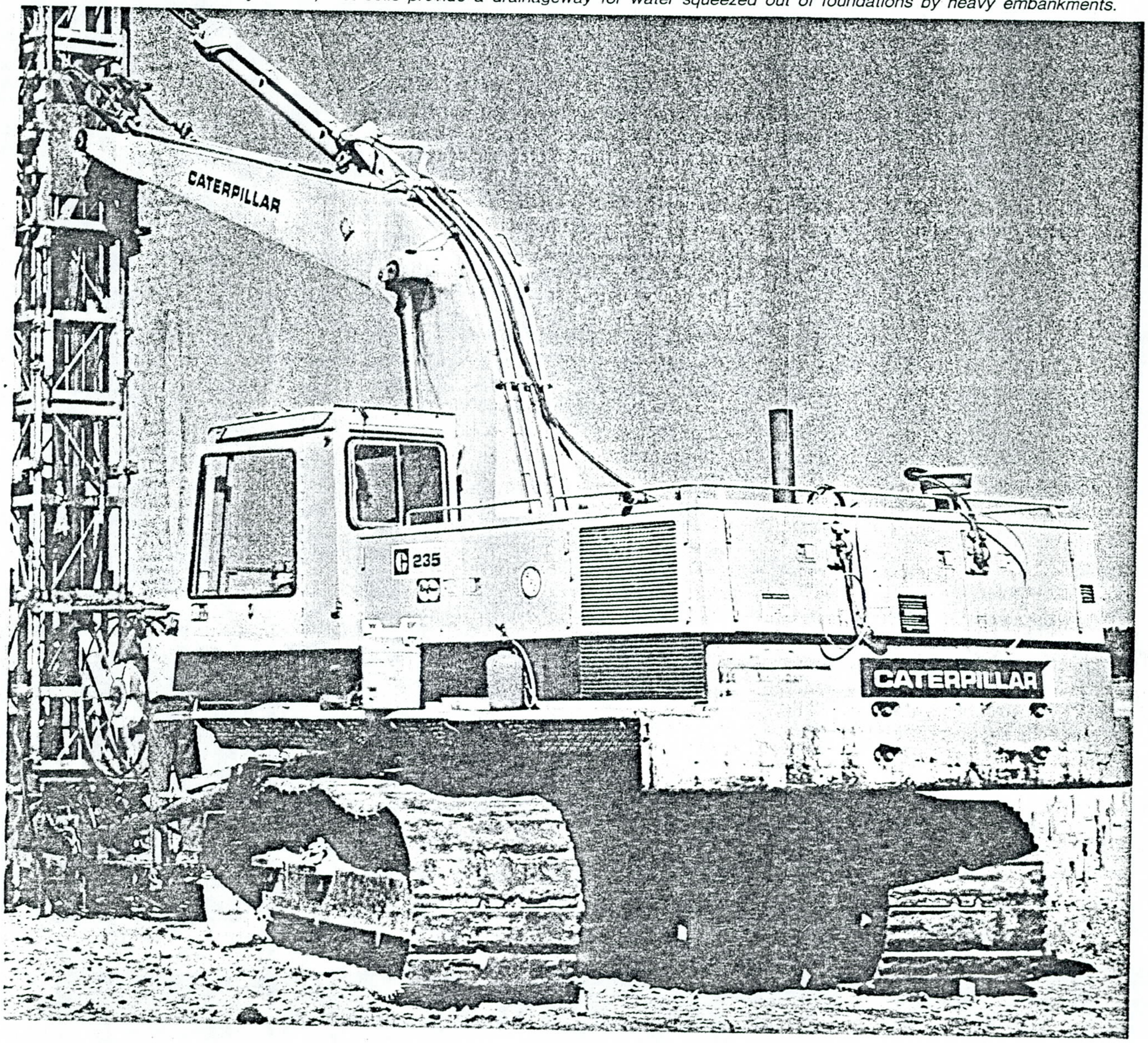
The three most important factors in highway design—according to an old engineering adage—are drainage, drainage, drainage. Good drainage of the subsoils and embankments provides the stable foundation needed to carry the loads. Good surface drainage avoids ponding on pavements and allows traffic to move safely. Good area drainage—properly positioned and adequately-sized culverts and bridges—maintains stream flows and protects the highway from flooding and wash out.

Those same principals apply to most construction projects, not just to highways. But there is a fourth often-neglected factor, too. Drainage of the construction site so the contractor can build the project. That's our outline—What's New and Different in Drainage . . . for foundations . . . for surface runoff . . . for area drainage . . . and for construction sites.

Foundations

Excavation and replacement, replacement by rolling surcharge, and gradual consolidation under the weight of an oversized embankment are tried and true methods of coping with wet or compressible foundation conditions. In some cases, sand drains or rock drains (vertical columns of sand or rock) support an embankment and also provide a drainageway through im-

Wick drains inserted vertically in soft, wet soils provide a drainageway for water squeezed out of foundations by heavy embankments.



permeable soils into an underlying water bearing strata.

But dynamic compaction and wick drains are relatively new methods of stabilizing foundations. Dynamic compaction—the dropping of multi-ton weights from heights of 50 to 100 ft.—is faster than building a heavy embankment surcharge to compact compressible soils, but it does little to drain foundations. Several companies which specialize in this kind of work (such as GKN Hayward Baker, Inc., and Geopac, Inc.) will provide further background on request.

Wick drains are the newest method for draining wet foundations. The wick is little more than a continuous sleeve of porous construction fabric surrounding an irregular plastic core. It is inserted vertically—usually to a depth of 20 ft. or more—in soft, wet soils to provide a drainageway for water squeezed out of the foundations by an oversized embankment. Companies such as Vibroflotation Foundation Co., Geotechnics and others should be consulted for further information on installing wicks.

Surface runoff

Adequate pavement cross slopes and curb and gutter sections having adequate longitudinal slopes are the standard in municipal paving. Stringlines and sensors have greatly improved grade control during paving, and modern slipformers can economically extrude a variety of curb and gutter sections to collect and carry runoff to designated points of discharge. But plugged inlets or heavy rainfalls can still cause ponding of runoff on the pavement, frequently extending well into the travelled lanes where it slows traffic and creates a hazard.

In some cases, particularly where the terrain is very flat or the paved areas are very large, slotted drains can be used to store that runoff and reduce ponding on the paved surface. Armco and ACO Polymer Products are two manufacturers of this type of drain which is being used increasingly in parking lots, driveways and municipal streets. It is probably being used on runways and other large paved areas at airports, although we're not aware of any such installations yet.

Most paving contractors are now familar with open graded friction courses, a thin asphalt surface placed on many highways these days. It improves highway safety through increased friction and better braking for vehicles, and by virtual elimination of hydroplaning. Both occur because the lack of fines in the paving mix creates a porous, sponge-like series of openings in the surface to carry runoff to the edges and to provide a means of escape for water which could otherwise be trapped between the tire and a perfectly smooth pavement.

Other contractors specialize in cutting grooves in pavement surfaces (usually concrete) to drain runoff and reduce the possibilities of hydroplaning. A series of diamond-tipped circular saws operating longitudinally on highway pavements and transversely on runways are the norm for this work.

Similar diamond-tipped circular saws eliminate rutting (and ponding in the wheel ruts) on worn concrete pavements. Milling machines with carbide-tipped cutting teeth perform similarly along asphalt highways. But the millers also remove the worn surfaces, which can then be recycled, and restore flow lines along curbs on municipal streets.

Much of the surface runoff on older concrete highway pavements drains through cracks or joints in the slabs into the underlying base. Many highway departments now specify longitudinal underdrains along each edge of a roadway.

Frequently, the underdrain trench is lined with a filter fabric to keep fine soils out of the perforated underdrain pipe. In other cases, coils of perforated plastic pipe already encased in a filter fabric sleeve are used.

In some areas, saw-like trenching machines are being used to retrofit old highways with underdrains. But at least one state—Georgia—prefers to invest in effective sealing of cracks and joints in the pavement to prevent intrusion of surface drainage, rather than investing in underdrains to remove that water.

Area drainage

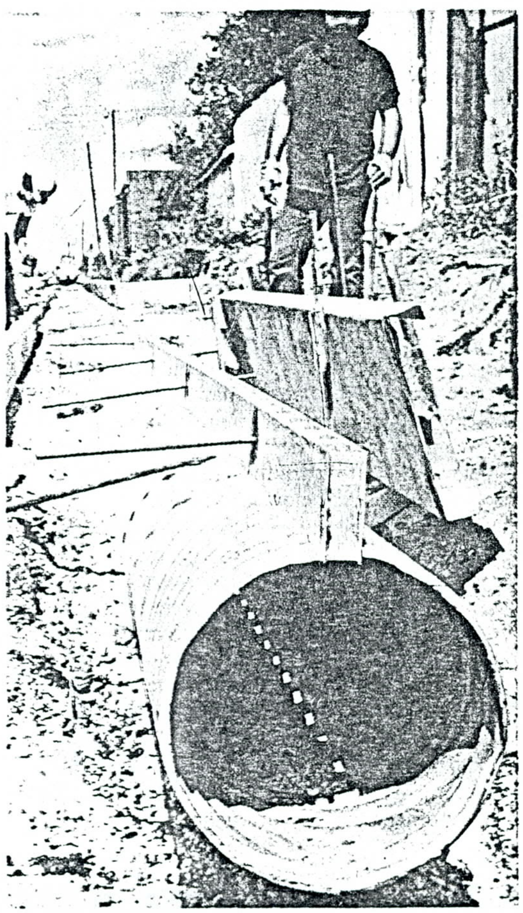
Urban development invariably converts large areas of rain-absorbing soils to water-shedding rooftops and pavements. That increases the amount of runoff after storms and temporarily overloads existing storm sewer systems and increases the likelihood of downstream flooding.

Many zoning codes now carry restrictions limiting peak runoffs *after construction* to the same flows that existed before development. The result is to force temporary on-site storage of peak runoff, with a gradual and controlled release when downstream facilities are able to cope with the flow.

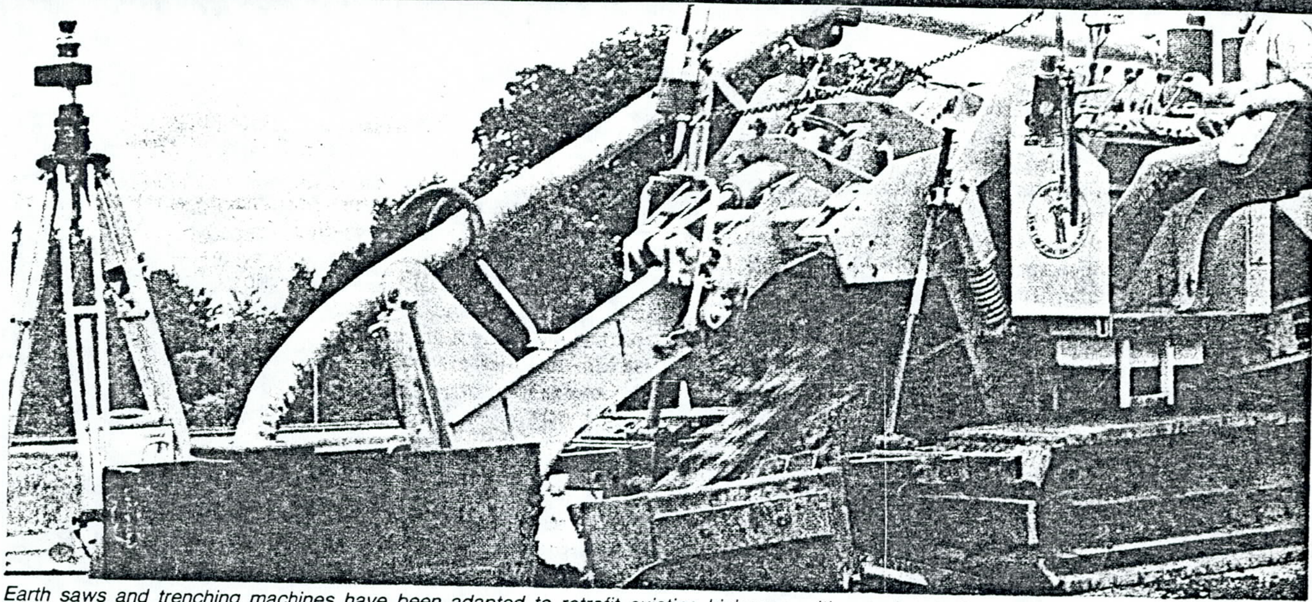
Construction of pre-planned, on-site retention basins as an initial part of site development now occurs with increasing regularity. Earthmovers are finding a new market in reshaping flat lands to create storage lakes and ponds. Culverts limit the outflows through dams, which are designed to detain peak flows exceeding the capacity of the outlet. Earthfill detention dams are most frequent, but Roller Compacted Concrete dams are being used in some cases (see following story).

This same stormwater storage concept is the basis for the deep tunnel systems now being constructed in the Chicago and Milwaukee Metropolitan Areas. Both areas have combined sewers which collect and convey sanitary *and* storm flows to treatment plants. In both cases, the treatment plants would be flooded by peak runoffs after rainstorms if those flows weren't discharged untreated into Lake Michigan. In both cases, those runoffs will eventually be stored underground and pumped back to the surface for treatment during off-peak periods.

In a similar vein, porous concrete pavements—which, like the open graded asphalt friction courses, contain little in the way of fines—are now being used in some parking lots to *store*



Slotted drains store runoff and reduce ponding on pavements after rainstorms.



Earth saws and trenching machines have been adapted to retrofit existing highways with new longitudinal underdrains.

as much as an inch of runoff within the pavement. That stored runoff later evaporates if the base is impermeable, or soaks into the subsoil if the porous concrete is used for the full depth of the pavement.

The latter concept is carried a step further in other cases where an open, precast concrete grid is placed over the subsoils, backfilled with topsoil and seeded. Further data on this approach is available through Armortec and other companies.

Water quality—rather than water quantity—also affects the design and construction of drainage facilities. Many power plants and other similar facilities are in enviromental hot water because of the high discharge temperature of their cooling waters into streams and waterways. New reservoir projects to further cool those waters are underway in several cases.

The Soil Conservation Service and other federal agencies are deeply concerned about windborne and waterborne erosion of agricultural lands. Land leveling, contour farming, check dams in drainage ways and settling basins are current methods of controlling soil erosion.

Construction sites

Most grading contractors are already well-versed in the use of check dams and brush barriers in drainage ways, and in settling basins and filter systems used to curtail soil erosion at or near a construction site. But water pumps have been greatly improved in recent years. Many pumps can be submerged, while others can be fitted with trash guards. Impeller pumps can "lift" (actually push) water for greater distances.

Wellpoints, actually small submersible pumps connected to a surface level storm drain, are a traditional dewatering answer to contractors working in sites below ground water levels. Several companies, including Stang Hydronics and Moretrench American, specialize in this type of dewatering.

Concrete cutoff walls constructed in Bentonite slurry-supported trenches are also used to protect many foundation excavations from unwanted inflows of water. ICOS and Case International are two of the companies active in this kind of work.

But the newest technique for temporarily protecting a construction site from ground water involves freezing—rather than draining—the surrounding soils. Firms like Geofreeze Corp. and Geo Systems, Inc., specialize in installing the coils and refrigeration equipment to permit excavation to proceed in areas which would otherwise defy drainage and construction.

References and training

Entire libraries of theoretical and technical data are available on the topic of drainage, and we won't bore you with any such listings. But there are two sources which may be of particular interest to designers and contractors involved in that type of business.

The American Public Works Assn.'s 1981 Special Report No. 49, titled *Urban Stormwater Management*, is one of the most comprehensive documents on that topic we've seen. It provides legal and operational perspective for managing urban stormwaters, and detailed guidelines for planning, designing and constructing stormwater management facilities. This 15-chapter, 285-page document is available at a cost of $30 plus postage through APWA, 1313 E. 60th St., Chicago, IL 60637.

The Federal Highway Administration's (FHWA) Demonstration Projects Div. is developing a new demonstration project which builds on an earlier, now completed series of workshops. It is expected to start late this year and to consist of three-day workshops to provide design guidance and procedures for hydrologic analysis, culvert design, channel design and bridge waterways. It will include demonstrations on the use of microcomputers in hydrolgic and hydraulic analyses. A portable hydraulic flume will be used. Further information on this demonstration project can be obtained through: Douglas A. Bernard, Chief; FHWA Demonstration Projects Div.; HHO, Nassif Building; 400 7th St., SW, Washington, DC 20590.

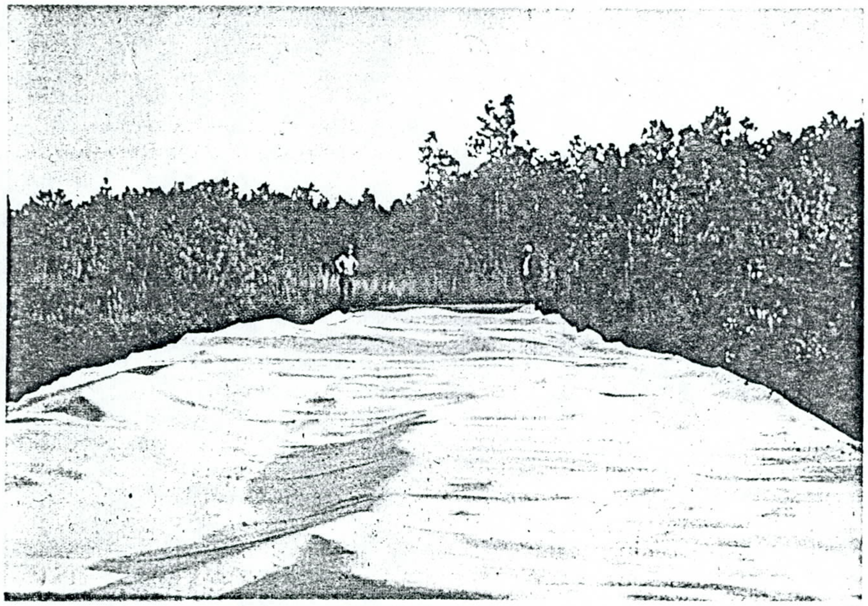
Reference manuals for these workshops are already available. They include:

- HEC 12—Drainage of Highway Pavements (1984);
- HEC 13—Hydraulic Design of Improved Inlets for Culverts (1972);
- HEC 14—Hydraulic Design of Energy Dissipators for Culverts and Channels (1983);
- HEC 15—Design of Stable Channels with Flexible Linings (1975); and,
- HEC 19—Hydrology (1984).

Reference manuals HEC 12 and 19 are available from the Government Printing Office. The others may be obtained, in limited quantities, from the FHWA Office of Engineering; Bridge Div., HNG-31; 400 7th St. SW, Washington, DC 20590. □

More information on equipment used is available by circling the appropriate Reader Service Numbers in this issue.
222 Dynamic compaction
223 Wick drains
224 Slotted drains
225 Open precast concrete grids
226 Earth saws/trenching machines
227 Corrugated polyethelene drains
228 Wellpoint systems
229 Bentonite slurry walls

Geofabric Floats Road On Swamp For Easy Access



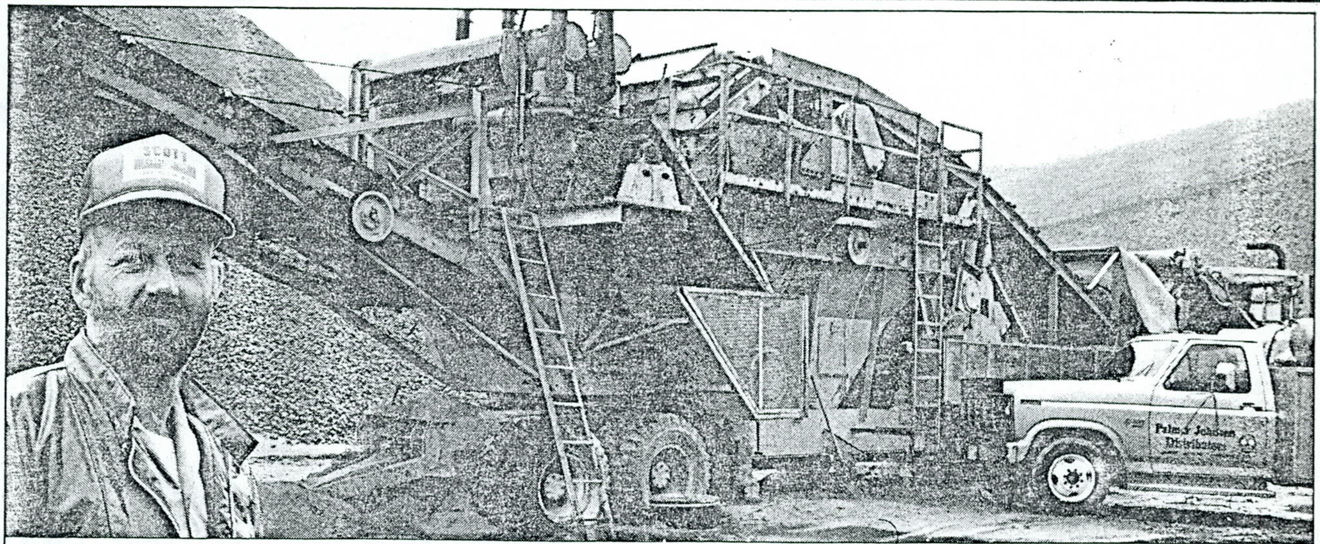
Geotextile fabric is placed prior to two ft. of sand rock fill being spread and compacted to create this access road over a swamp in Pennsylvania.

An access road was recently built quickly and inexpensively over a swamp. A high strength geotextile placed first on the surface of the swamp effectively prevented the loss of fill to the swamp.

D&F Coal, Penn Run, Pa., needed a new access to the coal mine. But the site was surrounded by swamp and the project appeared too costly and difficult. The use of a strong geotextile made the job feasible.

Phillips Supac 5WS(UV) was unrolled over the swampy material. Two ft. of sand rock fill was spread and compacted by a Cat D6 dozer and the road was ready to use. Encouraged by the success with the road, D&F placed fabric and fill over another couple of acres to increase their stockpile area. □

More information on equipment used is available by circling the appropriate Reader Service Numbers in this issue.
195 Geotextile
196 Dozer



"Palmer Johnson's quick delivery of a rebuilt clutch PTO saved me $10,000 a day."

Your Palmer Johnson rep is a veteran of years of on-the-job experience. With a phone call, you can have that technical skill at the job site.

Our 3 locations offer same day shipment of new or rebuilt Clutches, PTOs, Torque Converters and Transmissions, manufactured by TWIN DISC, WICHITA and FUNK. We also stock the parts you need.

Palmer Johnson Distributors offer the knowledgeable service that you need to stay on the job.

"A COMMITMENT TO SERVICE"

PALMER JOHNSON DISTRIBUTORS, INC.
POWER TRANSMISSION GROUP

Madison, WI 608-222-3532 | Chicago, IL 312-250-0370 | Minneapolis, MN 612-770-0440

For more details circle 34 on Reader Service Card

sla

SIMONS, LI & ASSOCIATES, INC.

3555 STANFORD ROAD
P.O. BOX 1816
FORT COLLINS, COLORADO 80522

TELEPHONE (303) 223-4100
TELEX: 706057

FLOOD CONTROL DISTRICT
RECEIVED
JAN 1 0 '86

CH ENG	HYDRO
ASST	LMgt
ADMIN	SUSP
3 C&O	5 FILE
1 ENGR	DESTROY
FINANCE	
REMARKS	

3.1 LH 1/13

January 9, 1986

Mr. Richard Perreault
Project Manager
Flood Control District of
Maricopa County
3335 West Durango
Phoenix, Arizona 85009

Re: Modified Soils Report, RID Canal Crossing of the Agua Fria River
(SLA Project Number AZ-MC-08 Phase 4)

Dear Dick:

Enclosed please find a preliminary design for the drain installation and a copy of the updated Desert Earth Engineering (DEE) report which specifically addresses the performance of vertical drains in the clay soil deposit. In the updated report, additional analysis of the long-term settlement behavior of the canal embankment has been performed, along with some additional soil tests to determine the clay properties.

In paraphrasing the report, the specific result of interest is that by placing a 10-foot high surcharge embankment on top of the canal embankment and allowing the underlying clay soil to reach 95 percent consolidation before removal of the surcharge, the expected differential settlement can be eliminated (see page 5 second paragraph, and page 7 first paragraph). This would make the canal embankment over the clay deposit equivalent in performance to embankment construction on normal granular soil. DEE has calculated drain performance based on sand columns which indicates that for a drain spacing of 5 feet, 95 percent consolidation can be achieved in approximately 2 months. Based on the literature included in our preliminary submittal to you, the use of fabric wick drains would increase the time required to reach 95 percent consolidation to approximately 5 months.

SLA still recommends the use of wick drains due to the increased reliability of fabric drains over sand columns. SLA also still recommends the implementation of a program for monitoring the settlement of the clay under the effects of the surcharge.

Dick, please feel free to share this material with the RID and Franzoy-Corey as you deem necessary to help the RID in the review of this construction alternative. Also, rest assured that SLA will continue to assist the FCDMC to the fullest extent possible in order to bring this project to a successful conclusion. If you or the RID require any further information or have any questions about the design, please do not hesitate to contact us. Finally, Dick, we would like to express our appreciation for the efforts and involvement that the FCDMC, and especially you, have contributed to this project.

Sincerely,

Noel Bormann

Noel E. Bormann, P.E.
Project Manager

Robert C. MacArthur

Robert C. MacArthur, Ph.D., P.E.
Vice President

RCM:NEB:bbv
R577.2/RDF205

cc: John Lynch, SLA

Enclosures

INTERNAL WORK SHEETS

Project/Subject R.I.D. Completion - Phase I Job No. 2156J002
Estimate Of Contract Time Req'd Date 2/28/86 Sheet 1 of 1
By Dal N. Wakefield

1.0 Mobilization of Wick Drain Equip't & Subcontractor Estimated (and submittals Appvl) ~~Duration~~ = * 15 Working Days

2.0 Construct Work Platform (see Sequence 1.0) = 2 Days

3.0 Stake-out drains = 2 Days

4.0 Install Wick Drains = 10 Days

5.0 Install Horizontal Drains = 1 Days

6.0 Install Settlement Plates = 1 Days

7.0 Place Miraffi Fabric = 5 Days

8.0 Construct Canal Embankment & Surcharge from R.I.D. 19+50 to 24+75, See Sequence 6.1 = 5 Days

Workday Subtotal = 41 Days

9.0 Construct balance of R.I.D. Embankment per Sequence 6.2 thru 6.4 = 4 Days

10.0 Construct levees/roads = 4 Days

11.0 Canal Excavation = 2 Days

12.0 ~~Fine Grade~~ Waste Excavation = 1 Day

13.0 Fine Grade, Cleanup & Demobilize = 5 Days

Total Working Days = 57

57 Work Days = 11.4 Weeks = 11(7) + 2 ~~..~~
= 79 Calendar Days

41 Work days = 8 Weeks + 1 Day = 57 Calendar Days
To Complete Surcharge

2 Months
from time of notice to proceed, minimum, to time of surcharge completion.

165

WESTERN TECHNOLOGIES INC.

R.I.D. COMPLETION - PHASE I
Scope of Construction Work
and Sequence

Ref. No. 2156J002

1.0 Construction Working Platform in wick drain area. This work includes removing toe of existing gravel pile back to north R/W Line, using excavated material to construct part of the platform. Contractor can then either haul material from canal trapezoid between R.I.D. 0+00 and R.I.D. 10+00± to between R.I.D. 20+50 and R.I.D. 24+00, or haul from south of the river Sta. 1+25. Grade surface to drain.

1.1 Minimize depth of working platform by making contractor test the wick area by loading with equipment intended for use. This will ensure minimizing length of drains.

1.2 Allow the alternative of using existing surface as working platform, but require moving gravel pile toe back to R/W Line.

2.0 Stake out (by WT) and Contractor Install Wick Drains, Install Horiz. Drains.

2.1 Install wick drains

~~2.1 During this period, contractor move stored rebar and sluice gates.~~

2.2 Install horizontal drains.

3.0 WT Install Settlement Plates

4.0 Place Mirafi Fabric

5.0 Channel Excavation

5.1 Excavate river bottom volume of 66,000± C.Y. for use in R.I.D. East Bank and West Bank.

5.1.1. R.I.D. East Bank needs 1,150C.Y. of the 66,000 C.Y. (=1,000 compacted C.Y.)

5.1.2 R.I.D. West Bank needs 64,850 C.Y. (=56,400 compacted C.Y.)

5.3 Excavate river bottom volume of 16,000± C.Y. for completing river levees embankments with earth ramps and access roads to close the levee gaps (East & West Banks) at and adjacent to Thomas Road.

5.4 After all embankment needs have been hauled, excavate to channel Flowline and haul as waste to the area between the east side of the East levee, the east construction easement, and River Stations ____________ to ____________________.

6.0 During 5.1. and 5.2 Construct East and West Bank R.I.D. embankments and surcharge. Use entire excavated volumes shown in 5.1. Place and compact in the following sequence:

6.1 Construct complete embankment and surcharge per plans details between R.I.D. Stations 19+00 and 24+75. (During this work the settlement plates rods and casings must be extended as fill height increases. Begin reading settlement data daily, beginning the 1st day of fill construction.)

6.2 Haul 1,150 C.Y. (excavated volume) to stockpile in the area bounded by R.I.D. Station 57+50 on the east, R.I.D. Station 59+20 on the west, the future R.I.D. canal centerline on the south, and the north embankment toe line for the future R.I.D. Canal.

6.3 Excavate the existing soils in the canal trapezoid between R.I.D. Stations 1+75 and 11+00~~*~~, and use the excavated soils in canal embankment construction under 6.4. x

6.4 Construct complete embankment on the north side of the existing flume to the lines shown on the plans between R.I.D. Stations 1+75 and 16+~~00~~ 50*.

*NOTE: This results in a gap between R.I.D. Stations 16+50 and 19+50 to be filled later from surcharge material.

7.0 During 5.2, construct levee embankments, levee access ramp, and levee access roads.

INTERNAL WORK SHEETS

Project/Subject: Agua Fria River Improvements — Quantities for completion of work S. of 1+25

Job. No. 2156J002 (~~2155J020~~)

Date 2-25-86 Sheet ___ of ___

By C. Jacyreni

WORK S. OF 1+25

203	CHANNEL EXCAVATION Available	91,000 C.Y
212	LEVEE EMBANKMENT	13,640 C.Y.
221.1	SOIL CEMENT	11,149 C.Y.
221.2	CEMENT (ESTIMATED)	2170 TON
505.1	STRUCTURAL CONCRETE	24.2 CY
505.2	REINFORCING STEEL	1522 #
515.2	DEBRIS RACK - PIPE & HDWL	4
515.2	FLAP GATE 36"	4
524	SHOTCRETE CANAL LINING	508 S.Y.
601	RELOCATE/REPLACE WATER LINE	1
618.1	36 in. RCP	312.0

Analysis of Waste from channel excavation south of 1+25:

Available = 91,000 C.Y.

RID = <1.15 x 58,000> = <66,700> C.Y.

Levees & ramps = <1.15 x 14,000> = <16,100> C.Y.

Waste = 8,200 C.Y.

WESTERN TECHNOLOGIES, INC.

165

INTERNAL WORK SHEETS

Project/Subject: AGUA FRIA RIVER IMPROVEMENTS

QUANTITIES REQUIRED FOR COMPLETION OF RID CANAL

Job. No. 2156J002 (~~2155J020~~)

Date: 2-25-86 Sheet ____ of ____

By: C. Jacquemin

RID CANAL

215.1	CANAL EXCAVATION	5,500 CY
215.2	CANAL EMBANKMENT	64,000 CY
215.3	GEOTEXTILE FABRIC (ON HAND 8,813 SY)	13,991 SY.
350.1	REMOVAL OF EXISTING IMPROVEMENTS	
350.2	REMOVAL OF EXISTING FLUME	
505.1	STRUCTURAL CONCRETE	357.35 C.Y.
505.2	REINFORCING STEEL (39,956 # ON HAND)	48,772 #
515.2	DEBRIS RACK - WASTEWAY	1
515.3	SLUICE GATES (3 ON HAND)	3
515.4	CATWALK	1
520.	SAFETY HANDRAIL	50 L.F.
526	SHOTCRETE CANAL LINING	15,081 S.Y.

INTERNAL WORK SHEETS

Project/Subject: Agua Fria River Improvements — Job. No. 2156J002 (~~2155J020~~)

RID CANAL REQUIREMENTS-EARTHWORK — Date 2-25-86 Sheet ___ of ___

for completion — By C. JACQUEMIN

CANAL EMBANKMENT:

1. REQUIRED TO COMPLETE

• EAST BANK: 0+00 to 24+75	60,182 CY
• FOR WASTEWAY STRUCTURE	1,454
• WEST BANK: 57+00 +6	2,965
	64,601

2. LESS

• MATERIAL IN TRAPAZOID STA 0+00 TO 10+00	<4,699>
• TRIMMING ON WEST SECTION 36+64 to 57+00	<2,027>
	57,875 CY

CANAL EXCAVATION

1. REQUIRED TO COMPLETE (original)	294 CY
2. Excavation of trapezoid between 0+00 and 10+00	4,699 CY
3. Excavation for E.B. Drain ditch @ E.B. sta. 3+30	≈ 500 CY
	5493 CY — Say 5500 CY

MATERIAL REQUIRED from South of 1+25 = 57,581 CY ?

165

INTERNAL WORK SHEETS

Project/Subject Agua Fria River Improvement (R.I.D. Quantities to Complete) Quantities

Job. No. 2156J002 ~~2155J120~~

Date 2-25-88 Sheet ___ of ___

By C. Jacquemin

GEOTEXTILE FABRIC (2100HP)

~~AGUA FRIA CHANNEL 17,714 S.Y.~~

RID 11+75 to 18+15 8,578

18+15 to 20+50 3,238

(Less Realignment) ⟨1,520⟩

20+50 to 24+00 3,695

NEED TO COMPLETE = 13,991 SY

~~TOTAL RID = 8578 + 3238 = , S.Y.~~

~~PLACED 1,323~~

~~S.Y.~~

SHIPPED & STORED 10,135.7
- 1323
8812.7 S.Y.

$38000 for 8812.7 S.Y.

$4.31 per YD

13,991 - 8813 = 5,178 S.Y.

WESTERN TECHNOLOGIES, INC.

INTERNAL WORK SHEETS

Project/Subject: Agua Fria River Improvements — Job. No. 2155J020
East Rio & S of I-25 Quantities — Date 2-25-86 Sheet ___ of ___
By C. [illegible]

505.1 Concrete

S. of I-25	24.2	
Wasteway & Spillway	350.05	357.35
Outlet Headwall 9+50	7.3	

505.2 Reinforcing Steel

South of I-25	1522#	
Wasteway & Spillway	48609	48,772
Outlet Hdwl 9+50	163	

221.1 Soil Cement

S. of I-25 — 11,149 C.Y.

221.2 Cement

$$\left(\frac{11,149}{.98}\right)(374)(1.02)\ /2000 = 2170 \text{ ton}$$

524 Shotcrete

Rio 0+00 to 24+75	12,521	15,081
57+00 to 60+95	2055	
Drainage Channel	505	
S. of I-25	508	

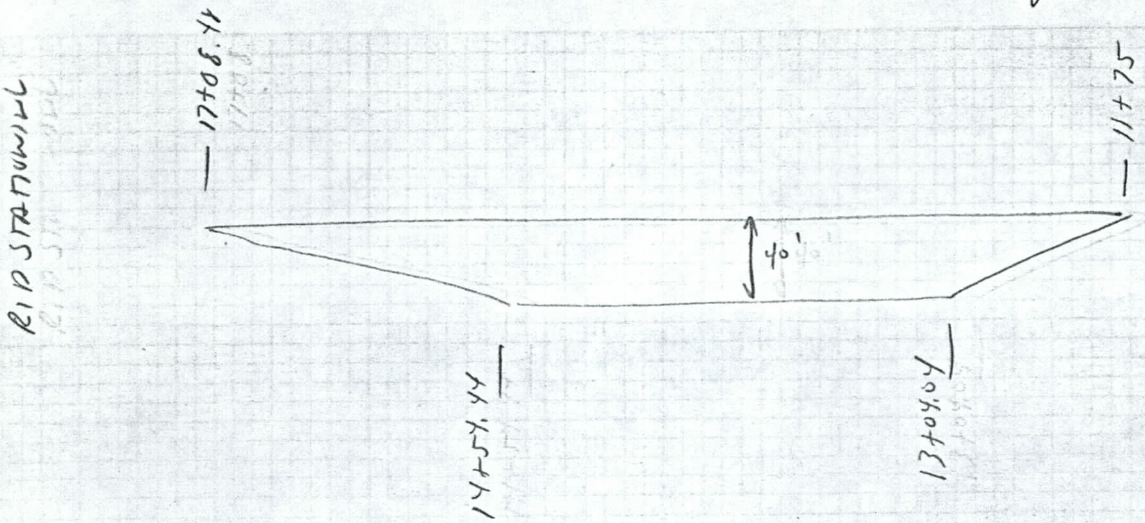
WESTERN TECHNOLOGIES, INC.

INTERNAL WORK SHEETS

Project/Subject: Agua Fria River Improvements — Job. No. 21563002 (~~2155302~~)

Geotextile Fabric – Reduction due to — Date: 2-27-84 — Sheet ___ of ___

Realignment of Canal — By: C. Jacquemin



$$\text{Area} = (1454.44 - 1304.04)(40) + (.5)(40)(1708.48 - 1454.44)$$

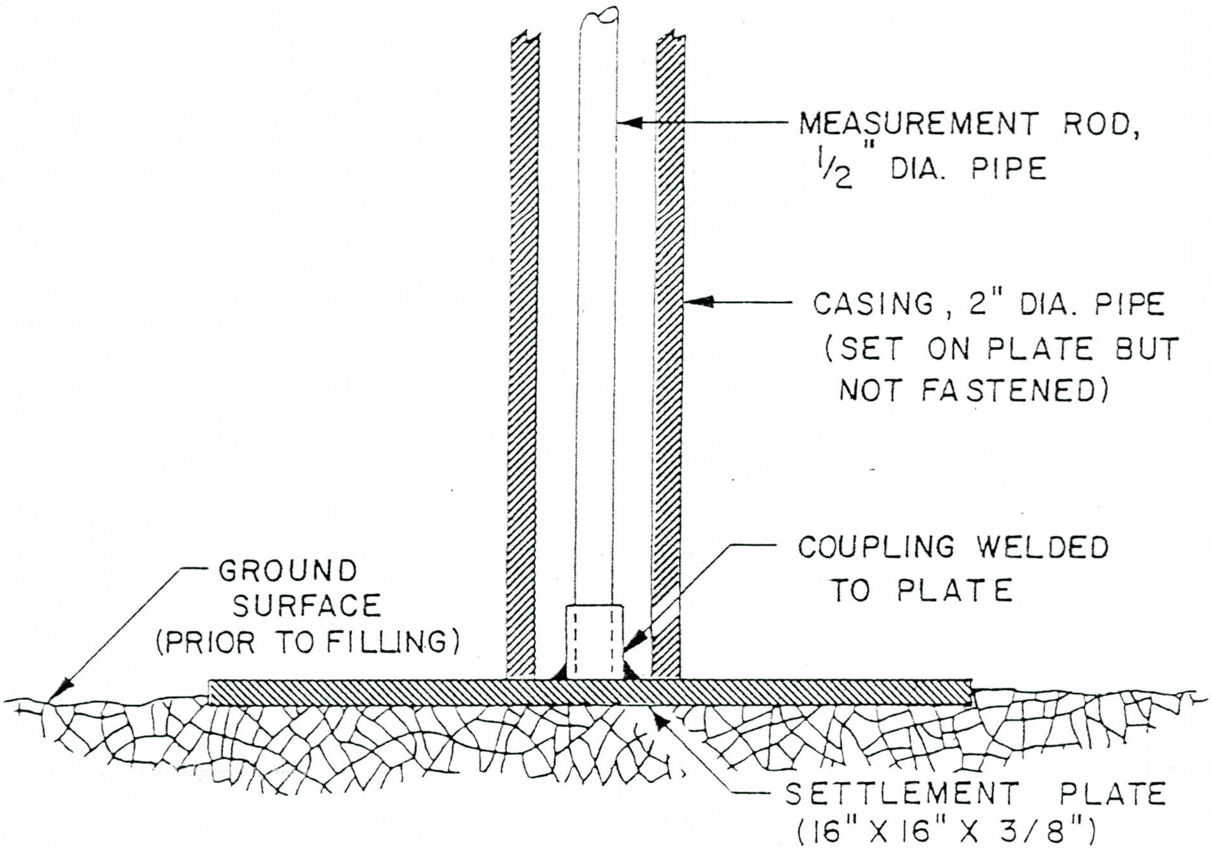
$$+ .5(40)(1304.04 - 1175)$$

$$= 13677.6 \text{ sq ft} = 1519.7 \Rightarrow 1520 \text{ S.Y.}$$

WESTERN TECHNOLOGIES, INC.

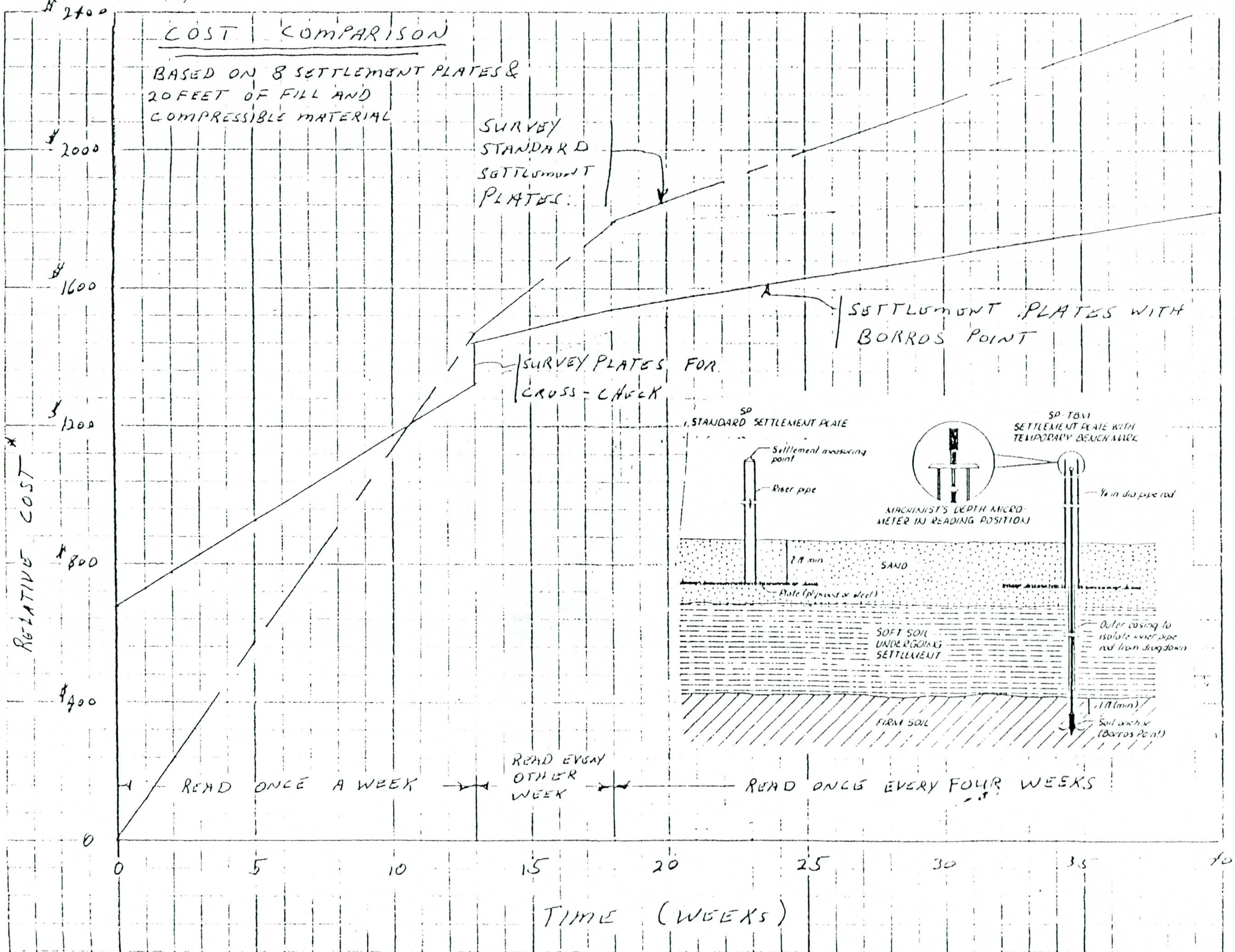
REVISIONS BY ____ DATE ____

BY ____ DATE ____ CHECKED BY ____ FILE ____



DETAIL OF SUGGESTED SETTLEMENT PLATE

(NOT TO SCALE)



* COST FOR INITIAL SURVEY AND SETTLEMENT PLATE AND RISER PIPE THE SAME FOR BOTH METHODS

Subject
Made by
Checked by
Approved by
Job No.
Date
Sheet No.

SIMONS, LI & ASSOCIATES, INC.

3555 STANFORD ROAD
POST OFFICE BOX 1816
FORT COLLINS, COLORADO 80522

TELEPHONE (303) 223-4100
TLX: 469370 SLA FTCN CI
CABLE CODE: SIMONSLI

Transmittal Letter

To Flood Control District Maricopa County
3335 West Durango
Phoenix Az. 85009

Date 1/31/86

Project RID Canal Modifications

Attention Dick Perreault
Nick Karan

Project Number AZ-MC-08 Phase 4

Enclosed please find:

Copies	Of
1	Original of DEE's stamped Geotechnical Report

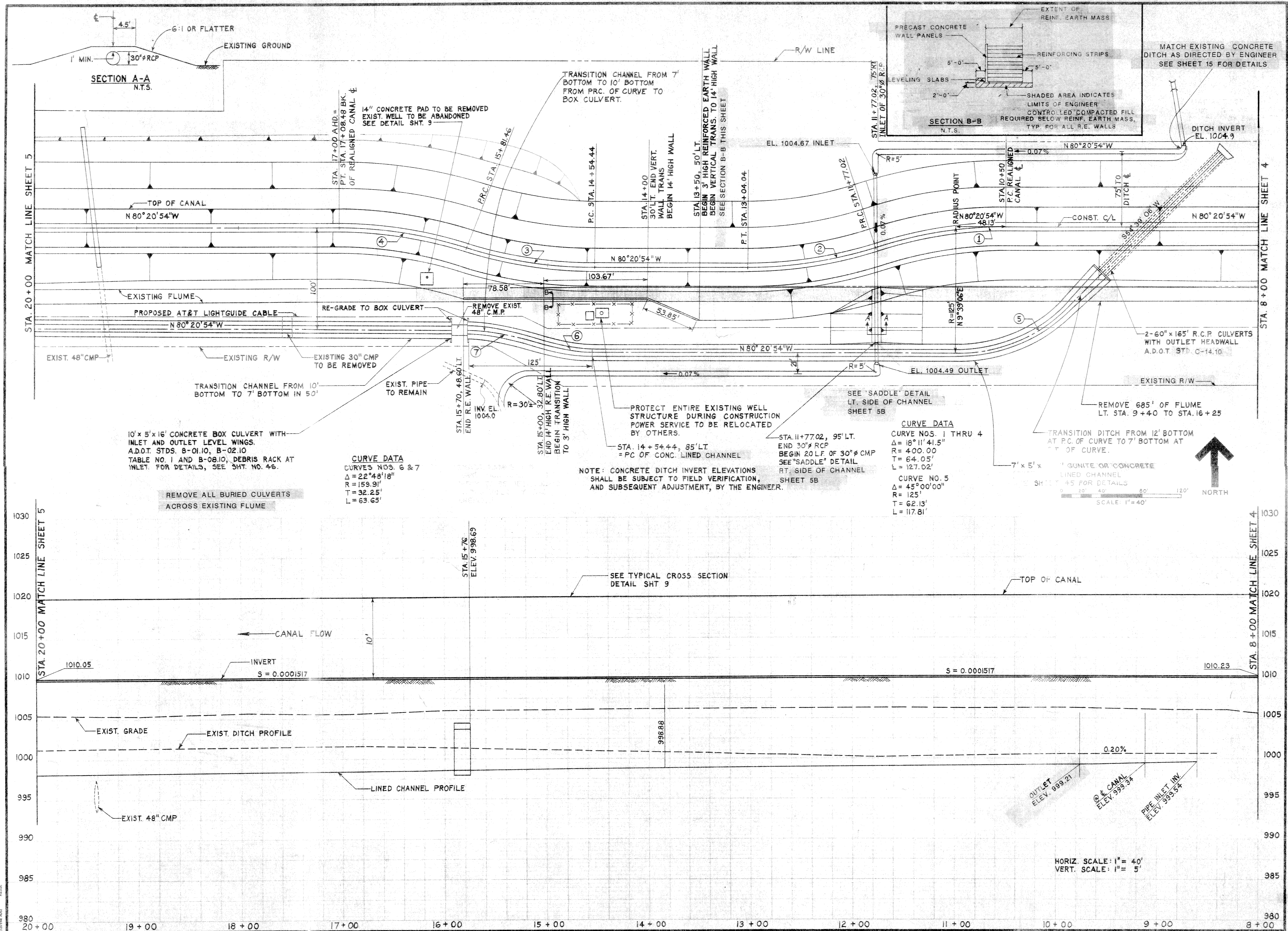
- [x] Forwarded
- [ ] Returned
- [ ] Prints
- [x] Originals
- [ ] Reports
- [ ] For Approval
- [ ] As Requested
- [x] For Your Use
- [ ] For Your Files
- [x] Mail
- [ ] Express Courier

Remarks Dick,
Please call if you have any questions

FLOOD CONTROL DISTRICT
RECEIVED
FEB 03 '86

CH ENG | HYDRO
ASST | LMgt
ADMIN | SUSP
C & O | FILE
ENGR | DESTROY
FINANCE | RGP
REMARKS

From Noel Bormann



SIMONS, LI & ASSOCIATES, INC.

Cheyenne, WY. • Colorado Springs, CO. • Denver, CO. • Fort Collins, CO. • Newport Beach, CA. • Pittsburgh, PA. • Salt Lake City, UT. • Tucson, AZ. • Washington, D.C.

FLOOD CONTROL DISTRICT OF MARICOPA CO.

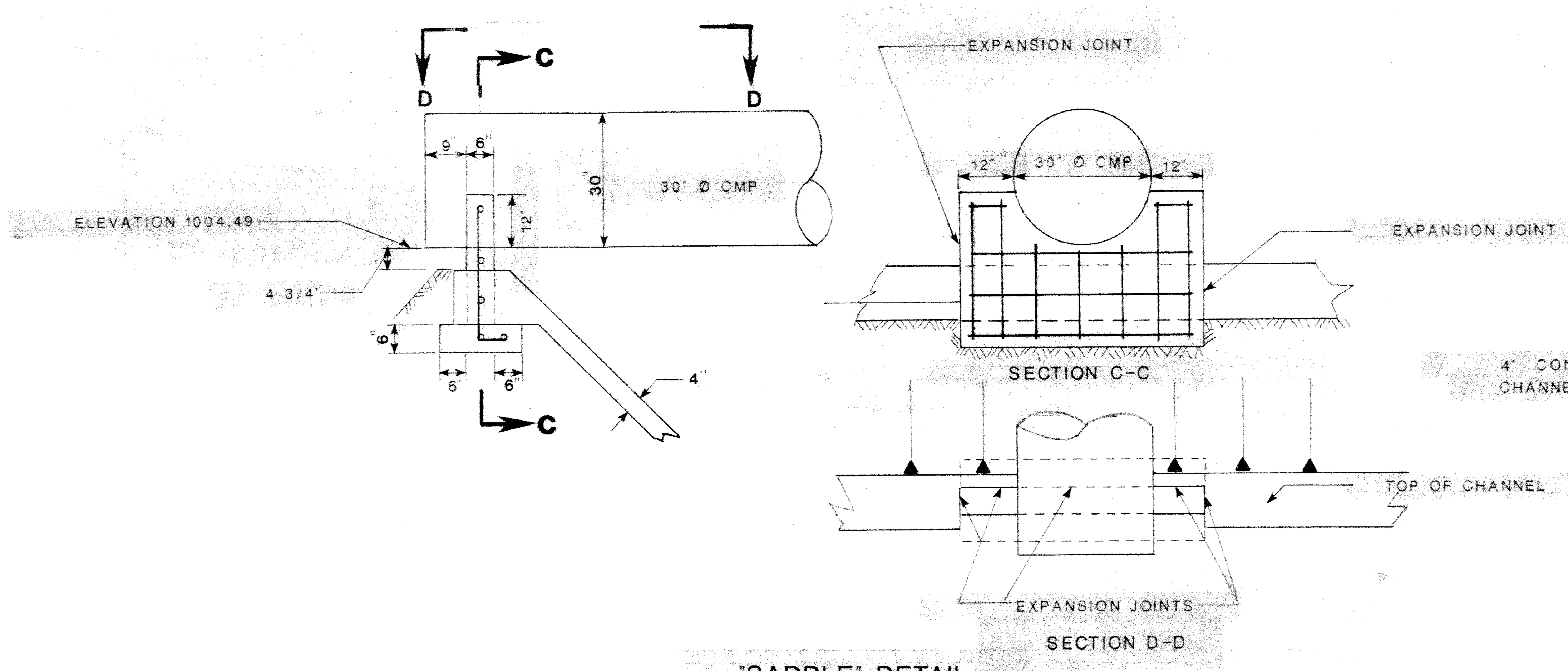
3335 West Durango Street · Phoenix Arizona 85009 · Tel. 602-262-1501

AGUA FRIA RIVER IMPROVEMENTS

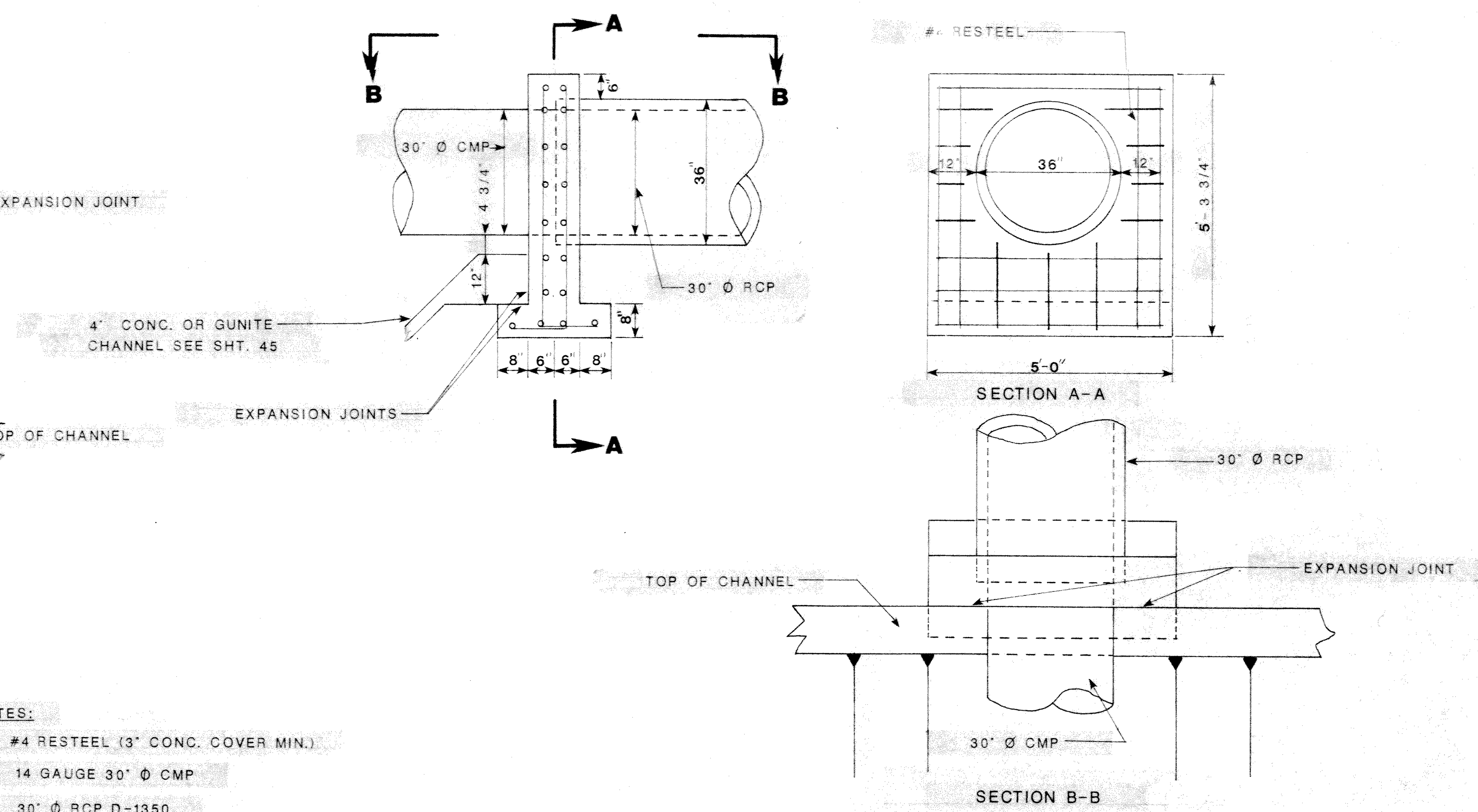
PHASE I - R.I.D. CANAL RECONSTRUCTION & SIPHON
CONTRACT NO. FCD 85-10
CHANGE ORDER NO.

Project No.	
Date:	SEPT. 13, 1985
Design:	J.B.L.
Drawn:	T.A.R.
Check:	
Revisions:	9/25/85
	R. ERDMAN

SHT. 5A OF 62



"SADDLE" DETAIL
LT. SIDE OF CHANNEL



"SADDLE" DETAIL
RT. SIDE OF CHANNEL

NOTES:

#4 RESTEEL (3" CONC. COVER MIN.)

14 GAUGE 30" Ø CMP

30" Ø RCP D-1350

CLASS 'A' CONCRETE

EXPANSION JOINTS SEE SHEET 15.
FIELD ADJUST DIMENSIONS
TO ALLOW FOR JOINT MATERIAL.

WESTERN TECHNOLOGIES INC.
3737 East Broadway Road • Phoenix, Arizona 85040 • (602) 437-3737

FLOOD CONTROL DISTRICT OF MARICOPA CO.
3335 West Durango Street • Phoenix, Arizona 85009 • (602) 262-1501

AGUA FRIA RIVER IMPROVEMENTS

PHASE I - R.I.D. CANAL RECONSTRUCTION & SIPHON

CONTRACT NO. FCD 85-10 CHANGE ORDER NO.

DESIGNED:
R. ERDMAN
9/25/85

SHT. 59 OF 62

sla

simons, li & associates, inc.

fort collins • cheyenne • denver • tucson • newport beach • pittsburgh
p.o. box 2712, tucson, arizona 85702 phone 602-884-9594