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Run-On Control Systems

SAFETY-KLEEN CORP.

RUN-ON CONTROL SYSTEM
LANDFILL CELLS 10 THROUGH 15
LONE MOUNTAIN FACILITY

REGISTERED PROFESSIONAL ENGINEER
9/20/99
MARVIN E. ALLEN
14802
OKLAHOMA

Marvin E. Allen

Prepared by:

HA&L ENGINEERING, INC.
Consulting Engineers
6771 South 900 East
Midvale, Utah 84047
(801) 566-5599

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HA&L ENGINEERING

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CHAPTER I

INTRODUCTION

HA&L Engineering, Inc. (HA&L) prepared a report in June 1990 addressing the Run-on Control System associated with Landfill Cells 10 through 15 at the Lone Mountain Facility. This report was entitled "Comparison of Developed Vs. Predeveloped Conditions and Run-on Conveyance Channel Design Lone Mountain Facility." Since 1990, some modifications have been made to the run-on control system. Safety-Kleen Corp. requested that HA&L update the Run-on Control System portion of the previous study to account for these modifications.

The purpose and scope of this report are to address the hydrology, run-on control channels, and run-on detention ponds associated with the Run-on Control System for Landfill Cells 10 through 15 at the Lone Mountain Facility, taking into consideration the current layout of the system. Information presented previously regarding the run-on control and conveyance system is consolidated herein. The information has been modified to reflect changes at the facility due to redirection of drainage flows resulting from modifications to the drainage control facilities, and recent updated mapping of the facility. The design information presented herein supersedes all previous information submitted with regard to the design of the run-on control system associated with Landfill Cells 10 through 15.

Summarized within this report are the following sections: 1) Methodology used in evaluation of the hydrology and the pond and channel designs, 2) Hydrology or the prediction of peak flow rates to be used as the basis for the design of the run-on control system, and 3) A discussion of the design of the run-on control system.

CHAPTER II

METHODOLOGY

This section presents the assumptions and methodology used to perform hydrologic and hydraulic calculations for the run-on control system at the Lone Mountain Facility. The methodology addresses hydrologic calculations used in the determination of peak runoff flow rates from a designated precipitation event, hydraulic calculations used in designing channels and culverts, and riprap design methods.

Storm water runoff volumes were evaluated using the Soil Conservation Service Curve Number methodology. Runoff calculations to determine peak flow rates at designated locations were performed using the Army Corps of Engineer's Flood Hydrograph Package HEC-1 computer model. Run-on control channel design was accomplished using Manning's Equation for open channel flow.

Storm Water Runoff Volume

According to the U.S. Soil Conservation Service (1972), the algebraic and hydrologic relations between storm rainfall, soil moisture storage, and runoff can be expressed by the equations:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$

and

$$S = \frac{1000}{CN} - 10$$

Where:

	Q =	direct runoff volume (inches)
	S =	watershed storage factor
	P =	accumulated precipitation (inches)
	CN =	runoff curve number (dimensionless)

The curve number (CN) designates the runoff potential for a watershed and depends on: (1) Soil type, (2) Hydrologic Soil Group (HSG), (3) Vegetation type, condition, and hydrologic properties, and (4) Professional judgement. The CN for each subwatershed area was determined using an area-weighted average.

HEC-1 Hydrologic Computer Model

Hydrologic calculations were performed utilizing the HEC-1 Computer Model developed by the Army Corps of Engineers. The HEC-1 model is a hydrologic model designed to simulate surface runoff response from a river basin (or watershed system) to precipitation by representing the basin as a system of hydrologic and hydraulic components. A component may represent a surface runoff entity or basin, a stream channel, or a reservoir. HEC-1 calculates runoff volume, stream flow hydrographs, and peak flows at desired locations within the drainage basin via a numerical modeling technique based on the Soil Conservation Service curve number unit hydrograph modeling option. Hydrographs are developed on a subwatershed basis with the input of area, watershed lag time, SCS curve number, precipitation distribution, etc. Routing of hydrographs can be accomplished using various options. The Kinematic wave option was used to route hydrographs in channels, and the storage routing technique was used for routing hydrographs through the run-on control detention ponds.

Input variables to the HEC-1 model include:

- Precipitation Distribution, depth and duration
- Storm Duration
- Return Period/Precipitation
- Drainage Basin Area
- SCS Curve Number
- Watershed Lag Time.
- For Kinematic Channel Routing - channel length, channel slope, Manning's n, channel cross-sectional type, and channel shape characteristics.
- For Pond Routing - storage-elevation relationships of the sediment ponds, stage-discharge relationships for the spillways, and storage volume at the beginning of the storm.

Input values used in the model are shown on the HEC-1 model printouts and are explained in the following text.

Precipitation Distribution, Storm Duration, and Return Period/Precipitation

A precipitation distribution is input to model the runoff hydrograph. The USDA-SCS Type II 24-hour storm distribution was used. The Type II storm distribution is a 24-hour distribution designed for use in all areas of the western continental United States except for the coastal side of the Sierra Nevada and Cascade Mountains (U.S. Soil Conservation Service, 1986).

A storm duration of 24 hours was used to model the watersheds for the run-on control system.

A precipitation amount is required for the appropriate return period. The 25-year 24-hour precipitation depth of 6.0 inches was used in evaluation of the run-on control system. This precipitation depth was determined from U. S. Weather Bureau Technical Paper No. 40 (1961).

Drainage Basin Area

The watershed areas for the drainages evaluated were determined by direct measurement from a 1" = 300' scale map.

SCS Curve Number

The U.S. Soil Conservation Services Curve Number designates the runoff potential of an area. Curve numbers were approximated based on hydrologic soil type, as well as type and amount of ground cover. A representative curve number of 89 was selected (U.S. Soil Conservation Services,

1972) for undisturbed areas based on a 45% average herbaceous ground cover density and hydrologic soil group D (U.S. Soil Conservation Service, 1968). A curve number of 92 was selected for disturbed areas with high runoff potential, a curve number of 76 was selected as representative of rock riprapped surfaces of closed landfill cells, and a curve number of 98 was selected for direct precipitation on detention pond areas assumed to have ponded water at the beginning of the storm (i.e., Run-on Pond 3).

Watershed Lag Time and Time of Concentration

The watershed lag time (L) and time of concentration (TC) may be estimated by several formulas. For the input value into the HEC-1 model, TC was determined from the following equations (U.S. Soil Conservation Service, TR-55, 1986):

$$TC = TI + TT$$

Where:	TC	=	time of concentration
	TI	=	overland or sheet flow travel time
	TT	=	travel time in a channel (channel length/velocity)

$$TI = \frac{0.007*(n*L)^{0.8}}{P_2^{0.5}*S^{0.4}}$$

Where	TI	=	as defined above, in hours
	n	=	Manning's roughness coefficient, use 0.13 for range land
	L	=	overland flow length in feet
	P_2	=	2-year, 24-hour rainfall (3.3 inches)
	S	=	slope (ft/ft)

For the gravel or rock surfaces of the closure caps for the landfill cells, TI was computed from the following equation (Denver Regional Council of Governments, 1969):

$$TI = \frac{1.8(1.1-C5)L^{0.5}}{S^{0.33}}$$

Where	TI	=	as defined above, in minutes
	C5	=	coefficient (0.25 for gravel or rock surfaces)
	L	=	overland flow length in feet
	S	=	slope (%)

Watershed lag (L) is then determined from (SCS, 1972):

$$L = 0.6 * TC$$

Where:	L	=	watershed lag
	TC	=	as defined above

Kinematic Channel Routing Parameters

Kinematic channel routing parameters include channel length, channel slope, Manning's roughness coefficient (n), channel cross-sectional type, and channel shape characteristics. Channel lengths and slopes were determined from 1" = 300' and 1" = 100' scale maps. The Manning's roughness coefficient (n) of 0.035 was assumed to be representative for an earthen lined channel with some stones (Haan, et. al., 1994). The Manning's roughness coefficient (n) for riprap lined channels was determined from the following equation (Haan, et. al., 1994):

$$n = 0.0395(D_{50})^{1/6}$$

Where:	n	=	Manning's roughness coefficient
	D_{50}	=	the riprap diameter in feet such that 50% of the stones have a diameter smaller than D_{50}

Channel cross-sectional type and shape characteristics such as side slopes were as per the channel design.

Spillway Stage Discharge Relationships

The stage-discharge relationships for outlet works for run-on detention ponds were evaluated either as culverts (for Run-on Detention Ponds 1 and 2) taking into consideration inlet and outlet conditions as defined by the U.S. Department of Transportation (1965), or as broad crested weirs (Run-on Detention Pond 3).

Weir flow is determined by the equation:

$$Q = C * L * H^{1.5}$$

Where:	Q	=	flow rate in cfs;
	C	=	coefficient determined by entrance conditions;
	L	=	length of the weir crest, in feet,
	H	=	head of water above the weir crest, in feet.

The entrance coefficient C was determined from Brater and King (1976) to be 2.63 for a broad crested weir with a minimum crest width of 15 feet.

Detention Pond Storage Elevation Relationships

Run-on detention pond storage capacity versus elevation relationships were determined by measuring the area at designated contour intervals and then using the average end area method for computing volume between contour intervals.

Channel Hydraulics

The run-on control channels were evaluated using Manning's Equation for open channel flow. Side slopes for the channels were generally set at 2H:1V or 3H:1V. The slope of the bed was fixed by design or determined from available mapping. Manning's Equation is as follows:

$$Q=\frac{1.486}{n}AR^{2/3}S^{1/2}$$

Where:
- Q = Peak discharge from storm event (cfs)
- n = Manning's roughness coefficient
- A = cross sectional area of flow (ft^2)
- R = hydraulic radius (ft)
- S = channel slope (ft/ft)

In earthen lined channels, a Manning's Roughness Coefficient of 0.035 was used which represents an earthen lined channel with some stones (Haan et. al. 1994). In channels requiring a rock riprap lining, Manning's Roughness Coefficient can be approximated from the equation referenced previously.

Rock Riprap

Rock riprap for the channel beds was evaluated according to the safety factor methodology developed by Colorado State University and as presented in Haan, et. al. (1994) as follows:

$$SF_{bed} = \frac{\cos\theta \tan\phi}{\sin\theta + \eta \tan\phi}$$

$$\eta = \frac{dS}{F(SG-1)D_{50}}$$

Where:
- SF_{bed} = factor of safety against bed failure
- θ = angle of channel bed (degrees)
- Φ = angle of repose for riprap (degrees)
- η = stability parameter
- d = depth of flow (ft)

S	=	channel slope (ft/ft)
F	=	dimensionless critical shear stress
SG	=	specific gravity of rock
D_{50}	=	mean riprap size (ft)

An analysis of side slope stability was completed by applying the following equations:

$$SF_{sides} = \frac{\cos\alpha \ \tan\phi}{\eta' \tan\phi + \sin\alpha \ \cos\beta}$$

$$\beta = \arctan\left(\frac{\cos\theta}{\frac{2\sin\alpha}{\eta\tan\phi} + \sin\theta}\right)$$

$$\eta' = C\,\eta\left(\frac{1 + \sin(\theta + \beta)}{2}\right)$$

Where:	SF_{sides}	=	factor of safety against bank (side) failure
	α	=	arctan(1/side slope) (degrees)
	η'	=	stability parameter
	C	=	0.76 for 2H:1V side slopes; 0.86 for 3H:1V side slopes.

(all other variables are as previously defined)

Riprap linings were designed to have a minimum factor of safety of 1.3. It was assumed in the design that the specific gravity of the rock was 2.65. "F" values (critical shear stress) were determined based on data published by Wang and Shen (1983).

CHAPTER III

HYDROLOGY

The watershed areas that are tributary to the Safety-Kleen Lone Mountain Facility, have been modeled to predict peak storm water drainage flow rates from the 25-year 24-hour precipitation event to be used as a basis for evaluation of the existing run-on control system. The run-on control system has been designed to divert drainage from the area tributary to the site safely around the existing and proposed RCRA hazardous waste landfill cells (Cells 10 through 15).

The HEC-1 watershed model and methodology referenced in Chapter II were used to model the fully developed condition at the Safety-Kleen Lone Mountain Facility (see computations in Exhibit A).

Watershed Characteristics

The hydrologic subbasins associated with the Lone Mountain Facility are illustrated on Drawing 1. A summary of the hydrologic characteristics for each subbasin used in the analysis is presented in Table 1. Subbasin areas were named based on the first major run-on control channel each subbasin is tributary to (i.e., subbasin 3H is subbasin H tributary to Run-on Control Channel No. 3). The runoff analysis was performed assuming that all landfill cells (Cells 10 through 15) are capped. While a cell is active (open), all runoff from a storm up to a 25-year 24-hour event will be contained within the cell as part of the runoff control plan. Once the cell is closed (capped), runoff from the cap surfaces will be conveyed to the run-on control system, consisting of detention ponds, culverts, and channels.

25-Year 24-Hour Peak Flow Rates

The estimated peak flow rates to each of the run-on control channels or detention basins from storm water drainage from the 25-year 24-hour precipitation event are summarized in Table 2. Also, included in Table 2 is a listing of the tributary subbasins to each of the run-on control features. Run-on control features include run-on control channels designated as Run-on Control Channels No. 1 through 5 and D3H-1; run-on control detention ponds, designated as Run-on Control Detention Ponds No. 1 through 3; and Run-on control culverts, designated as Culverts C2A-1 (outlet to Pond No. 2), C3G-1 (upstream end of channel D3H-1), C3H-1 (located between Channel D3H-1 and Channel No. 3), C4B-1 (drop culvert into Pond No. 3), and C5G-1 (located between the upper and lower sections of Channel No. 5).

Two alternatives (Alternative 1 and Alternative 2) are referenced in Table 2. These two alternatives have reference to alternative configurations for Run-on Detention Pond No. 1, and the impact that these two alternatives have on estimated flows for downstream detention ponds, culverts, and channels. As will be discussed subsequently, without Run-on Detention Pond No. 1, the existing conveyance capacities of Culvert C3G-1, Channel D3H-1, and Culvert C3H-1 are inadequate to convey the peak runoff flow rate from the 25-year 24-hour precipitation event.

TABLE 1

SUMMARY OF HYDROLOGIC CHARACTERISTICS FOR WATERSHEDS AND BASINS TRIBUTARY TO RUN-ON CONTROL SYSTEM (CELLS 10 THRU 15) LONE MOUNTAIN FACILITY

Sub-basin No.	Sub-basin Area Acres	Time of Concentration Hours	Weighted Curve No.
1-A	2.82	0.31	76.0
1-B	3.02	0.17	89.2
1-C	6.34	0.23	92.0
2-A	16.19	0.32	81.5
2-B	7.70	0.30	77.5
2-C	1.86	0.17	83.1
3-A	9.67	0.11	89.8
3-B	10.64	0.35	83.8
3-C	6.15	0.33	92.0
3-D	1.92	0.25	92.0
3-E	6.40	0.13	92.0
3-F	7.35	0.08	92.0
3-G	17.25	0.23	91.6
3-H	23.38	0.29	90.4
3-I	27.81	0.31	84.8
3-J	7.06	0.14	91.3
4-A	156.30	0.35	90.1
4-B	3.06	0.31	89.0
4-C	12.03	0.30	96.5
4-D	16.14	0.33	88.0
4-E	27.62	0.32	81.9
5-A	11.53	0.14	89.0
5-B	6.95	0.22	88.1

TABLE 1 (cont.)

SUMMARY OF HYDROLOGIC CHARACTERISTICS FOR WATERSHEDS AND BASINS TRIBUTARY TO RUN-ON CONTROL SYSTEM (CELLS 10 THRU 15)
LONE MOUNTAIN FACILITY

Sub-basin No.	Sub-basin Area Acres	Time of Concentration Hours	Weighted Curve No.
5-C	4.45	0.18	92.0
5-D	2.99	0.23	86.0
5-E	2.34	0.31	83.7
5-F	7.48	0.23	92.0
5-G	24.10	0.22	82.0
5-H	39.23	0.26	80.8
5-I	55.00	0.52	89.0
5-J	1.52	0.28	76.0

TABLE 2

25-YEAR 24-HOUR PEAK FLOW RATES
RUN-ON CONTROL FACILITIES

RUN-ON CONTROL FEATURE	TRIBUTARY SUBBASINS	25YR 24HR FLOW RATE (cfs)
Channel No. 1	1A thru 1C	47
Detention Pond No. 2 (Inflow)	2A	55
Detention Pond No. 2 (Outflow)	2A	37
Channel No. 2	2A thru 2C	61
Detention Pond No. 1 - Alternative No. 1 (Inflow)	3A thru 3G, and 3J	274
Detention Pond No. 1 - Alternative No. 2 (Inflow)	3A thru 3H, and 3J	368
Detention Pond No. 1 - Alternative No. 1 (Outflow)	3A thru 3G, and 3J	93
Detention Pond No. 1 - Alternative No. 2 (Outflow)	3A thru 3H, and 3J	206
Channel D3H-1- Alternative 1	3A thru 3H, and 3J	165
Channel No. 3 - Alternative 1	3A thru 3J	261
Channel No. 3 - Alternative 2	3A thru 3J	304
Detention Pond No. 3 - Alternative 1 (Inflow)	3A thru 3J and 4A thru 4C	937
Detention Pond No. 3 - Alternative 2 (Inflow)	3A thru 3J and 4A thru 4C	981
Detention Pond No. 3 - Alternative 1 (Outflow)	3A thru 3J and 4A thru 4C	616
Detention Pond No. 3 - Alternative 2 (Outflow)	3A thru 3J and 4A thru 4C	682
Channel No. 4 - Alternative 1	3A thru 3J and 4A thru 4E	691
Channel No. 4 - Alternative 2	3A thru 3J and 4A thru 4E	758
Channel No. 5 (Upper Section)	1A thru 1C, 2A thru 2C, 5A thru 5G & 5J	342
Channel No. 5 (Lower Section)	1A thru 1C, 2A thru 2C, 5A thru 5J	633
Culvert No. C2A-1	2A	55
Culvert No. C3G-1	3A thru 3G, and 3J	93
Culvert No. C3H-1	3A thru 3H, and 3J	165
Culvert No. C4B-1	4B	12
Culvert No. C5G-1	1A thru 1C, 2A thru 2C, 5A thru 5G, 5I & 5J	522

Alternative 1 consists of constructing Detention Pond No. 1 upstream from Culvert C3G-1 as illustrated on Drawings No. 1 and No. 2. This alternative would require significant excavation upstream from Culvert C3G-1 in order to construct Detention Pond No. 1. Culvert C3G-1 would be the outlet to this detention basin under Alternative 1.

Alternative 2 consists of removing Culvert C3G-1 and evaluating the existing topography upstream from Culvert C3H-1 as Detention Pond No. 1. This alternative would require no excavation to construct Detention Pond No. 1, only the removal of Culvert C3G-1. Due to the flat gradient of the channel (Channel D3H-1) upstream from Culvert C3H-1, Detention Pond No. 1 under this alternative would include the existing area of Channel D3H-1 plus the existing expanded area upstream from Culvert C3G-1. Culvert C3H-1 would be the outlet to Detention Pond No. 1 under this alternative.

CHAPTER IV

RUN-ON CONTROL FACILITIES DESIGN

Runoff due to precipitation events on watersheds, which would be tributary to the area on which Cells 10 through 15 are to be located, will be controlled and conveyed around the facility via the run-on control system. The run-on control system surrounding the cells consists of six run-on control channels, which collect storm water drainage from the tributary areas west of the landfill cells or from the caps of the landfill cells upon closure, and which convey this collected flow around the landfill cells to an existing channel located on the west side of the county road (see Drawing 1). Run-on Control Channel No. 1 collects runoff from the drainage area to the south of Landfill Cell 11 (referred to as subbasins 1A through 1C on Drawing 1) and conveys this collected flow along the south side of Cell 11 to discharge into Run-on Control Channel No. 5 on the east side of the cells which bears northward. Run-on Control Channel No. 2 collects runoff from the side slopes and eventually from portions of the caps of Landfill Cells 8, 10, 11, and 13 upon closure (subbasins 2A through 2C) and conveys this collected flow along the south side of Cell 11 to Channel No. 5. Run-on Control Channel No. D3H-1 conveys outflows from Run-on Detention Pond No. 1 to Run-on Control Channel No. 3 in Alternative 1 for Detention Pond No. 1, discussed previously. In Alternative 2 for Detention Pond No. 1, Run-on Control Channel No. D3H-1 becomes part of Run-on Detention Pond No. 1. Run-on Control Channel No. 3 diverts runoff from subbasins 3A through 3J (see Drawing 1) to Detention Pond No. 3. Run-on Control Channel No. 4 is the outlet channel for Run-on Detention Pond No. 3 and collects runoff from subbasins 3A thru 3J and 4A through 4E and conveys this collected flow to the drainage confluence near the east quarter corner of Section 28 which is the location where drainage waters have historically combined to exit the property. Run-on Control Channel No. 5 receives flows from Channel No. 1, Channel No. 2, and subbasins 5A through 5J and conveys these flows north to the confluence near the east quarter corner of Section 28.

Run-on Control Channel No. 1

Run-on Control Channel No. 1, located parallel to the containment dike on the south side of Landfill Cell 11, collects and diverts tributary flows from the drainage area to the south of Landfill Cell 11 (referred to as subbasins 1A through 1C on Drawing 1) and conveys this collected flow along the south side of Cell 11 to discharge into the Run-on Control Channel No. 5 on the east side of the cells, which bears northward.

Engineering design calculations and details for Run-on Control Channel No. 1 were submitted in the HA&L 1990 study referenced previously. Plan and profile design details for Run-on Control Channel No. 1 are presented in Exhibit B. Hydraulic design calculations for Channel No. 1 are included in Exhibit A. The Channel No. 1 design calculations, presented in Exhibit A, are based on a design flow rate of 155 cfs. As indicated previously, the 25-year 24-hour flow rates modeled with the Army Corps of Engineers' watershed model (HEC-1) reflect changes at the facility to drainage control facilities (thereby modifying tributary areas), modifications to the design return period, etc. As noted in Exhibit A, due to these modifications, the design flow rate from the 25-year 24-hour precipitation event for Channel No. 1 is 47 cfs. Therefore, since the channel was originally designed for a larger flow rate than currently estimated; the channel, as designed, is adequate to convey the current 25-year 24-hour flow rate.

Originally, the 60-inch diameter culvert at the upstream end of Run-on Control Channel No. 1 drained a subbasin area on the southwest side of Landfill Cell 10 and conveyed the runoff from that area into Channel No. 1. However, the upstream end of this culvert has been intentionally sealed, and the area southwest of Cell 10 has been diverted to the north into Run-on Detention Pond No. 3 via Run-on Detention Pond No. 1, Channel No. D3H-1, and Channel No. 3.

Channel No. 1 was designed on a 0.7% channel grade with a trapezoidal channel cross-section, having a bottom width of 6 feet, a channel side slopes of 3H:1V, and a channel depth to the top of the riprap of 4.5 feet. Geotechnical reports for the facility have classified the soils where this channel is to be constructed as very stiff to hard clay and silt. Unlined channels constructed in colloidal stiff clays have a maximum permissible velocity of about five feet per second (U.S. Department of Transportation, 1979) before unacceptable scour takes place. Based on the original design calculations, velocities in excess of five feet per second would be experienced in this channel on the channel grade of 0.7%. Therefore, a riprap channel lining was placed in this channel from the exit of the 60-inch diameter culvert to the confluence of Channel No. 1 with Channel No. 5. Riprap having a mean rock diameter (D_{50}) of 14 inches was placed at the culvert outlet for a distance of 60 feet downstream to dissipate the energy of flow released from the culvert into the channel. Riprap having a mean rock diameter (D_{50}) of 4 inches was determined to be adequate with a safety factor in excess of 1.5 from the point 60 feet downstream of the culvert to the major channel bend near the confluence with Channel No. 5. Riprap having a mean rock diameter (D_{50}) of 6 inches was placed in the channel through the channel bend in order to accommodate the increased shear stress concentrated on the riprap through the bend. A 1-foot thick filter blanket was placed between the riprap and the natural ground subgrade to prevent erosion of the subgrade due to a pumping action of water within the riprap. The filter blanket is Type II, graded as specified in Table 3. Riprap gradations as per the specified D_{50} are presented in Table 4.

Run-on Control Channel No. 2 and Detention Pond No. 2

Run-on Control Channel No. 2 is actually the channel referred to as the "Runoff Control Channel" in the engineering design report for Landfill Cells 10 and 11. Since runoff from the waste inside the landfill cells will be totally contained inside the cells, there is no need to have a separate runoff control system outside of the cells as was designed for Landfill Cells 10 and 11. Therefore, this channel was converted from a runoff control channel to a run-on control channel and was rerouted from the southeast corner of Landfill Cell 11 toward the northeast to a confluence with Run-on Control Channel No. 5. Design calculations presented herein are for the existing portion and the extended portion of this channel. A 54-inch diameter culvert was installed through the access ramp to Landfill Cells 10 and 11 to provide drainage through the access ramp for Run-on Control Channel No. 2.

The area upstream from the 54-inch diameter culvert serves as a detention pond and is referred to as Run-on Detention Pond No. 2. A headwater depth of 2.4 feet will be required to pass the peak outflow from this detention pond of 37 cfs. The invert elevation of the culvert is 1388.3 feet and the minimum elevation of the top of the dike along the southwest side of the pond is approximately

1398 feet. This detention pond functions as a flood control pond, taking advantage of storage within the pond to reduce the peak discharge of 55 cfs from the inflowing hydrograph to 37 cfs of the outflow hydrograph (based on the HEC-1 routing routine).

TABLE 3

TYPE II GRANULAR FILTER BLANKET

U.S. Standard Sieve Size	Percent Passing by Weight
3 inches	90 - 100
3/4 inch	35 - 90
No. 4	0 - 30
No. 16	0 - 15
No. 200	0 - 3

TABLE 4

RIPRAP GRADATIONS

Riprap Thickness (Inches)	Riprap Designation	% Smaller Than Given Size By Weight	Intermediate Rock* Weight Dimension (Lbs.)	(Inches)	D_{50}** (Inches)
12	Type VL	100	150	11.6	6
		50	30-50	6.8-8.1	
		20	20	5.9	
18	Type L	100	350	15.4	9
		50	70-125	9.0-10.9	
		20	30	6.8	
24	Type M	100	1000	21.9	14
		50	225-400	13.3-16.1	
		20	40	7.5	
30	Type MH	100	1000	21.9	14
		50	225-400	13.3-16.1	
		20	40	7.5	

* Dimension based on volume of cube and SG=2.65

** D_{50} = Nominal particle size

As indicated above, a 2.4-foot headwater depth is required for the culvert to convey the peak outflow from the pond of 37 cfs. The containment dike controls the overall depth of the pond at the inlet to the culvert. The top of the containment dike is approximately 9.7 feet above the 54-inch diameter culvert invert to provide the required freeboard for Run-on Detention Pond No. 2, giving 7.3 feet of freeboard above the 25-year 24-hour design depth in Pond No. 2 upstream from the culvert.

Engineering design calculations and details for Run-on Control Channel No. 2 were submitted in the HA&L 1990 study referenced previously. Hydraulic design calculations for Channel No. 2 are included in Exhibit A. The Channel No. 2 design calculations, presented in Exhibit A, are based on a design flow rate of 152 cfs. As indicated previously, the 25-year 24-hour flow rates modeled with the Army Corps of Engineers' watershed model (HEC-1) reflect changes at the facility to drainage control facilities (thereby modifying tributary areas), modifications to the design return period, etc. As noted in Exhibit A, due to these modifications, the design flow rate from the 25-year 24-hour precipitation event for Channel No. 2 downstream from the 54-inch diameter culvert is 61 cfs. Therefore, since the channel was originally designed for a larger flow rate than currently estimated; the channel, as designed, is adequate to convey the current 25-year 24-hour flow rate.

The channel (from the culvert outlet to the southeast corner of Landfill Cell 11) has been designed with 2H:1V side slopes, a channel depth of 4.5 feet, a 0.7 percent channel slope, and a bottom width of 10 feet. Without a channel lining, erosive velocities in excess of 5 feet per second would result in the channel under the design flood event. Therefore, a riprap channel lining was designed along the entire length of the channel. With the exception of a short channel segment at the outlet of the 54-inch diameter culvert, a mean rock diameter (D_{50}) of 4-inches was determined to provide adequate erosion protection with a safety factor in excess of 1.5 for Channel No. 2 between the 54-inch diameter culvert and the southeast corner of Cell 11. The mean rock diameter of the riprap was increased to 14-inches for a distance of approximately 50 feet downstream from the 54-inch diameter culvert to provide erosion protection at the outlet of the culvert.

Running from the southeast corner of Landfill Cell 11 to the confluence of the channel with Run-on Control Channel No. 5, along the west side of the County Road, Run-on Control Channel No. 2 was designed at a 0.88% slope with a single four-foot drop structure. Plan and profile design details are presented in Exhibit B for Run-on Control Channel No. 2 from the southeast corner of Cell 11 to its confluence with Channel No. 5. A drop structure is necessary since the straight slope of the channel between the southeast corner of Cell 11 and the confluence with the existing channel would produce a Froude Number of approximately 1, which would result in flow in the channel being in the unstable region around critical depth. Design procedures for loose riprap channel lining protection recommend that the channel gradient be less than 0.7 times the critical slope (Froude Number less than about 0.8) (SCS Technical Release No. 59, 1976). The channel was designed with a similar cross-section to that of the upstream segment of the channel, i.e., a trapezoidal cross-section with a bottom width of ten feet. However, the channel side slope was flattened from a 2H:1V to a 3H:1V.

It was determined that on the proposed 0.88% channel grade, velocities in excess of five feet per second would be experienced during the design event which would be erosive. Therefore, a riprap channel lining was designed and placed in Run-on Control Channel No. 2 from the southeast corner of Cell 11 to the intersection with Run-on Control Channel No. 5. Riprap having a mean rock diameter (D_{50}) of 12 inches was placed for the channel bend of the extended channel at the southeast corner of Cell 11, and a mean rock diameter (D_{50}) of nine inches was placed at the channel bend near the confluence of the run-on control channel with the existing channel along the County Road and for a distance of approximately fifty feet downstream from the bends. With the exception of the channel at the four-foot drop structure, riprap having a mean rock diameter (D_{50}) of six inches was determined to be adequate with a safety factor in excess of 1.5 for the straight segment of the channel between the channel bends. Riprap having a mean rock diameter (D_{50}) of 14 inches was determined to provide adequate erosion protection for a twenty-foot distance downstream and upstream from the drop structure. The riprap thickness for the fourteen-inch riprap is two feet upstream from the structure and three feet downstream from the structure. A 1-foot thick filter blanket was placed between the riprap and the natural ground subgrade to prevent erosion of the subgrade to the rock due to a pumping action of water within the riprap. The filter blanket is Type II, graded as specified in Table 3. Riprap gradations as per the specified D_{50} are presented in Table 4. Where a D_{50} of 12 inches was found to be adequate, the two-foot thickness of rock, which has a D_{50} of 14 inches, was used.

Run-on Control Channel D3H-1 and Detention Pond No. 1

Run-on Control Channel D3H-1 and proposed Detention Pond No. 1 are new features to the run-on control system since the preparation of the HA&L 1990 study. Subbasins 3A through 3G and 3J (see Drawing 1) were previously tributary to Run-on Control Channel No. 1 and Run-on Control Channel No. 5. However, storm water drainage from these basins has been rerouted through existing Channel D3H-1 into existing Run-on Control Channel No. 3 and Run-on Detention Pond No. 3. Two existing culverts are located within this system, Culvert C3G-1 (a 7-foot square box culvert) located at the upstream end of Channel D3H-1, and Culvert C3H-1 (two parallel 42-inch diameter CMP culverts) located between Channel D3H-1 and Channel No. 3. Because of the extremely flat channel grade of Channel D3H-1 (0.04%) between the two culverts, Channel D3H-1 must be evaluated in conjunction with Culvert C3G-1 as a single system with the headwater depth of Culvert C3H-1 influencing the tailwater depth of Culvert C3G-1. Without detention storage above Culvert C3H-1, the existing conveyance capacities of Culvert C3G-1, Channel C3H-1, and Culvert C3H-1 are inadequate to convey the peak runoff flow rate from the 25-year 24-hour precipitation event. Thus, Detention Pond No. 1 is required (at some location upstream from Culvert C3H-1) to reduce the peak flowrate through these facilities. Without Detention Pond No. 1, the two 42-inch diameter culverts (C3H-1) would definitely be inadequate. However, considering the location of the potential overflow upstream of Culvert C3H-1(should its capacity be exceeded), it is unlikely that adverse effects to the landfill cells would occur.

As discussed in Chapter III, two alternatives have been evaluated for Detention Pond No. 1. Alternative 1 consists of constructing Detention Pond No. 1 upstream from Culvert C3G-1 as illustrated on Drawings No. 1 and No. 2. This alternative would require significant excavation upstream from Culvert C3G-1 in order to construct Detention Pond No. 1. Culvert C3G-1 would be the outlet to this detention basin under Alternative 1.

Alternative 2 consists of removing Culvert C3G-1 and evaluating the existing topography upstream from Culvert C3H-1 as Detention Pond No. 1. This alternative would require no excavation to construct Detention Pond No. 1, only the removal of Culvert C3G-1. Due to the flat gradient of the channel (Channel D3H-1) upstream from Culvert C3H-1, Detention Pond No. 1 under this alternative would include the existing area of Channel D3H-1 plus the existing expanded area upstream from Culvert C3G-1. Culvert C3H-1 would be the outlet to Detention Pond No. 1 under this alternative.

Safety-Kleen can decide which of these two alternatives best meets their operational plans for the facility. The hydraulic evaluation of these two alternatives is addressed below.

Pond No. 1 Alternative 1

The proposed configuration of Alternate 1 Detention Pond No. 1 is illustrated on Drawing 2. It is anticipated that construction of this pond can occur during construction of the next phase of Landfill Cell 15. Therefore, the material removed during excavation of the pond can be used as embankment fill material. It should also be noted that the configuration of the pond may be modified as desired by the Lone Mountain Facility as long as the elevation capacity relationship assumed in the calculations is maintained. If the Lone Mountain Facility desires to modify the elevation capacity relationship, then the new relationship should be evaluated prior to construction.

A headwater depth of 6.38 feet will be required to pass the 25-year 24-hour peak outflow from Run-on Detention Pond No. 1 of 93 cfs. The invert elevation of the outlet culvert (C3G-1) is 1388.76 feet and the minimum top elevation of the dike between Detention Pond No. 1 and Detention Pond No. 2 is 1398 feet. This detention pond functions as a flood control pond, taking advantage of storage within the pond to reduce the peak discharge of 274 cfs of the inflowing hydrograph to 93 cfs of the outflow hydrograph (based on the HEC-1 routing routine).

As indicated above, a 6.38-foot headwater depth is required for the culvert to convey the peak outflow from the pond of 93 cfs. The containment dike controls the overall depth of the pond at the inlet to the culvert. The top of the containment dike is approximately 9.2 feet above the 7-foot square box culvert invert to provide the required freeboard for Run-on Detention Pond No. 1, giving 2.9 feet of freeboard above the 25-year 24-hour design depth in Pond No. 1 upstream from the culvert.

Hydraulic design calculations for Channel No. D3H-1 are included in Exhibit A. Channel D3H-1 was constructed with a low flow rectangular channel excavated into the mudstone formation (having dimensions of 5 feet in width and 3 feet in height) and then a higher flow trapezoidal shaped channel with 2H:1V side slopes above the low flow channel. At the 25-year 24-hour design flow rate of 165 cfs, the flow velocity in Channel D3H-1 is only 1.7 fps. Therefore, erosion protection within the channel will not be required. The required headwater depth in Culvert C3H-1 at the downstream end of Channel D3H-1 is 6.33 feet. The channel has sufficient depth to accommodate this head requirement.

Pond No. 1 Alternative 2

The only excavation required for Alternative 2 Detention Pond No. 1 would be the removal of Culvert C3G-1 (the 7-foot square box culvert). Also, a 75-foot section of the dike near the fuel pad would need to be raised a foot or less to maintain a 1398-foot top elevation for the dike around the detention pond.

A headwater depth of 9.74 feet will be required to pass the 25-year 24-hour peak outflow from Detention Pond 1 Alternative 2 of 206 cfs. The invert elevation of the twin 42-inch diameter outlet culverts (C3H-1) is 1386.87 feet and the minimum top elevation of the dike between Detention Pond No. 1 and Detention Pond No. 2 is 1398 feet. The top of the dike is approximately 11.1 feet above the Culvert C3H-1 invert to provide the required freeboard for Run-on Detention Pond No. 1, giving 1.4 feet of freeboard above the 25-year 24-hour design depth in Pond No. 1 upstream from the culvert.

Hydraulic design calculations for the Channel No. D3H-1 portion of Pond No. 1 are included in Exhibit A. Channel D3H-1 was constructed with a low flow rectangular channel excavated into the mudstone formation (having dimensions of 5 feet in width and 3 feet in height) and then a higher flow trapezoidal shaped channel with 2H:1V side slopes above the low flow channel. At the 25-year 24-hour design flow rate of 206 cfs, the flow velocity in the Channel No. D3H-1 portion of Pond No. 1 is only 1.8 fps. Therefore, erosion protection within the channel will not be required. The required headwater depth in Culvert C3H-1 at the downstream end of Pond 1 is 9.74 feet. The Pond has sufficient depth to accommodate this head requirement.

Run-on Control Channel No. 3

Run-on Control Channel No. 3, which is located west of Landfill Cell 13, diverts runoff into Run-on Detention Pond No. 3 from Run-on Control Channel D3H-1, the north half of Landfill Cell 13, the south half of Landfill Cell 14, and the maintenance yard area (see Drawing 1). Engineering design calculations and details for Run-on Control Channel No. 3 were submitted in the HA&L 1990 study referenced previously. Hydraulic design calculations for Channel No. 3 are included in Exhibit A. Channel No. 3 has been designed in two reaches, referred to as the upper reach and lower reach herein. The upper reach receives runoff from Subbasin 3I. The Channel No. 3 upper reach design calculations, presented in Exhibit A, are based on a design flow rate of 140 cfs. As indicated previously, the 25-year 24-hour flow rates modeled with the Army Corps of Engineers' watershed model (HEC-1) reflect changes at the facility to drainage control facilities (thereby modifying tributary areas), modifications to the design return period, etc. As noted in Exhibit A, due to these modifications, the design flow rate from the 25-year 24-hour precipitation event for the upper reach of Channel No. 3 is 101 cfs. Therefore, since the upper reach of this channel was originally designed for a larger flow rate than currently estimated; the upper reach of the channel, as designed, is adequate to convey the current 25-year 24-hour flow rate.

The upper reach of Run-on Control Channel No. 3 was designed on a 1.4% channel grade with a trapezoidal cross-section, having a bottom width of 12 feet, side slopes of 3H:1V, and a channel depth to the top of the riprap lining of 2.9 feet. It was determined that on the proposed 1.4% channel grade, velocities in excess of five feet per second would be experienced during the design event, which would be erosive. Therefore, a riprap channel lining was designed and placed in the upper reach of Run-on Control Channel No. 3. Riprap having a mean rock diameter (D_{50}) of 9 inches was determined to be adequate with a safety factor of 1.4 for the channel, including the channel bend. The riprap thickness is 18 inches. A 1-foot thick filter blanket was placed between the riprap and the natural ground subgrade to prevent erosion of the subgrade to the rock due to a pumping action of water within the riprap. The filter blanket is Type II, graded as specified in Table 3. Riprap gradations as per the specified D_{50} are presented in Table 4.

The tributary area to the lower reach of Run-on Control Channel No. 3 has been modified to include the tributary areas to Channel No. D3H-1 referenced previously. The lower reach of Channel No. 3 was originally designed for a flow rate of 205 cfs. However, with the additional tributary area to the lower reach of Channel No. 3, the current 25-year 24-hour peak flow rate to the lower reach based on Detention Pond No. 1 Alternative 1 is 261 cfs, and for Detention Pond No. 1 Alternative 2 is 304 cfs. Therefore, the calculations for the lower reach of Channel No. 3 have been modified to reflect the larger flow rates (See Exhibit A). Plan and profile details for Channel No. 3 are included in Exhibit B.

The lower reach of Run-on Control Channel No. 3 was designed on a 1.4% channel grade with a trapezoidal cross-section, having a bottom width of 15 feet, side slopes of 3H:1V, and a channel depth to the top of the riprap lining of 2.9 feet. It was determined that on the proposed 1.4% channel grade, velocities in excess of five feet per second would be experienced during the design event which would be erosive. Therefore, a riprap channel lining was designed and placed in the lower reach of Run-on Control Channel No. 3. At the 25-year 24-hour peak flow rate of 304 cfs for Alternative 2, riprap having a mean rock diameter (D_{50}) of 12 inches was determined to be adequate with a safety factor in excess of 1.5 for the channel, including the channel bend. Since the riprap is adequate at the Alternative 2 flow rate of 304 cfs, it would also be adequate at the lower Alternative 1 flow rate of 261 cfs. The riprap thickness is 24 inches. A 1-foot thick filter blanket was placed between the riprap and the natural ground subgrade for the reason indicated above. The filter blanket is Type II, graded as specified in Table 3. Riprap gradations as per the specified D_{50} are presented in Table 4 (the 2-foot thickness rock was used which has a D_{50} of 14 inches).

Run-on Control Channel No. 4 and Detention Pond No. 3

Run-on Control Channel No. 4 conveys the outflow from Run-on Detention Pond No. 3 to the existing channel located on the west side of the county road (see Drawing 1). Subbasin areas tributary to Pond No. 3 include Subbasins 3A thru 3J and 4A thru 4C. As presented earlier in the hydrology section, runoff detention storage created by Run-on Detention Pond No. 3 reduces the peak 25-year 24-hour discharge at the head of Channel No. 4 to 616 cfs for Run-on Detention Pond No. 1 Alternative 1 and to 682 cfs for Run-on Detention Pond No. 1 Alternative 2. Storm water drainage from Subbasins 4D and 4E enter Channel No. 4 along the length of the channel resulting in a combined 25-year 24-hour design discharge for Channel No. 4 of 691 cfs and 758 cfs for Run-on Detention Pond No. 1 Alternatives 1 and 2, respectively.

Engineering design calculations and details for Run-on Control Channel No. 4 were submitted in the HA&L 1990 study referenced previously. Plan and profile design details for Run-on Control Channel No. 4 are presented in Exhibit B. Hydraulic design calculations for Channel No. 4 are included in Exhibit A. The Channel No. 4 design calculations, presented in Exhibit A, are based on a design flow rate of 965 cfs. As indicated previously, the 25-year 24-hour flow rates modeled with the Army Corps of Engineers' watershed model (HEC-1) reflect changes at the facility to drainage control facilities (thereby modifying tributary areas), modifications to the design return period, etc. As noted above, due to these modifications, the design flow rate from the 25-year 24-hour precipitation event for Channel No. 4 is 691 cfs and 758 cfs for Run-on Detention Pond No. 1 Alternatives 1 and 2, respectively. Therefore, since the channel was originally designed for a larger flow rate than currently estimated; the channel, as designed, is adequate to convey the current 25-year 24-hour flow rate.

Inflow into Run-on Detention Pond No. 3 is controlled via two inlet structures (in addition to Run-on Control Channel No. 3), a pipe inlet (Culvert C4B-1) and a 14-foot vertical concrete drop structure/energy dissipator. The pipe inlet will convey drainage from Subbasin 4B down into the pond. The peak flow from the 25-year 24-hour event from Subbasin 4B (which is the design flow for this pipe inlet) is only 12 cfs. The existing 30-inch diameter CMP pipe (Culvert C4B-1) will provide adequate conveyance capacity for this pipe inlet. A riprap splash basin is provided at the outlet to the pipe to control erosion in the bottom of the pond.

The 14-foot vertical concrete drop structure/energy dissipator conveys drainage from the major subbasin (Subbasin 4A) which is tributary to the pond. Engineering design calculations and details for this drop structure were submitted in the HA&L 1990 study referenced previously. Hydraulic design calculations are included in Exhibit A. The drop structure design calculations, presented in Exhibit A, are based on a design flow rate of 1133 cfs. As indicated previously, the 25-year 24-hour flow rates modeled with the Army Corps of Engineers' watershed model (HEC-1) reflect changes at the facility to drainage control facilities (thereby modifying tributary areas), modifications to the design return period, etc. As noted in Exhibit A, due to these modifications, the design flow rate from the 25-year 24-hour precipitation event for the drop structure is 613 cfs. Therefore, since the drop structure was originally designed for a larger flow rate than currently estimated; the structure, as designed, is adequate to convey the current 25-year 24-hour flow rate.

Run-on Control Channel No. 4 was designed on a 1.17% channel grade with a trapezoidal cross-section, having a bottom width of 18 feet, side slopes of 3H:1V, and a channel depth to the top of the riprap lining of 5.0 feet along the straight sections of the channel and 5.1 feet through the curve in the channel. Velocities in excess of five feet per second would be experienced on the 1.17% channel grade during the design event which would be erosive. Therefore, a riprap channel lining was designed and placed in Run-on Control Channel No. 4. Riprap having a mean rock diameter (D_{50}) of 14 inches was determined to be adequate with a safety factor of 1.5 for the channel, including the channel bend. The riprap thickness is 24 inches. A 1-foot thick filter blanket was placed between the riprap and the natural ground subgrade to prevent erosion of the subgrade due to a pumping action of water within the riprap. The filter blanket is Type II, graded as specified in Table 3. Riprap gradations as per the specified D_{50} are presented in Table 4.

Run-on Control Channel No. 4 is the outlet to Run-on Detention Pond No. 3. The original design invert elevation to Channel No. 4 at the outlet to Pond No. 3 was 1380 feet. The outlet elevation was subsequently raised by 3 feet to 1383 feet. Therefore, calculations in Exhibit A have been modified to reflect this change. This has resulted in a steeper channel section for a short distance at the outlet to Detention Pond No. 3. Since the original channel section and riprap were designed based on the original channel grade of 1.17%, the riprap in this steeper section of channel should be grouted through the spillway portion and for a distance of 30 feet downstream from the change in channel grade between the steeper section and the existing section at the designed channel grade of 1.17%. Other alternatives to grouting the inlet to Channel No. 4 would include:

1. Lower the invert to Channel No. 4 at the outlet to Pond No. 3 to the original design elevation of 1380 feet, and grade the channel to the original design grade of 1.17%.

2. Flatten the channel grade, between the Pond No. 3 raised outlet elevation (1383 feet) and the intersection of the raised channel section with the original channel section, to a maximum of 5 percent and place riprap having a D_{50} of 2 feet down the 5% channel grade and for a distance of 30 feet into the original channel section beyond the 5% sloped channel section.

Run-on Control Channel No. 5

Run-on Control Channel No. 5 has been designed in two reaches, referred to herein as the upper reach and the lower reach. The upper reach of Channel No. 5 extends from the confluence of Channel No. 5 with Run-on Control Channel No. 1 down to the junction of Channel No. 5 with the culvert that conveys flow under the county road from Subbasin 5I. The lower reach of Channel No. 5 extends from the junction with the culvert under the county road down to the end of the channel where it discharges into the existing channel near the northern edge of the facility boundary. The upper reach of Run-on Control Channel No. 5 receives flow from Subbasins 1A through 1C, 2A through 2C, 5A through 5G and 5J. The lower reach of Run-on Control Channel No. 5 receives flow from the upper reach and from Subbasins 5H and 5I.

Engineering design calculations and details for Run-on Control Channel No. 5 were submitted in the HA&L 1990 study referenced previously. Plan and profile design details for Run-on Control Channel No. 5 are presented in Exhibit B. Hydraulic design calculations for Channel No. 5 are included in Exhibit A. The Channel No. 5 design calculations, presented in Exhibit A, are based on a design flow rate of 540 cfs for the upper reach and 1130 cfs for the lower reach. As indicated previously, the 25-year 24-hour flow rates modeled with the Army Corps of Engineers' watershed model (HEC-1) reflect changes at the facility to drainage control facilities (thereby modifying tributary areas), modifications to the design return period, etc. As noted above, due to these modifications, the design flow rate from the 25-year 24-hour precipitation event for Channel No. 5 is 342 cfs for the upper reach and 633 cfs for the lower reach. Therefore, since the channel was originally designed for larger flow rates than currently estimated; the channel, as designed, is adequate to convey the current 25-year 24-hour flow rates.

The upper reach of Run-on Control Channel No. 5 was designed on a 0.9% channel grade with a trapezoidal cross-section, having a bottom width of 16 feet, side slopes of 3H:1V, and a channel depth to the top of the riprap lining of 4.3 feet. It was determined that on the proposed 0.9% channel grade, velocities in excess of five feet per second would be experienced during the design event which would be erosive. Therefore, a riprap channel lining was designed and placed in the upper reach of Run-on Control Channel No. 5. Riprap having a mean rock diameter (D_{50}) of 9 inches was determined to be adequate with a safety factor in excess of 1.5. The riprap thickness is 18 inches. A 1-foot thick filter blanket was placed between the riprap and the natural ground subgrade to prevent erosion of the subgrade to the rock due to a pumping action of water within the riprap. The filter blanket is Type II, graded as specified in Table 3. Riprap gradations as per the specified D_{50} are presented in Table 4.

The lower reach of Run-on Control Channel No. 5 was designed on a 0.6% channel grade with a trapezoidal cross-section, having a bottom width of 40 feet, side slopes of 3H:1V, and a channel depth to the top of the riprap lining of 4.5 feet. It was determined that on the proposed 0.6% channel grade, velocities in excess of five feet per second would be experienced during the design event which would be erosive. Therefore, a riprap channel lining was designed and placed in the lower reach of Run-on Control Channel No. 5. Riprap having a mean rock diameter (D_{50}) of 6 inches was determined to be adequate with a safety factor in excess of 1.5. The riprap thickness is 12 inches. A 1-foot thick filter blanket was placed between the riprap and the natural ground subgrade for the reasons indicated above. The filter blanket is Type II, graded as specified in Table 3. Riprap gradations as per the specified D_{50} are presented in Table 4.

Culvert C5G-1 has been placed in Channel No. 5 at the upstream end of the lower section to provide construction and operational access to the facility across Channel No. 5. Culvert C5G-1 consists of four 60-inch diameter culverts. Calculations for Culvert C5G-1 are included in Exhibit A. These culverts can pass the 25-year 24-hour peak discharge or 522 cfs at a headwater depth of 5.6 feet.

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OTE:
TWO ALTERNATIVES ARE PRESENTED FOR CONSTRUCTION OF RUN-ON DETENTION POND NO. 1.

1. ALTERNATIVE 1: INCLUDES CONSTRUCTION OF THE POND UPSTREAM FROM CULVERT C3G-1 AS SHOWN ON THIS DRAWING (NO. 1) AND DRAWING NO. 2. THE CONFIGURATION OF THIS POND CAN BE MODIFIED AS DESIRED BY THE LONE MOUNTAIN FACILITY AS LONG AS THE ELEVATION CAPACITY RELATIONSHIP ASSUMED IN THE CALCULATIONS IS MAINTAINED.
2. ALTERNATIVE 2: CONSISTS OF REMOVING CULVERT C3G-1 AND EVALUATING THE EXISTING TOPOGRAPHY UPSTREAM FROM CULVERT C3H-1 AS DETENTION POND NO. 1. DETENTION POND NO. 1 UNDER THIS ALTERNATIVE WOULD INCLUDE THE EXISTING AREA OF CHANNEL D3H-1 PLUS THE EXISTING AREA UPSTREAM FROM CULVERT C3G-1 BELOW ELEVATION 1398 FEET. THIS ALTERNATIVE WILL REQUIRE NO ADDITIONAL CONSTRUCTION OTHER THAN REMOVAL OF CULVERT C3G-1 AND SHAPING AND EXTENDING CHANNEL D3H-1 THROUGH THE AREA WHERE THE CULVERT IS REMOVED.

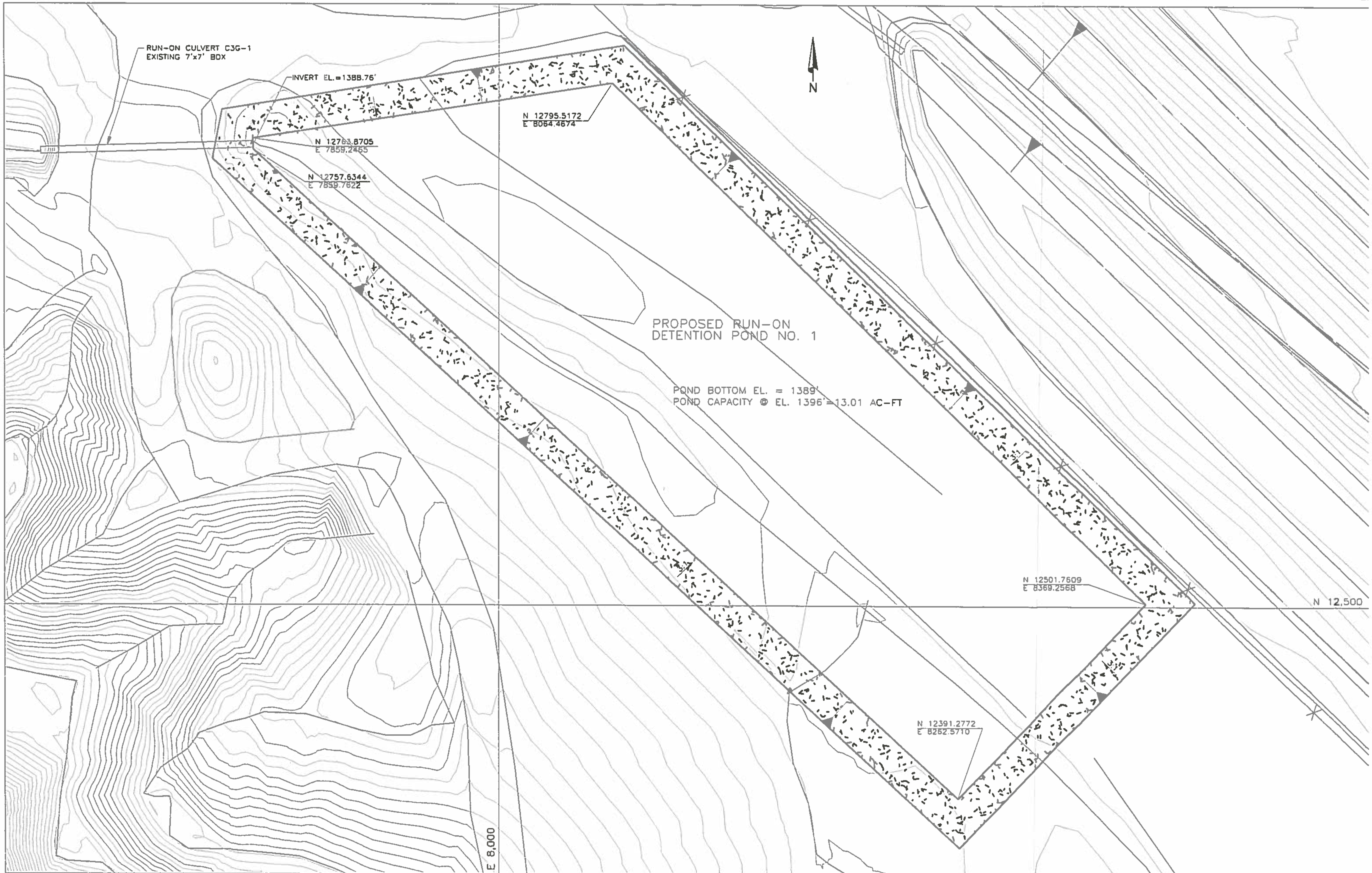
THE LONE MOUNTAIN FACILITY WILL DETERMINE WHICH OF THE TWO ALTERNATIVES (LISTED ABOVE) IT WILL CONSTRUCT.

LEGEND

SUBWATERSHED BOUNDARY

RUN-ON CONTROL CHANNELS

I&L ENGINEERING	CONSULTANTS ENGINEERS Salt Lake City Utah	PROJECT ENGINEER	DESIGNED MPW	3		SCALE 1" = 300'	VERIFY SCALE: BAR IS ONE INCH ON ORIGINAL DRAWING. IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.	safety-kleen corp.
			DRAFTED SS	2				LONE MOUNTAIN FACILITY
			CHECKED MEA	1				RUN-ON CONTROL SYSTEM (CELLS 10-15)
			DATE MAY 1998	NO.	DATE / REVISIONS / BY / APVD.			SITE DRAINAGE PLAN



XREF FILE 064\63-100\TBLK1117 R1.DWG
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ORIGIN:
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DWG UNITS: 1 =1
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FILE DATE 9/21/1999 11:09:20 (WH)

HA&L ENGINEERING	CONSULTANTS ENGINEERS Salt Lake City Utah	PROJECT ENGINEER	DESIGNED MPW	3		REVISIONS	BY	APVD.	SCALE 1" = 50'	safety-kleen corp.	LONE MOUNTAIN FACILITY RUN-ON CONVEYANCE SYSTEM RUN-ON DETENTION POND NO. 1 ALTERNATIVE 1	DRAWING 2 064-63
			DRAFTED SS	2								
			CHECKED MEA	1								
			DATE MAY 1998	NO.	DATE							

EXHIBIT A

HYDROLOGIC AND HYDRAULIC DESIGN CALCULATIONS

HA&L ENGINEERING

CLIENT: Laidlaw
PROJECT: Lone Mtn. Storm Drainage Revisions
FEATURE: Hydrology
PROJECT NO.: 64.63.100

SHEET 1 OF
COMPUTED: JMA
CHECKED: VCS
DATE: 4/3/98

1 - Watershed Characteristics

A - Subwatershed Areas:

Sub-watershed areas are listed on the attached spreadsheet - Sheet 2.

Subwatersheds are identified by which major run-on conveyance channel they are tributary to. There are five major run-on conveyance channels, referred to as Run-on Conveyance Channel No. 1, etc.

Basin areas were determined using a planimeter.

B - Time of Concentration:

Time of concentration was determined using methods presented in SCS-TR55 as follows:

$TC = TI + TT$

where TI = overland or sheet flow travel time

$$= \frac{0.007(n \times L)^{0.8}}{P_2^{0.5}\, S^{0.4}} \text{ in hours}$$

Use 0.13 range land

n = Manning's Roughness Coef.
L = Overland flow length
P_2 = 2-yr, 24 hr rainfall = 3.3 inches
S = Slope

TT = Channel Length / Velocity

or. TC was determined for graveled or rock covered tops of closed landfill cells using the Denver Storm Drainage Criteria Manual.

$$TI = \frac{1.8(1.1 - C5)\, L^{0.5}}{S^{0.33}}$$

TI = Overland flow time in minutes
$C5$ = 0.25 for gravel
L = Sheet flow length
S = Slope
TT = Same as above.

See attached spreadsheet for calculations.

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LAIDLAW ENVIRONMENTAL SERVICES
LONE MOUNTAIN FACILITY
STORM DRAINAGE REVISIONS
64.63.100
April 24, 1998

SUBWATERSHED DRAINAGE AREAS

BASIN	AREA		
	FT2	AC	MI2
1-A	122760	2.82	0.00440
1-B	131750	3.02	0.00473
1-C	276210	6.34	0.00991
2-A	705189	16.19	0.02530
2-B	335627	7.70	0.01204
2-C	81065	1.86	0.00291
3-A	421291	9.67	0.01511
3-B	463451	10.64	0.01662
3-C	267841	6.15	0.00961
3-D	83700	1.92	0.00300
3-E	279000	6.40	0.01001
3-F	320153	7.35	0.01148
3-G	751209	17.25	0.02695
3-H	1018352	23.38	0.03653
3-I	1211560	27.81	0.04346
3-J	307598	7.06	0.01103
4-A	6808311	156.30	0.24421
4-B	133223	3.06	0.00478
4-C	523824	12.03	0.01879
4-D	703081	16.14	0.02522
4-E	1203190	27.62	0.04316
5-A	502201	11.53	0.01801
5-B	302716	6.95	0.01086
5-C	193905	4.45	0.00696
5-D	130432	2.99	0.00468
5-E	101835	2.34	0.00365
5-F	325733	7.48	0.01168
5-G	1049608	24.10	0.03765
5-H	1708878	39.23	0.06130
5-I	2395800	55.00	0.08594
5-J	66262	1.52	0.00238

LAIDLAW ENVIRONMENTAL SERVICES
LONE MOUNTAIN FACILITY
STORM DRAINAGE REVISIONS
1.63.100

April 24, 1998

TIME OF CONCENTRATION (TC) AND LAG TIME (TL)

TC = TI + TT   Refrence:SCS TR-55
Overland Flow Travel Time TI = (0.007(n*L)^0.8/(P2^0.5*S^0.4))
n = Manning's roughness coefficient
L = Overland flow length
S = Channel slope
P2 = 2-yr 24-hr precipitation = 3.3 inches
Channel Travel Time TT = CHANNEL DISTANCE / VELOCITY
VELOCITY V = (1.49/n)* (R^0.67)*S^0.5
R = hydraulic radius
S = Channel slope
n = Manning's roughness coefficient

* For Gravel Surfaces of the Closure Caps
Use Denver Drainage Criteria Manual Method for TI
TI = (1.8(1.1-C5)L^0.5)/(S^0.333) in minutes
L = Overland flow length
S = Clope in %
C5 = 0.25 for gravel

BASIN	L ft	S ft/ft	n	Ti hrs	CHANNEL REACH	CHANNEL LENGTH ft	R ft	S ft/ft	n	V fps	TT hrs	TC hrs	LAG TIME hrs
1-A	210	0.023	*	0.28	1	200	0.5	0.006	0.035	2.07	0.03	0.31	0.18
1-B	110	0.06	*	0.15	1	110	0.5	0.006	0.035	2.07	0.01		
					2	260	0.8	0.03	0.035	6.35	0.01	0.17	0.10
1-C	100	0.01	0.13	0.19	1	600	0.8	0.01	0.035	3.67	0.05	0.23	0.14
2-A	150	0.05	*	0.18	1	370	0.5	0.005	0.035	1.89	0.05		
					2	850	2	0.002	0.035	3.03	0.08	0.32	0.19
2-B	180	0.05	*	0.20	1	420	0.5	0.005	0.035	1.89	0.06		
					2	800	2	0.009	0.035	6.43	0.03	0.30	0.18
2-C	110	0.06	*	0.15	1	110	0.5	0.006	0.035	2.07	0.01		
					2	270	0.8	0.03	0.035	6.35	0.01	0.17	0.10
3-A	100	0.06	0.13	0.09	1	300	0.5	0.5	0.035	18.92	0.00		
					2	400	1	0.03	0.035	7.37	0.02	0.11	0.07
3-B	230	0.03	*	0.27	1	130	0.5	0.005	0.035	1.89	0.02		
					2	650	1	0.004	0.035	2.69	0.07	0.35	0.21
3-C	250	0.02	0.13	0.30	1	700	1	0.028	0.035	7.12	0.03	0.33	0.20
3-D	200	0.02	0.13	0.25	1	130	1	0.029	0.035	7.25	0.00	0.25	0.15
3-E	100	0.25	0.13	0.05	1	1050	1	0.008	0.035	3.81	0.08	0.13	0.08
3-F	150	0.64	0.13	0.05	1	800	1	0.027	0.035	7.00	0.03	0.08	0.05
3-G	200	0.05	0.13	0.17	1	1020	2	0.005	0.035	4.79	0.06	0.23	0.14
3-H	300	0.17	0.13	0.15	1	200	1	0.25	0.035	21.29	0.00		
					2	700	2	0.0004	0.035	1.35	0.14	0.29	0.18
3-I	200	0.1	*	0.17	1	780	0.5	0.005	0.035	1.89	0.11		
					2	950	2	0.014	0.035	8.01	0.03	0.31	0.19
3-J	100	0.04	0.13	0.11	1	1600	1	0.1	0.035	13.46	0.03	0.14	0.09
4-A	300	0.17	0.13	0.15	1	600	0.2	0.3	0.035	7.93	0.02		
					2	3100	1	0.013	0.035	4.85	0.18	0.35	0.21
4-B	260	0.02	0.13	0.31	1	200	1	0.06	0.035	10.43	0.01	0.31	0.19
4-C	Pond - use TC = 18 min. =											0.30	0.18
4-D	200	0.02	0.13	0.25	1	800	0.5	0.01	0.035	2.68	0.08	0.33	0.20
4-E	250	0.1	*	0.19	1	900	0.25	0.005	0.015	2.77	0.09		
					2	1600	3	0.0117	0.035	9.61	0.05	0.32	0.19
5-A	100	0.04	0.13	0.11	1	400	1	0.5	0.035	30.10	0.00		
					2	600	1	0.02	0.035	6.02	0.03	0.14	0.08
5-B	200	0.056	*	0.20	1	300	1	0.01	0.035	4.26	0.02	0.22	0.13
5-C	100	0.02	0.13	0.14	1	500	0.5	0.02	0.035	3.78	0.04	0.18	0.11
5-D	165	0.056	*	0.18	1	170	0.5	0.005	0.035	1.89	0.02		
					2	800	1	0.05	0.035	9.52	0.02	0.23	0.14
5-E	230	0.03	*	0.27	1	170	0.5	0.005	0.035	1.89	0.02		
					2	200	1	0.008	0.035	3.81	0.01	0.31	0.18
5-F	100	0.01	0.13	0.19	1	300	1	0.1	0.035	13.46	0.01		
					2	800	3	0.004	0.035	5.62	0.04	0.23	0.14
5-G	180	0.05	*	0.20	1	650	3	0.009	0.035	8.43	0.02	0.22	0.13
5-H	200	0.1	*	0.17	1	2200	3	0.006	0.035	6.88	0.09	0.26	0.15
5-I	300	0.06	0.13	0.22	1	3200	1	0.005	0.035	3.01	0.30	0.52	0.31
5-J	210	0.023	*	0.28	1	0	3	0.005	0.035	6.28	0.00	0.28	0.17

C - Curve Number

Use CN = 89 Undisturbed areas - based on 45% herbaceous ground cover density and hydrologic soil group D

CN = 76 Estimated to represent riprapped surface of closed landfill cells

CN = 92 for disturbed areas

Curve numbers were then weighted by area to determine a basin-wide curve number. See attached spreadsheet.

D: Precipitation

25-yr, 24-hr = 6.0 inches

use SCS-Type II distribution 24-hr.

2 - Peak Flows

Use Army Corps of Engineers HEC-1 model, to predict peak flows. Use SCS curve number method or module within HEC-1.

Two alternatives were considered for detention Pond 1 upstream from Culvert C3H-1. Without some detention storage upstream from this culvert and/or C3G-1, these two culverts in series have insufficient capacity for the 25-yr, 24-hr event. These 2 alternatives include:

Alternative 1 - Leave both culverts C3G-1 and C3H-1 in place, and excavate a new detention pond upstream of C3G-1, to be called 'Detention Pond No. 1'.

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PROJECT Lone Mtn. Storm Drainage Plan COMPUTED MA

FEATURE Hydrology CHECKED

PROJECT NO. 64.63.1100 DATE 9/17/99

Alternative 2 - Remove Culvert C3G-1 and evaluate the existing storage area upstream of Culvert C3H-1 as a detention basin. This existing storage area would be called Detention Pond No. 1.

Attached are printouts from HEC-1 for the 25-yr, 24-hr precipitation event.

Printouts for Alternative 1 are in Attachment 1A.

Printouts for Alternative 2 are in Attachment 1B.

Summarized on the attached spreadsheet are the peak flowrates for the run-on control system for the Landfill Cells 10-15 area.

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LAIDLAW ENVIRONMENTAL SERVICES, INC.
LONE MOUNTAIN FACILITY
STORM DRAINAGE REVISIONS
64.63.100

April 24, 1998

WEIGHTED CURVE NUMBERS

Use CN=89 for Undisturbed Areas, CN=92 for Disturbed Areas,
CN = 76 for Rock Covered Cap areas, and CN = 98 for Pond Areas

BASIN	UNDISTURBED AREA AC	DISTURBED AREA AC	ROCK RIPRAP AREAS AC	POND AREA AC	TOTAL AREA AC	WEIGHTED CN
1-A			2.82		2.82	76.0
1-B		2.50	0.52		3.02	89.2
1-C		6.34			6.34	92.0
2-A		5.61	10.58		16.19	81.5
2-B		0.70	7.00		7.70	77.5
2-C		0.83	1.03		1.86	83.1
3-A	7.20	2.47			9.67	89.8
3-B		5.22	5.42		10.64	83.8
3-C		6.15			6.15	92.0
3-D		1.92			1.92	92.0
3-E		6.40			6.40	92.0
3-F		7.35			7.35	92.0
3-G	2.06	15.19			17.25	91.6
3-H	12.40	10.98			23.38	90.4
3-I		15.26	12.55		27.81	84.8
3-J	1.57	5.49			7.06	91.3
4-A	97.80	58.50			156.30	90.1
4-B	3.06				3.06	89.0
4-C		2.95		9.08	12.03	96.5
4-D		12.10	4.04		16.14	88.0
4-E		10.12	17.50		27.62	81.9
5-A	11.53				11.53	89.0
5-B		5.25	1.70		6.95	88.1
5-C		4.45			4.45	92.0
5-D		1.87	1.12		2.99	86.0
5-E		1.12	1.22		2.34	83.7
5-F		7.48			7.48	92.0
5-G		8.97	15.13		24.10	82.0
5-H		11.89	27.34		39.23	80.8
5-I	55.00				55.00	89.0
5-J			1.52		1.52	76.0

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LAIDLAW ENVIRONMENTAL SERVICES
LONE MOUNTAIN FACILITY
STORM DRAINAGE REVISIONS
64.63.100
April 17, 1998 Revised September 19, 1999

DIVERSION CHANNELS - TRIBUTARY BASINS AND 25-YR 24-HR PEAK FLOWS

CHANNEL NO.	TRIBUTARY BASINS	25YR 24HR PEAK FLOW RATE	
		ALTERNATIVE 1 CFS	ALTERNATIVE 2 CFS
RUNON NO. 1	1A THRU 1C	47	47
RUNON NO. 2	2A THRU 2C	61	61
D3H-1	3A THRU 3H, AND 3J	165	206
RUNON NO. 3	3A THRU 3J	261	304
RUNON NO. 4U	POND 3 OUTFLOW AND 4D	646	714
RUNON NO. 4L	POND 3 OUTFLOW AND 4D & 4E	691	758
RUNON NO. 5U	1A-1C, 2A-2C, 5A-5G, AND 5J	342	342
RUNON NO. 5L	1A-1C, 2A-2C, AND 5A-5J	633	633

CULVERTS - TRIBUTARY BASINS AND 25-YR 24-HR PEAK FLOWS

CULVERT NO.	TRIBUTARY BASINS	25YR 24HR PEAK FLOW RATE	
		ALTERNATIVE 1 CFS	ALTERNATIVE 2 CFS
C2A-1	2A	55	55
C3G-1	3A THRU 3G, AND 3J	93	*
C3H-1	3A THRU 3H, AND 3J	165	206
C4B-1	4B	12	12
C5G-1	1A-1C, 2A-2C, 5A-5G, 5I AND 5J	522	522

* Culvert C3G-1 is removed for Alternative 2.

Rev 9/17/98

3 - Runon Detention Ponds

A - Runon Detention Pond No. 2

- Stage Capacity was determined by end area method. See attached spreadsheet.

- Stage Discharge for existing 54" Dia CMP, with Steel inlet section. - See previous calculations in Attachment 2.

B - Runon Detention Pond No. 3

Original stage capacity, stage discharge calculations are applicable, with minor modifications

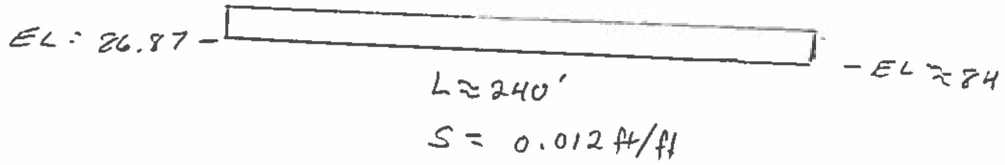
See Attachment 3.

C - Run-on Detention Pond No. 1

- Stage capacity was determined by the end area method. See Attached spreadsheet for Alternative 1 and Alternative 2

- Stage Discharge.

Twin 42" Dia Culverts between D3H-1 and Runon-channel No. 3



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LAIDLAW ENRIVONMENTAL SERVICES, INC.
?ONE MOUNTAIN FACILITY
RUNON DETENTION POND NO 2
ELEVATION CAPACITY RELATIONSHIP
April 22, 1998

ELEV. FT	AREA FT2	AVE AREA FT2	VOLUME FT3	VOLUME AC	ACCUMULATED VOLUME AC-FT
1388.3	0				0.0
1390	21080	10540	17918	0.41	0.41
1392	42470	31775	63550	1.46	1.87
1394	54560	48515	97030	2.23	4.10
1396	66262	60411	120822	2.77	6.87
1398	79360	72811	145622	3.34	10.21

LAIDLAW ENRIVONMENTAL SERVICES, INC.
LONE MOUNTAIN FACILITY
RUNON DETENTION POND NO 1 - ALTERNATIVE 1
ELEVATION CAPACITY RELATIONSHIP
April 24, 1998

ELEV. FT	AREA FT2	AVE AREA FT2	VOLUME FT3	VOLUME AC	ACCUMULATED VOLUME AC-FT
1389	66175				0.0
1390	70393	68284	68284	1.57	1.57
1392	78830	74611.5	149223	3.43	4.99
1394	87266	83048	166096	3.81	8.81
1396	95703	91484.5	182969	4.20	13.01
1398	117605	106654	213308	4.90	17.90

LAIDLAW ENRIVONMENTAL SERVICES, INC.
LONE MOUNTAIN FACILITY
RUNON DETENTION POND NO 1 - ALTERNATIVE 2
ELEVATION CAPACITY RELATIONSHIP
September 3, 1999

ELEV. FT	AREA FT2	AVE AREA FT2	VOLUME FT3	VOLUME AC	ACCUMULATED VOLUME AC-FT
1386.90				0.00	0.00
1388.00	1240.00	620.00	700.60	0.02	0.02
1390.00	5115.00	3177.50	6355.00	0.15	0.17
1392.00	8064.00	6589.50	13179.00	0.30	0.47
1394.00	24731.00	16397.50	32795.00	0.75	1.22
1396.00	74736.00	49733.50	99467.00	2.28	3.50
1398.00	227017.00	150876.00	301753.00	6.93	10.43

Note: Alternative 2 includes in the above relationship the run-on detention in channel A3H-1 listed on the following sheet (9A). Sheet 9A is used with Alternative 1.

9A/

LAIDLAW ENRIVONMENTAL SERVICES, INC.
LONE MOUNTAIN FACILITY
RUNON DETENTION IN CHANNEL D3H-1
ELEVATION CAPACITY RELATIONSHIP
April 23, 1998

ELEV. FT	AREA FT2	AVE AREA FT2	VOLUME FT3	VOLUME AC	ACCUMULATED VOLUME AC-FT
1386.87	0				0.0
1388	1240	620	700.6	0.02	0.02
1390	5115	3177.5	6355	0.15	0.16
1392	6820	5967.5	11935	0.27	0.44
1394	17570	12195	24390	0.56	1.00
1396	25885	21727.5	43455	1.00	1.99
1398	37355	31620	63240	1.45	3.45

For tailwater depth, assume flow depth in Runon Channel 3 for the peak flow from Subbasin 3-I plus the flow in the culvert. Assume a minimum tailwater elev. of 1387 feet from Pond 3 (i.e. minimum tailwater depth = 3 feet).

Basin 3-I 25yr, 24-hr peak = 101 cfs
Normal Flow depth - See attached printout

= 2.25 ft.

Then go by increments of 20 cfs to determine added depth @ tailwater

Q cfs	Channel 3 Flow Depth (ft)
101	1.92
121	2.08
141	2.23
161	2.37
181	2.50
201	2.62
221	2.73
241	2.84
261	2.94
281	3.04
301	3.13
321	3.22
341	3.41

Evaluate culvert for stage discharge relationship for both inlet & outlet conditions. See attached spreadsheet.

Stage Discharge - 2 - 42" dia Culverts

Elev ft	Discharge cfs
1386.87	0
1388.90	40
1390.02	80
1391.14	120
1392.82	160
1396.04	200
1399.99	240

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Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	24-Apr-98
Project No. :	64.63.100	Time :	04:32 PM
Channel Section:	RUNON CH NO. 3 UPPER (3-I ONLY)	Compute	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	101.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	* AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	1.92	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.075	
	Required Depth:	2.92	feet
	Area:	34.17	ft2
	Perimeter:	24.16	feet
	Hydraulic Radius (R):	1.41	feet
	Velocity:	2.96	ft/sec
	Froude Number:	0.43	
CALCULATION: (Velocity Check)	Depth (Max. S):	1.92	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.075	
	Required Depth:	2.42	feet
	Area:	34.17	ft2
	Perimeter:	24.16	feet
	Hydraulic Radius (R):	1.41	feet
	Velocity:	2.96	ft/sec
	Froude Number:	0.43	

DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	2.92	feet

12/

Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	24-Apr-98
Project No. :	64.63.100	Time :	04:33 PM
Channel Section:	RUNON CH NO. 3 UPPER (3-I + INCR.)	Compute	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	121.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	2.08	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.073	
	Required Depth:	3.08	feet
	Area:	38.05	ft2
	Perimeter:	25.18	feet
	Hydraulic Radius (R):	1.51	feet
	Velocity:	3.18	ft/sec
	Froude Number:	0.45	
CALCULATION: (Velocity Check)	Depth (Max. S):	2.08	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.073	
	Required Depth:	2.58	feet
	Area:	38.05	ft2
	Perimeter:	25.18	feet
	Hydraulic Radius (R):	1.51	feet
	Velocity:	3.18	ft/sec
	Froude Number:	0.45	

DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	3.08	feet

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Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	24-Apr-98
Project No. :	64.63.100	Time :	04:41 PM
Channel Section:	RUNON CH NO. 3 UPPER (3-I + INCR.)	Compute	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	141.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	2.23	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.071	
	Required Depth:	3.23	feet
	Area:	41.74	ft2
	Perimeter:	26.12	feet
	Hydraulic Radius (R):	1.60	feet
	Velocity:	3.38	ft/sec
	Froude Number:	0.46	
CALCULATION: (Velocity Check)	Depth (Max. S):	2.23	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.071	
	Required Depth:	2.73	feet
	Area:	41.74	ft2
	Perimeter:	26.12	feet
	Hydraulic Radius (R):	1.60	feet
	Velocity:	3.38	ft/sec
	Froude Number:	0.46	

DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	3.23	feet

Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	24-Apr-98
Project No. :	64.63.100	Time :	04:41 PM
Channel Section:	RUNON CH NO. 3 UPPER (3-1 + INCR.)	Compute	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	161.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	2.37	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.070	
	Required Depth:	3.37	feet
	Area:	45.26	ft2
	Perimeter:	26.98	feet
	Hydraulic Radius (R):	1.68	feet
	Velocity:	3.56	ft/sec
	Froude Number:	0.48	
CALCULATION: (Velocity Check)	Depth (Max. S):	2.37	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.070	
	Required Depth:	2.87	feet
	Area:	45.26	ft2
	Perimeter:	26.98	feet
	Hydraulic Radius (R):	1.68	feet
	Velocity:	3.56	ft/sec
	Froude Number:	0.48	

DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	3.37	feet

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Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	24-Apr-98
Project No. :	64.63.100	Time :	04:38 PM
Channel Section:	RUNON CH NO. 3 UPPER (3-I + INCR.)	Compute	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	181.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	2.50	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.069	
	Required Depth:	3.50	feet
	Area:	48.65	ft2
	Perimeter:	27.79	feet
	Hydraulic Radius (R):	1.75	feet
	Velocity:	3.72	ft/sec
	Froude Number:	0.49	
CALCULATION: (Velocity Check)	Depth (Max. S):	2.50	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.069	
	Required Depth:	3.00	feet
	Area:	48.65	ft2
	Perimeter:	27.79	feet
	Hydraulic Radius (R):	1.75	feet
	Velocity:	3.72	ft/sec
	Froude Number:	0.49	
DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	3.50	feet

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Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	24-Apr-98
Project No. :	64.63.100	Time :	04:37 PM
Channel Section:	RUNON CH NO. 3 UPPER (3-I + INCR.)	Compute	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	201.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	2.62	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.068	
	Required Depth:	3.62	feet
	Area:	51.92	ft2
	Perimeter:	28.54	feet
	Hydraulic Radius (R):	1.82	feet
	Velocity:	3.87	ft/sec
	Froude Number:	0.50	
CALCULATION: (Velocity Check)	Depth (Max. S):	2.62	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.068	
	Required Depth:	3.12	feet
	Area:	51.92	ft2
	Perimeter:	28.54	feet
	Hydraulic Radius (R):	1.82	feet
	Velocity:	3.87	ft/sec
	Froude Number:	0.50	

DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	3.62	feet

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Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	24-Apr-98
Project No. :	64.63.100	Time :	04:37 PM
Channel Section:	RUNON CH NO. 3 UPPER (3-I + INCR.)	Compute	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	221.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION:	Depth (Min. S):	2.73	feet
(Channel Depth)			
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.067	
	Required Depth:	3.73	feet
	Area:	55.09	ft2
	Perimeter:	29.26	feet
	Hydraulic Radius (R):	1.88	feet
	Velocity:	4.01	ft/sec
	Froude Number:	0.51	
CALCULATION:	Depth (Max. S):	2.73	feet
(Velocity Check)			
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.067	
	Required Depth:	3.23	feet
	Area:	55.09	ft2
	Perimeter:	29.26	feet
	Hydraulic Radius (R):	1.88	feet
	Velocity:	4.01	ft/sec
	Froude Number:	0.51	

DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	3.73	feet

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Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	24-Apr-98
Project No. :	64.63.100	Time :	04:37 PM
Channel Section:	RUNON CH NO. 3 UPPER (3-I + INCR.)	Compute	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	241.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	2.94	feet
	Q-1.49AR(2/3)S(1/2)/n=	-20.000	Accuracy
	Calc n Value	0.066	
	Required Depth:	3.94	feet
	Area:	61.19	ft2
	Perimeter:	30.59	feet
	Hydraulic Radius (R):	2.00	feet
	Velocity:	3.94	ft/sec
	Froude Number:	0.48	
CALCULATION: (Velocity Check)	Depth (Max. S):	2.94	feet
	Q-1.49AR(2/3)S(1/2)/n=	-20.000	Accuracy
	Calc n Value	0.066	
	Required Depth:	3.44	feet
	Area:	61.19	ft2
	Perimeter:	30.59	feet
	Hydraulic Radius (R):	2.00	feet
	Velocity:	3.94	ft/sec
	Froude Number:	0.48	

DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	3.94	feet

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Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	24-Apr-98
Project No. :	64.63.100	Time :	04:37 PM
Channel Section:	RUNON CH NO. 3 UPPER (3-I + INCR.)	Compute	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	261.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	2.94	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.066	
	Required Depth:	3.94	feet
	Area:	61.19	ft2
	Perimeter:	30.59	feet
	Hydraulic Radius (R):	2.00	feet
	Velocity:	4.27	ft/sec
	Froude Number:	0.52	
CALCULATION: (Velocity Check)	Depth (Max. S):	2.94	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.066	
	Required Depth:	3.44	feet
	Area:	61.19	ft2
	Perimeter:	30.59	feet
	Hydraulic Radius (R):	2.00	feet
	Velocity:	4.27	ft/sec
	Froude Number:	0.52	

DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	3.94	feet

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Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	24-Apr-98
Project No. :	64.63.100	Time :	04:40 PM
Channel Section:	RUNON CH NO. 3 UPPER (3-I + INCR.)	Compute	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	281.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	3.04	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.065	
	Required Depth:	4.04	feet
	Area:	64.13	ft2
	Perimeter:	31.21	feet
	Hydraulic Radius (R):	2.05	feet
	Velocity:	4.38	ft/sec
	Froude Number:	0.53	
CALCULATION: (Velocity Check)	Depth (Max. S):	3.04	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.065	
	Required Depth:	3.54	feet
	Area:	64.13	ft2
	Perimeter:	31.21	feet
	Hydraulic Radius (R):	2.05	feet
	Velocity:	4.38	ft/sec
	Froude Number:	0.53	

DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	4.04	feet

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Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	24-Apr-98
Project No. :	64.63.100	Time :	04:37 PM
Channel Section:	RUNON CH NO. 3 UPPER (3-I + INCR.)	Compute	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	301.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	3.13	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.064	
	Required Depth:	4.13	feet
	Area:	67.01	ft2
	Perimeter:	31.81	feet
	Hydraulic Radius (R):	2.11	feet
	Velocity:	4.49	ft/sec
	Froude Number:	0.54	
CALCULATION: (Velocity Check)	Depth (Max. S):	3.13	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.064	
	Required Depth:	3.63	feet
	Area:	67.01	ft2
	Perimeter:	31.81	feet
	Hydraulic Radius (R):	2.11	feet
	Velocity:	4.49	ft/sec
	Froude Number:	0.54	

DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	4.13	feet

Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	24-Apr-98
Project No. :	64.63.100	Time :	04:37 PM
Channel Section:	RUNON CH NO. 3 UPPER (3-I + INCR.)	Compute	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	321.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	3.22	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.064	
	Required Depth:	4.22	feet
	Area:	69.82	ft2
	Perimeter:	32.38	feet
	Hydraulic Radius (R):	2.16	feet
	Velocity:	4.60	ft/sec
	Froude Number:	0.54	
CALCULATION: (Velocity Check)	Depth (Max. S):	3.22	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.064	
	Required Depth:	3.72	feet
	Area:	69.82	ft2
	Perimeter:	32.38	feet
	Hydraulic Radius (R):	2.16	feet
	Velocity:	4.60	ft/sec
	Froude Number:	0.54	

DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	4.22	feet

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Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	24-Apr-98
Project No. :	64.63.100	Time :	04:37 PM
Channel Section:	RUNON CH NO. 3 UPPER (3-I + INCR.)	Compute	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	341.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	3.31	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.064	
	Required Depth:	4.31	feet
	Area:	72.59	ft2
	Perimeter:	32.93	feet
	Hydraulic Radius (R):	2.20	feet
	Velocity:	4.70	ft/sec
	Froude Number:	0.55	
CALCULATION: (Velocity Check)	Depth (Max. S):	3.31	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.064	
	Required Depth:	3.81	feet
	Area:	72.59	ft2
	Perimeter:	32.93	feet
	Hydraulic Radius (R):	2.20	feet
	Velocity:	4.70	ft/sec
	Froude Number:	0.55	

DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	4.31	feet

LAIDLAW ENVIRONM[illegible]L SERVICES - LONE MOUNTAIN
STORM DRAINAGE REVISIONS
April 24, 1998

COMPARES INLET VERSUS OUTLET CONDITIONS
Inlet Control Uses U.S. D.O.T. Hydraulic Charts for the Selection of Highway Culverts
Outlet Control - Assumes Full Flowing Pipe with the following:

Ke = Entrance Loss Coefficient = 0.9 for projecting from fill, no headwall, 0.5 for headwall condition
H = (1 + Ke + (29*n^2*L)/(R^1.33))*V^2/2g
HW = H +ho - LSo

Assume: All culverts have projecting entrance types, no headwall
All culverts are CMP

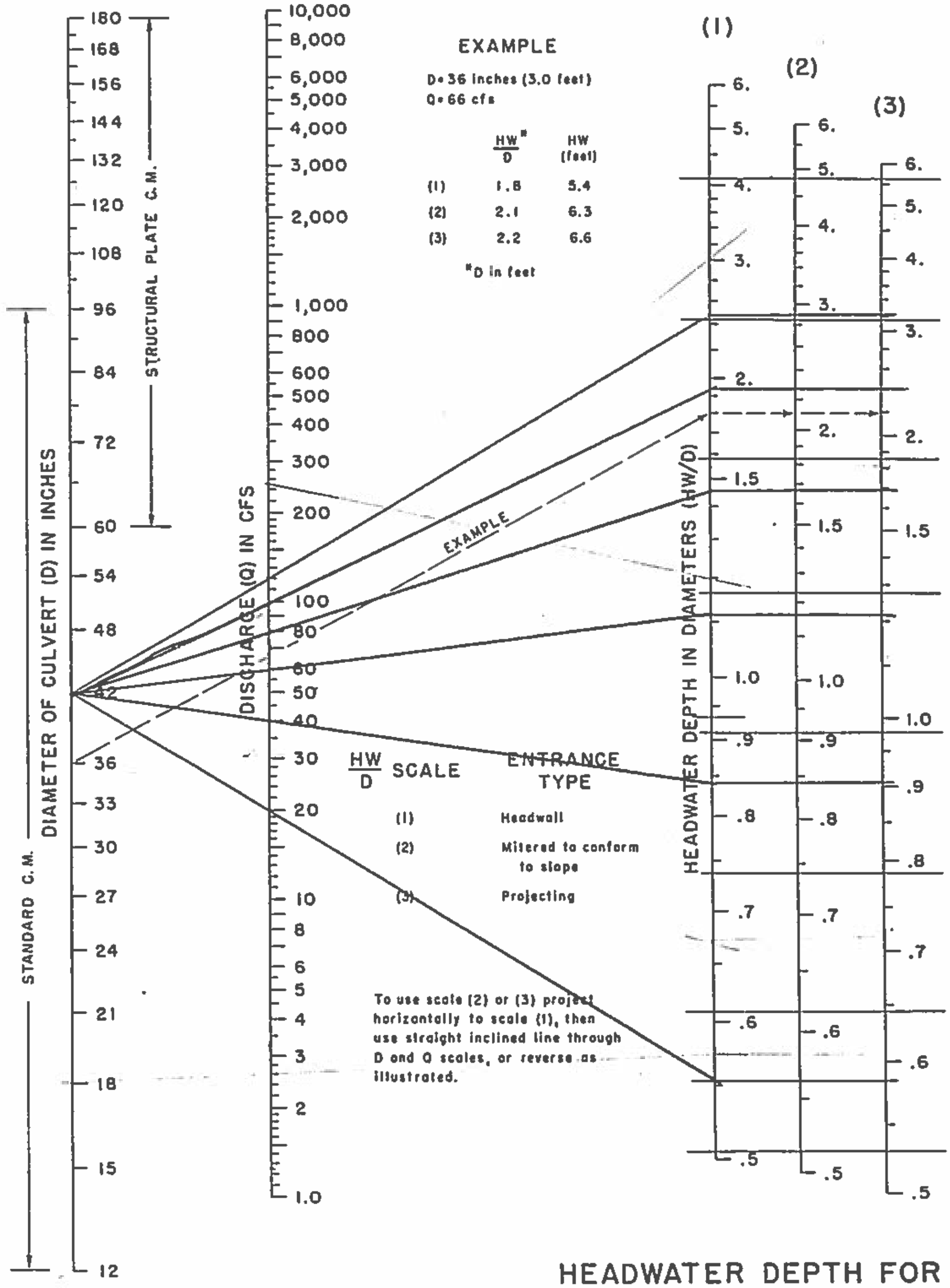
			INLET CONTROL		OUTLET CONTROL																
CULVERT NO.	CULVERT DIAMETER ft	DISCHARGE cfs	HW/D	HW ft	Ke	Manning's n	Flow Area A ft2	Wetted Perimeter P ft	Hydraulic Radius R ft	Velocity Full Pipe V fps	Culvert Length L ft	Culvert Slope So %	H ft	Critical Depth dc ft	(dc+D)/2 ft	Tailwater Depth TW ft	ho ft	LSo ft.	HW ft	CONTROLLING HW ft	OUTLET VELOCITY fps
*C3H-1	3.5	20	0.58	2.03	0.9	0.02	9.62	11.00	0.88	2.08	240	1.2	0.35	1.37	2.435	3	3.00	2.88	0.47	2.03	6.4
	3.5	40	0.9	3.15	0.9	0.02	9.62	11.00	0.88	4.16	240	1.2	1.40	1.97	2.735	3	3.00	2.88	1.52	3.15	7.7
	3.5	60	1.22	4.27	0.9	0.02	9.62	11.00	0.88	6.24	240	1.2	3.16	2.43	2.965	3	3.00	2.88	3.28	4.27	8.4
	3.5	80	1.7	5.95	0.9	0.02	9.62	11.00	0.88	8.32	240	1.2	5.61	2.79	3.145	3	3.15	2.88	5.87	5.95	8.3
	3.5	100	2.2	7.7	0.9	0.02	9.62	11.00	0.88	10.39	240	1.2	8.77	3.07	3.285	3	3.29	2.88	9.17	9.17	10.4
	3.5	120	3.1	10.85	0.9	0.02	9.62	11.00	0.88	12.47	240	1.2	12.62	3.25	3.375	3	3.38	2.88	13.12	13.12	12.5

* Has TWO 3.5-foot diameter culverts. Thus, each culvert carries one half of discharge.

24/

25

CHART 5



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BUREAU OF PUBLIC ROADS JAN. 1963

HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

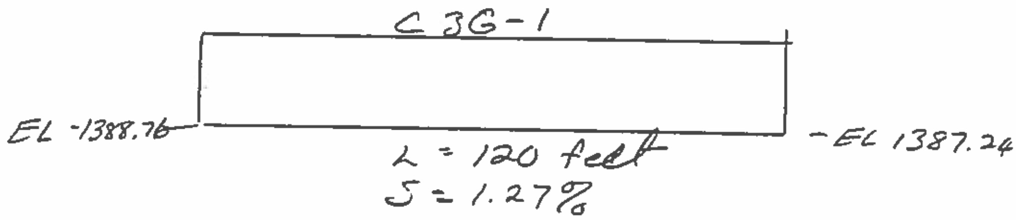
HA&L ENGINEERING

CLIENT: Laidlaw
PROJECT: Lme. Mtn. Storm Drainage Rev.
FEATURE: Hydrology - Channel Design
PROJECT NO.: 64163.100

SHEET: 26 OF
COMPUTED: DMA
CHECKED: KCS
DATE: 4/21/98

Rev 9/17/99

- Stage Discharge - 7' Box Culvert Between Runon Pond 1 and D3H-1 (Alternative 1)



To be conservative, for a tailwater depth, route Basin 3-H, first through Channel D3H-1 and determine maximum stage through Culverts C3H-1. Then use this maximum stage as the beginning tailwater for C3G-1. The 25 yr 24-h peak from Basin 3-H is 94 cfs when routed through the channel. The peak stage is 1390.4 ft.

Evaluate box culvert stage discharge relationship for both inlet and outlet conditions. For tailwater add additional flow rate to stage discharge relationship for C3H-1.

Q cfs	Tailwater
0	3.16
40	4.45
80	6.63
120	10.08

See Attached spreadsheet for Box Culvert Eval.

Stage Discharge

ELEV ft	Discharge cfs
1388.76	0
1390.40	0
1391.71	40
1393.96	80
1397.53	120

REVISED SEP 3 1999

LAIDLAW ENVIRONM[illegible]L SERVICES - LONE MOUNTAIN
STORM DRAINAGE REVISIONS
April 24, 1998

COMPARES INLET VERSUS OUTLET CONDITIONS
Inlet Control Uses U.S. D.O.T. Hydraulic Charts for the Selection of Highway Culverts
Outlet Control - Assumes Full Flowing Pipe with the following:

Ke = Entrance Loss Coefficient = 0.9 for projecting from fill, no headwall, 0.5 for headwall condition
H = (1 + Ke + (29*n ^ 2*L)/(R ^ 1.33))*V ^ 2/2g
HW = H +ho - LSo

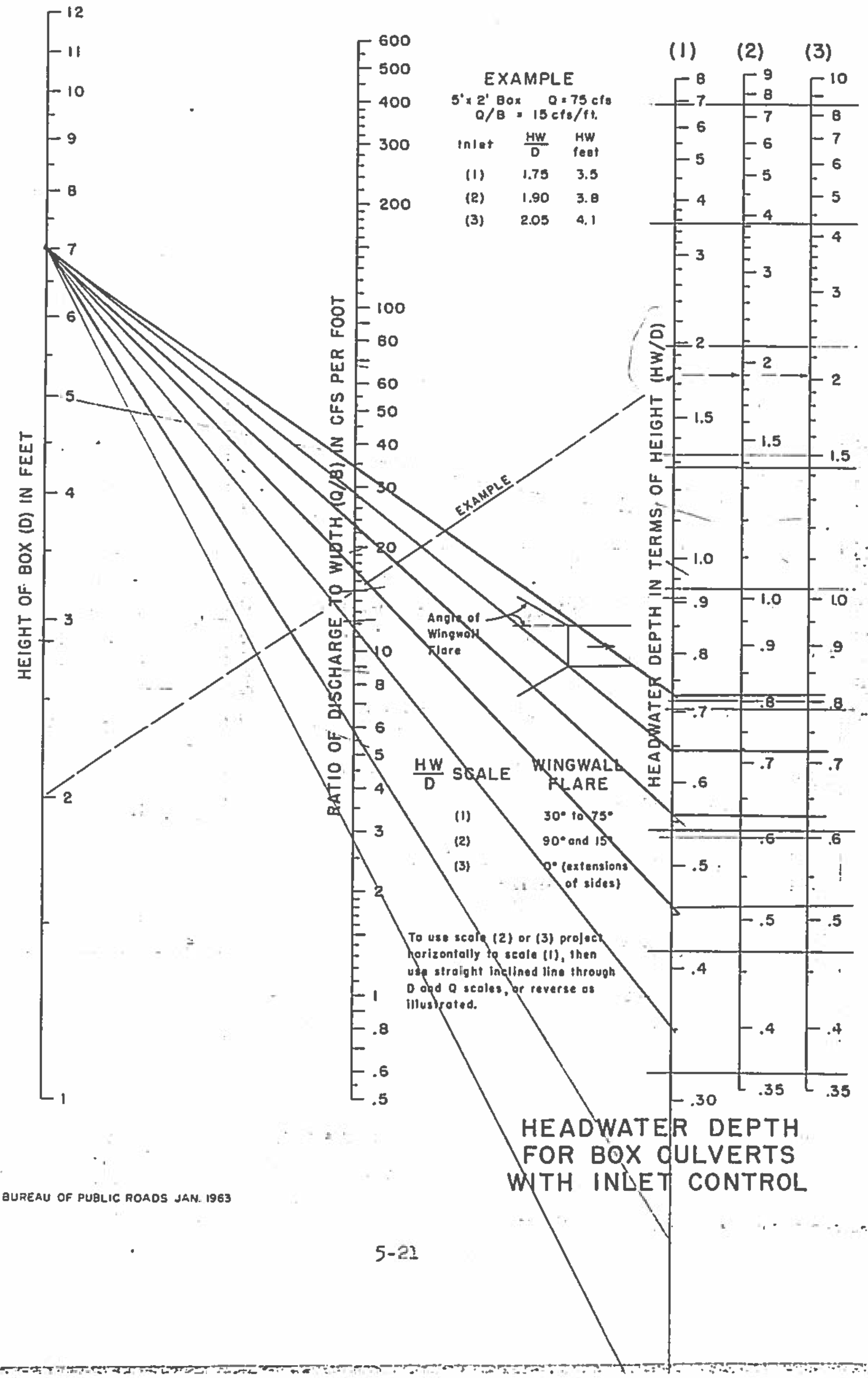
Assume: All culverts have projecting entrance types, no headwall
All culverts are CMP
BOX CULVERT DIMENSIONS 7 X 7

			INLET CONTROL		OUTLET CONTROL																
CULVERT NO.	CULVERT HEIGHT ft	DISCHARGE cfs	HW/D	HW ft	Ke	Manning's n	Flow Area A ft2	Wetted Perimeter P ft	Hydraulic Radius R ft	Velocity Full Pipe V fps	Culvert Length L ft	Culvert Slope So %	H ft	Critical Depth dc ft	(dc+D)/2 ft	Tailwater Depth TW ft	ho ft	LSo ft.	HW ft	CONTROLLING HW ft	OUTLET VELOCITY fps
C3G-1	7	40	0.25	1.75	0.9	0.015	49.00	28.00	1.75	0.82	120	1.27	0.02	1	4	4.45	4.45	1.52	2.95	2.95	
	7	80	0.4	2.8	0.9	0.015	49.00	28.00	1.75	1.63	120	1.27	0.09	1.59	4.295	6.63	6.63	1.52	5.20	5.20	
	7	120	0.52	3.64	0.9	0.015	49.00	28.00	1.75	2.45	120	1.27	0.21	2.09	4.545	10.08	10.08	1.52	8.77	8.77	

27/

28/

CHART I



HEADWATER DEPTH
FOR BOX CULVERTS
WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

HA&L ENGINEERING

CLIENT Laidlaw
PROJECT Lone Mtn. Storm Drainage Rev.
FEATURE Hydrology - Channel Design
PROJECT NO. 64.63.150

SHEET 29 OF NA
COMPUTED MA
CHECKED KCS
DATE 4/21/98

4 - Run-on Channel Design

A - Runon - Channel No. 1

Run-on Channel No 1 was originally designed for a 100-yr, 24-hr peak flow rate of 155 cfs. However, due to modifications to tributary areas to Channel No. 1, the revised 25yr 24 hr peak flow rate is only 47 cfs.

Since the channel was designed for a much higher peak flow rate, no modifications to the original design are necessary.

See Attachment 4 for original calculations based on 155 cfs.

B - Runon - Channel No. 2.

Run-on Channel No. 2 was originally designed for a 100yr, 24-hr peak flow rate of 152 cfs. However, due to modifications in tributary areas or hydrologic characteristics associated with Channel No. 2, the revised 25-yr, 24-hr peak flowrate outletting from the culvert into Channel No 2 is 39 cfs.
The 25yr 24hr peak flowrate for Channel No. 2 is 61 cfs.

Since the channel was originally designed for a larger peak flow rate, no modifications to the original design are necessary. See Attachment 5 for original design calculations based on an outflow from the existing culvert between Run-on Detention Pond 2 and Channel No. 2 of 65 cfs and a design flow rate for Channel No. 2 of 152 cfs.

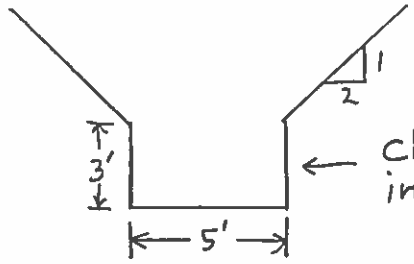
HA&L ENGINEERING

CLIENT: Laidlaw
PROJECT: Lone Mtn Storm Drainage
FEATURE: Hydrology - Channel Design
PROJECT NO.: 64.63.100

SHEET 30A OF
COMPUTED: SCG
CHECKED:
DATE: 9/17/99

C- Runon Channel D3H-1 / Pond No. 1

- Channel Section



Channel cut down in Mudstone Formation

Alternative 1

- Flowrate - 25 yr, 24-hr = 165 cfs
- channel Slope = 0.0004 ft/ft
- see attached spreadsheet for solution to Manning's Equation:

Uniform Flow depth, y = 8.29 ft

Velocity = 1.70 fps

Due to the low velocity, channel should be stable without any additional erosion protection.

Alternative 2

- Flowrate - 25 yr, 24-hr = 206 cfs
- channel Slope = 0.0004 ft/ft
- see attached spreadsheet for solution to Manings Equation:

Uniform Flow depth, y = 8.92 ft

Velocity = 1.80 fps

Due to the low velocity, channel/Pond should be stable without any additional erosion protection.

Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	17-Sep-99
Project No. :	64.63.100	Time :	02:21 PM
Channel Section:	CHANNEL D3H-1 (ALTERNATIVE 1)	Computed	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	165.00	cfs
	Bottom Width:	5.0	feet
	Side Slope1:	2.0	1/m1
	Side Slope2:	2.0	1/m2
	Friction Factor:		
	Assumed D50:	0.00	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	5	
	Input n value for X=5:	0.035	
	Min. Bottom Slope:	0.0004	ft/ft
	Max. Bottom Slope:	0.0004	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	8.29	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.035	
	Required Depth:	9.29	feet
	Area:	97.33	ft2
	Perimeter:	34.64	feet
	Hydraulic Radius (R):	2.81	feet
	Velocity:	1.70	ft/sec
	Froude Number:	0.19	
CALCULATION: (Velocity Check)	Depth (Max. S):	8.29	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.035	
	Required Depth:	8.79	feet
	Area:	97.33	ft2
	Perimeter:	34.64	feet
	Hydraulic Radius (R):	2.81	feet
	Velocity:	1.70	ft/sec
	Froude Number:	0.19	

DESIGN CRITERIA:	Bottom Width:	5.0	feet
	Side Slope 1:	2.0	1/m1
	Side Slope 2:	2.0	1/m2
	Min. Bottom Slope:	0.0	%
	Max. Bottom Slope:	0.0	%
	Min Channel Depth:	9.29	feet

30C/

Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	17-Sep-99
Project No. :	64.63.100	Time :	02:18 PM
Channel Section:	CHANNEL D3H-1 (ALTERNATIVE 2)	Computed	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	206.00	cfs
	Bottom Width:	5.0	feet
	Side Slope1:	2.0	1/m1
	Side Slope2:	2.0	1/m2
	Friction Factor:		
	Assumed D50:	0.00	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	5	
	Input n value for X=5:	0.035	
	Min. Bottom Slope:	0.0004	ft/ft
	Max. Bottom Slope:	0.0004	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	8.92	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.035	
	Required Depth:	9.92	feet
	Area:	114.76	ft2
	Perimeter:	37.48	feet
	Hydraulic Radius (R):	3.06	feet
	Velocity:	1.80	ft/sec
	Froude Number:	0.19	
CALCULATION: (Velocity Check)	Depth (Max. S):	8.92	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.035	
	Required Depth:	9.42	feet
	Area:	114.76	ft2
	Perimeter:	37.48	feet
	Hydraulic Radius (R):	3.06	feet
	Velocity:	1.80	ft/sec
	Froude Number:	0.19	

DESIGN CRITERIA:	Bottom Width:	5.0	feet
	Side Slope 1:	2.0	1/m1
	Side Slope 2:	2.0	1/m2
	Min. Bottom Slope:	0.0	%
	Max. Bottom Slope:	0.0	%
	Min Channel Depth:	9.92	feet

HA&L ENGINEERING

CLIENT Laidlaw
PROJECT Lone Mtn Storm Drainage
FEATURE Hydrology - Channel Design
PROJECT NO. 64.63.100

SHEET 31 OF ___
COMPUTED SCQ
CHECKED ___
DATE 9/17/99

D- Run-on Channel No. 3.

Run-on channel No. 3 was originally designed for a peak flow rate of 140 cfs in its upper reach and 205 cfs in its lower reach. Due to modifications in hydrology, channels, etc., the revised 25-yr, 24-hr peak flow rate to the upper reach is 101 cfs.
The peak flow rate to the lower reach and below the lower reach is: 261 cfs (alternative 1)

304 cfs (alternative 2)

SEE original calculations in Attachment 6

See revised calculations below for lower section only @ 261 cfs for Alternative 1 and 304 cfs for Alternative 2.

Rev 9/17/99

- Channel Section - Trapezoidal
From station 0+00 to 3+10:
$b = 15'$
$m = 3:1$
Riprap $D_{50} = 14'' = 1.17$ ft

From station 3+10 to 8+00
$b = 12'$
$m = 3:1$
$D_{50} = 9'' = 0.75'$

Solve Manning's Equation and check riprap safety factor using Colorado State University safety factor method.

See attached spreadsheets for solutions:

Parameter	Alternative 1	Alternative 2	Section
Flow Depth (ft)	2.09	2.27	0+00+3+10
	2.21	2.39	3+10 to 8+00
Riprap S.F.	1.99	1.96	0+00 to 3+10
	1.65	1.60	3+10 to 8+00

Since Safety Factor (S.F.) > 1.3 OK

Riprap Channel Depth = 2.9 ft.

	Alternative 1	Alternative 2	Section
Freeboard (ft)	0.81	0.63	0+00+3+10
	0.69	0.51	3+10+8+00

OK.

E- Runon Channel No 4

Runon Channel No. 4, was originally designed for a peak flow rate of 965 cfs. Due to modifications in tributary area, design event etc. the peak flow rate from the 25yr 24hr event is: 691 cfs. (Alternative 1)
758 cfs (Alternative 2)

Since the channel was designed for a higher flow rate, no modifications to the original design are necessary.

See Attachment 7 for original calculation based on a flow rate of 965 cfs.

33A/

Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW	Date :	17-Sep-99
Project No. :	64.63.100	Time :	02:36 PM
Channel Section:	CHANNEL NO. 3 LOWER(ALTERNATIVE 1)	Computed	MEA

SECTION 0+00 to 3+10

			UNITS
GENERAL CRITERIA:	Design Flow:	261.00	cfs
	Bottom Width:	15.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	1.17	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	' AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	1	
	Input n value for X=5:	0.035	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	2.09	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.041	
	Required Depth:	3.09	feet
	Area:	44.37	ft2
	Perimeter:	28.20	feet
	Hydraulic Radius (R):	1.57	feet
	Velocity:	5.88	ft/sec
	Froude Number:	0.82	
CALCULATION: (Velocity Check)	Depth (Max. S):	2.09	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.041	
	Required Depth:	3.09	feet
	Area:	44.37	ft2
	Perimeter:	28.20	feet
	Hydraulic Radius (R):	1.57	feet
	Velocity:	5.88	ft/sec
	Froude Number:	0.82	

DESIGN CRITERIA:	Bottom Width:	15.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	3.09	feet

33B1

RIPRAP DESIGN - Using Safety Factor Methodology from Haan, Barfield and Hayes, 1994

Client :	LAIDLAW	Date :	17-Sep-99
Project No. :	64.63.100	Time :	02:36 PM
Channel Section:	CHANNEL NO. 3 LOWER(ALTERNATIVE 1)	Computed:	MEA

			UNITS
DESIGN CRITERIA:	Design Flow:	261.00	cfs
	Bottom Width:	15.00	feet
	Side Slope1:	3.00	1/m1
	Side Slope2:	3.00	1/m2
	Friction Factor:	0.04	
	Min. Bottom Slope (S):	0.014	ft/ft
	Max. Bottom Slope (S):	0.014	ft/ft
	Flow Depth (d) @ Min. S:	2.09	feet
	Flow Depth (d) @ Max. S:	2.09	feet
	Angle Repose (Ar):	41	degrees
	Specific Gravity (SG):	2.65	
	Reynolds No. = U*D50/v, where U=Shear Velocity, v=viscosity		
	U=(gRS)^0.5 for Smin	0.84	
	Reynolds No. for Smin	70386	
	U=(gRS)^0.5 for Smax	0.84	
	Reynolds No. for Smax	70386	
	T = G*d*S where G=unit weight of water		
	Nb = F*T/(G(SG-1)D50)		
	F=(1/0.047)=21.3 for flat slopes with Reynolds No. < 500		
	F=(1/0.062)=16.1 for 500 < Reynolds No. < 40,000		
	F=varies from (1/0.062)=16.1 for Reynolds = 40,000 to (1/0.25)=4 for Reynolds No. = 500,000 or larger		
	F for Smin:	15.2	
	F for Smax:	15.2	
	SFb = (Cos a tan b)/(sin a + Nb tan b)		
	Tmax= K*G*d*S		
	Set K=0.75 for 1.5:1 slope, 0.76 for 2:1 slope, and 0.85 for 3:1 slope		
	K:	0.85	
	Ns = F*Tmax/(G(SG-1)D)		
	A = Atan(1/m)		
	B = Atan(Cos(Ar)/(2Sin(A)/NsTan)Ar))+Sin(Ar))		
	n = Ns(1+Sin(Ar+B)/2)		
	SFs = Cos(A)Tan(Ar)/(nTan(Ar)+Sin(A)Cos(B))		

	Smin	Smax	
D50	1.17	1.17	feet
T	1.82	1.82	lb/ft2
Nb	0.23	0.23	
Tmax	1.55	1.55	lb/ft2
Ns	0.20	0.20	
m Critical	3.00	3.00	
A (m crit)	18.44	18.44	degrees
B	14.99	14.99	degrees
Nsp	0.12	0.12	
SFb	4.06	4.06	
SFs	1.99	1.99	

34A1

Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW	Date :	17-Sep-99
Project No. :	64.63.100	Time :	02:40 PM
Channel Section:	CHANNEL NO. 3 LOWER(ALTERNATIVE 2)	Computed	MEA

SECTION 0+00 to 3+10

			UNITS
GENERAL CRITERIA:	Design Flow:	304.00	cfs
	Bottom Width:	15.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	1.17	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	1	
	Input n value for X=5:	0.035	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	2.27	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.041	
	Required Depth:	3.27	feet
	Area:	49.40	ft2
	Perimeter:	29.33	feet
	Hydraulic Radius (R):	1.68	feet
	Velocity:	6.15	ft/sec
	Froude Number:	0.83	
CALCULATION: (Velocity Check)	Depth (Max. S):	2.27	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.041	
	Required Depth:	3.27	feet
	Area:	49.40	ft2
	Perimeter:	29.33	feet
	Hydraulic Radius (R):	1.68	feet
	Velocity:	6.15	ft/sec
	Froude Number:	0.83	

DESIGN CRITERIA:	Bottom Width:	15.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	3.27	feet

34B/

RIPRAP DESIGN - Using Safety Factor Methodology from Haan, Barfield and Hayes, 1994

Client :	LAIDLAW	Date :	17-Sep-99
Project No. :	64.63.100	Time :	02:40 PM
Channel Section:	CHANNEL NO. 3 LOWER(ALTERNATIVE 2)	Computed:	MEA

DESIGN CRITERIA:

		UNITS
Design Flow:	304.00	cfs
Bottom Width:	15.00	feet
Side Slope1:	3.00	1/m1
Side Slope2:	3.00	1/m2
Friction Factor:	0.04	
Min. Bottom Slope (S):	0.014	ft/ft
Max. Bottom Slope (S):	0.014	ft/ft
Flow Depth (d) @ Min. S:	2.27	feet
Flow Depth (d) @ Max. S:	2.27	feet
Angle Repose (Ar):	41	degrees
Specific Gravity (SG):	2.65	

Reynolds No. = U*D50/v, where U=Shear Velocity, v=viscosity

U=(gRS)^0.5 for Smin	0.87
Reynolds No. for Smin	72816
U=(gRS)^0.5 for Smax	0.87
Reynolds No. for Smax	72816

T = G*d*S where G=unit weight of water

Nb = F*T/(G(SG-1)D50)

F=(1/0.047)=21.3 for flat slopes with Reynolds No. < 500

F=(1/0.062)=16.1 for 500 < Reynolds No. < 40,000

F=varies from (1/0.062)=16.1 for Reynolds = 40,000 to (1/0.25)=4 for Reynolds No. = 500,000 or larger

F for Smin:	14.9
F for Smax:	14.9

SFb = (Cos a tan b)/(sin a + Nb tan b)

Tmax= K*G*d*S

Set K=0.75 for 1.5:1 slope, 0.76 for 2:1 slope, and 0.85 for 3:1 slope

K: 0.85

Ns = F*Tmax/(G(SG-1)D)

A = Atan(1/m)

B = Atan(Cos(Ar)/(2Sin(A)/NsTan)Ar))+Sin(Ar))

n = Ns(1+Sin(Ar+B)/2)

SFs = Cos(A)Tan(Ar)/(nTan(Ar)+Sin(A)Cos(B))

	Smin	Smax	
D50	1.17	1.17	feet
T	1.98	1.98	lb/ft2
Nb	0.24	0.24	
Tmax	1.68	1.68	lb/ft2
Ns	0.21	0.21	
m Critical	3.00	3.00	
A (m crit)	18.44	18.44	degrees
B	15.90	15.90	degrees
Nsp	0.13	0.13	
SFb	3.83	3.83	
SFs	1.96	1.96	

35A/

Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW	Date :	17-Sep-99
Project No. :	64.63.100	Time :	02:45 PM
Channel Section:	CHANNEL NO. 3 LOWER(ALTERNATIVE 1)	Computed	MEA

SECTION 3+10 to 8+00

			UNITS
GENERAL CRITERIA:	Design Flow:	261.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	1	
	Input n value for X=5:	0.035	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	2.21	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.038	
	Required Depth:	3.21	feet
	Area:	41.05	ft2
	Perimeter:	25.95	feet
	Hydraulic Radius (R):	1.58	feet
	Velocity:	6.36	ft/sec
	Froude Number:	0.88	
CALCULATION: (Velocity Check)	Depth (Max. S):	2.21	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.038	
	Required Depth:	3.21	feet
	Area:	41.05	ft2
	Perimeter:	25.95	feet
	Hydraulic Radius (R):	1.58	feet
	Velocity:	6.36	ft/sec
	Froude Number:	0.88	

DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	3.21	feet

3513/

RIPRAP DESIGN - Using Safety Factor Methodology from Haan, Barfield and Hayes, 1994

Client :	LAIDLAW	Date :	17-Sep-99
Project No. :	64.63.100	Time :	02:45 PM
Channel Section:	CHANNEL NO. 3 LOWER(ALTERNATIVE 1)	Computed:	MEA

			UNITS
DESIGN CRITERIA:	Design Flow:	261.00	cfs
	Bottom Width:	12.00	feet
	Side Slope1:	3.00	1/m1
	Side Slope2:	3.00	1/m2
	Friction Factor:	0.04	
	Min. Bottom Slope (S):	0.014	ft/ft
	Max. Bottom Slope (S):	0.014	ft/ft
	Flow Depth (d) @ Min. S:	2.21	feet
	Flow Depth (d) @ Max. S:	2.21	feet
	Angle Repose (Ar):	41	degrees
	Specific Gravity (SG):	2.65	

Reynolds No. = U*D50/v, where U=Shear Velocity, v=viscosity

U=(gRS)^0.5 for Smin	0.84	
Reynolds No. for Smin	45243	
U=(gRS)^0.5 for Smax	0.84	
Reynolds No. for Smax	45243	

T = G*d*S where G=unit weight of water

Nb = F*T/(G(SG-1)D50)

F=(1/0.047)=21.3 for flat slopes with Reynolds No. < 500

F=(1/0.062)=16.1 for 500 < Reynolds No. < 40,000

F=varies from (1/0.062)=16.1 for Reynolds = 40,000 to (1/0.25)=4 for Reynolds No. = 500,000 or larger

F for Smin: 16

F for Smax: 16

SFb = (Cos a tan b)/(sin a + Nb tan b)

Tmax= K*G*d*S

Set K=0.75 for 1.5:1 slope, 0.76 for 2:1 slope, and 0.85 for 3:1 slope

K: 0.85

Ns = F*Tmax/(G(SG-1)D)

A = Atan(1/m)

B = Atan(Cos(Ar)/(2Sin(A)/NsTan)Ar))+Sin(Ar))

n = Ns(1+Sin(Ar+B)/2)

SFs = Cos(A)Tan(Ar)/(nTan(Ar)+Sin(A)Cos(B))

	Smin	Smax	
D50	0.75	0.75	feet
T	1.93	1.93	lb/ft2
Nb	0.40	0.40	
Tmax	1.64	1.64	lb/ft2
Ns	0.34	0.34	
m Critical	3.00	3.00	
A (m crit)	18.44	18.44	degrees
B	24.85	24.85	degrees
Nsp	0.24	0.24	
SFb	2.41	2.41	
SFs	1.65	1.65	

36A/

Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW	Date :	17-Sep-99
Project No. :	64.63.100	Time :	02:44 PM
Channel Section:	CHANNEL NO. 3 LOWER(ALTERNATIVE 2)	Computed	MEA

SECTION 3+10 to 8+00

			UNITS
GENERAL CRITERIA:	Design Flow:	304.00	cfs
	Bottom Width:	12.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.75	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	1	
	Input n value for X=5:	0.035	
	Min. Bottom Slope:	0.0140	ft/ft
	Max. Bottom Slope:	0.0140	ft/ft
	Freeboard:	1.00	feet
CALCULATION:	Depth (Min. S):	2.39	feet
(Channel Depth)			
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.038	
	Required Depth:	3.39	feet
	Area:	45.78	ft2
	Perimeter:	27.11	feet
	Hydraulic Radius (R):	1.69	feet
	Velocity:	6.64	ft/sec
	Froude Number:	0.89	
CALCULATION:	Depth (Max. S):	2.39	feet
(Velocity Check)			
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.038	
	Required Depth:	3.39	feet
	Area:	45.78	ft2
	Perimeter:	27.11	feet
	Hydraulic Radius (R):	1.69	feet
	Velocity:	6.64	ft/sec
	Froude Number:	0.89	

DESIGN CRITERIA:	Bottom Width:	12.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.4	%
	Max. Bottom Slope:	1.4	%
	Min Channel Depth:	3.39	feet

RIPRAP DESIGN - Using Safety Factor Methodology from Haan, Barfield and Hayes, 1994

Client :	LAIDLAW	Date :	17-Sep-99
Project No. :	64.63.100	Time :	02:44 PM
Channel Section:	CHANNEL NO. 3 LOWER(ALTERNATIVE 2)	Computed:	MEA

			UNITS
DESIGN CRITERIA:	Design Flow:	304.00	cfs
	Bottom Width:	12.00	feet
	Side Slope1:	3.00	1/m1
	Side Slope2:	3.00	1/m2
	Friction Factor:	0.04	
	Min. Bottom Slope (S):	0.014	ft/ft
	Max. Bottom Slope (S):	0.014	ft/ft
	Flow Depth (d) @ Min. S:	2.39	feet
	Flow Depth (d) @ Max. S:	2.39	feet
	Angle Repose (Ar):	41	degrees
	Specific Gravity (SG):	2.65	

Reynolds No. = U*D50/v, where U=Shear Velocity, v=viscosity

U=(gRS)^0.5 for Smin	0.87
Reynolds No. for Smin	46743
U=(gRS)^0.5 for Smax	0.87
Reynolds No. for Smax	46743

T = G*d*S where G=unit weight of water

Nb = F*T/(G(SG-1)D50)

F=(1/0.047)=21.3 for flat slopes with Reynolds No. < 500

F=(1/0.062)=16.1 for 500 < Reynolds No. < 40,000

F=varies from (1/0.062)=16.1 for Reynolds = 40,000 to (1/0.25)=4 for Reynolds No. = 500,000 or larger

F for Smin:	15.9
F for Smax:	15.9

SFb = (Cos a tan b)/(sin a + Nb tan b)

Tmax= K*G*d*S

Set K=0.75 for 1.5:1 slope, 0.76 for 2:1 slope, and 0.85 for 3:1 slope

K: 0.85

Ns = F*Tmax/(G(SG-1)D)

A = Atan(1/m)

B = Atan(Cos(Ar)/(2Sin(A)/NsTan)Ar))+Sin(Ar))

n = Ns(1+Sin(Ar+B)/2)

SFs = Cos(A)Tan(Ar)/(nTan(Ar)+Sin(A)Cos(B))

	Smin	Smax	
D50	0.75	0.75	feet
T	2.09	2.09	lb/ft2
Nb	0.43	0.43	
Tmax	1.77	1.77	lb/ft2
Ns	0.37	0.37	
m Critical	3.00	3.00	
A (m crit)	18.44	18.44	degrees
B	26.49	26.49	degrees
Nsp	0.27	0.27	
SFb	2.24	2.24	
SFs	1.60	1.60	

36C/

Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	05-May-98
Project No. :	64.63.100	Time :	11:35 AM
Channel Section:	RUNON CHANNEL NO. 4 @ POND 3 OU	Compute	MEA

Alternative 1

For 5% slope option at outlet to Pond No. 3. Use 24" Dia Riprap D50, no grout.

			UNITS
GENERAL CRITERIA:	Design Flow:	616.00	cfs
	Bottom Width:	18.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	2.00	feet ← 24" D50
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0117	ft/ft
	Max. Bottom Slope:	0.0500	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	4.95	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.094	
	Required Depth:	5.95	feet
	Area:	162.68	ft2
	Perimeter:	49.32	feet
	Hydraulic Radius (R):	3.30	feet
	Velocity:	3.79	ft/sec
	Froude Number:	0.36	
CALCULATION: (Velocity Check)	Depth (Max. S):	3.67	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.108	
	Required Depth:	4.17	feet
	Area:	106.40	ft2
	Perimeter:	41.20	feet
	Hydraulic Radius (R):	2.58	feet
	Velocity:	5.79	ft/sec
	Froude Number:	0.63	

DESIGN CRITERIA:	Bottom Width:	18.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.2	%
	Max. Bottom Slope:	5.0	%
	Min Channel Depth:	5.95	feet

360

RIPRAP DESIGN - Using Safety Factor Methodology from Haan, Barfield and Hayes, 1994

Client :	LAIDLAW/ECDC	Date :	05-May-98
Project No. :	64.63.100	Time :	11:35 AM
Channel Section:	RUNON CHANNEL NO. 4 @ POND 3 OU	Computed	MEA

			UNITS
DESIGN CRITERIA:	Design Flow:	616.00	cfs
	Bottom Width:	18.00	feet
	Side Slope1:	3.00	1/m1
	Side Slope2:	3.00	1/m2
	Friction Factor:	0.03	
	Min. Bottom Slope (S):	0.012	ft/ft
	Max. Bottom Slope (S):	0.050	ft/ft
	Flow Depth (d) @ Min. S:	4.95	feet
	Flow Depth (d) @ Max. S:	3.67	feet
	Angle Repose (Ar):	41	degrees
	Specific Gravity (SG):	2.65	

Reynolds No. = U*D50/v, where U=Shear Velocity, v=viscosity

U=(gRS)^0.5 for Smin	1.11	
Reynolds No. for Smin	159255	
U=(gRS)^0.5 for Smax	2.04	
Reynolds No. for Smax	291298	

T = G*d*S where G=unit weight of water

Nb = F*T/(G(SG-1)D50)

F=(1/0.047)=21.3 for flat slopes with Reynolds No. < 500

F=(1/0.062)=16.1 for 500 < Reynolds No. < 40,000

F=varies from (1/0.062)=16.1 for Reynolds = 40,000 to (1/0.25)=4 for Reynolds No. = 500,000 or larger

F for Smin:	12.5
F for Smax:	9.09

SFb = (Cos a tan b)/(sin a + Nb tan b)

Tmax= K*G*d*S

Set K=0.75 for 1.5:1 slope, 0.76 for 2:1 slope, and 0.85 for 3:1 slope

K: 0.85

Ns = F*Tmax/(G(SG-1)D)

A = Atan(1/m)

B = Atan(Cos(Ar)/(2Sin(A)/NsTan)Ar))+Sin(Ar))

n = Ns(1+Sin(Ar+B)/2)

SFs = Cos(A)Tan(Ar)/(nTan(Ar)+Sin(A)Cos(B))

	Smin	Smax	
D50	2.00	2.00	feet
T	3.61	11.45	lb/ft2
Nb	0.22	0.51	
Tmax	3.07	9.73	lb/ft2
Ns	0.19	0.43	
m Critical	3.00	3.00	
A (m crit)	18.44	18.44	degrees
B	14.33	29.79	degrees
Nsp	0.12	0.33	
SFb	4.29	1.77	
SFs	2.02	1.47	

36E/

Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW	Date :	17-Sep-99
Project No. :	64.63.100	Time :	03:03 PM
Channel Section:	CHANNEL NO. 4 @ POND 3 OUT(ALT 2)	Computed	MEA

Alternative 2

For 5% slope option at outlet to Pond No. 3. Use 24" Dia Riprap, D50 No Grout

			UNITS
GENERAL CRITERIA:	Design Flow:	682.00	cfs
	Bottom Width:	18.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	2.00	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, input n value		
	X:	3	
	Input n value for X=5:	0.000	
	Min. Bottom Slope:	0.0117	ft/ft
	Max. Bottom Slope:	0.0500	ft/ft
	Freeboard:	1.00	feet
CALCULATION: (Channel Depth)	Depth (Min. S):	5.17	feet
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.093	
	Required Depth:	6.17	feet
	Area:	173.01	ft2
	Perimeter:	50.67	feet
	Hydraulic Radius (R):	3.41	feet
	Velocity:	3.94	ft/sec
	Froude Number:	0.37	
CALCULATION: (Velocity Check)	Depth (Max. S):	3.82	feet
	Q-1.49AR(2/3)S(1/2)/n=	0.000	Accuracy
	Calc n Value	0.106	
	Required Depth:	4.82	feet
	Area:	112.73	ft2
	Perimeter:	42.19	feet
	Hydraulic Radius (R):	2.67	feet
	Velocity:	6.05	ft/sec
	Froude Number:	0.64	

DESIGN CRITERIA:	Bottom Width:	18.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	1.2	%
	Max. Bottom Slope:	5.0	%
	Min Channel Depth:	6.17	feet

36F

RIPRAP DESIGN - Using Safety Factor Methodology from Haan, Barfield and Hayes, 1994

Client :	LAIDLAW	Date :	17-Sep-99
Project No. :	64.63.100	Time :	03:03 PM
Channel Section:	CHANNEL NO. 4 @ POND 3 OUT(ALT 2)	Computed:	MEA

			UNITS
DESIGN CRITERIA:	Design Flow:	682.00	cfs
	Bottom Width:	18.00	feet
	Side Slope1:	3.00	1/m1
	Side Slope2:	3.00	1/m2
	Friction Factor:	0.00	
	Min. Bottom Slope (S):	0.012	ft/ft
	Max. Bottom Slope (S):	0.050	ft/ft
	Flow Depth (d) @ Min. S:	5.17	feet
	Flow Depth (d) @ Max. S:	3.82	feet
	Angle Repose (Ar):	41	degrees
	Specific Gravity (SG):	2.65	

Reynolds No. = U*D50/v, where U=Shear Velocity, v=viscosity

U=(gRS)^0.5 for Smin	1.13
Reynolds No. for Smin	162030
U=(gRS)^0.5 for Smax	2.07
Reynolds No. for Smax	296302

T = G*d*S where G=unit weight of water

Nb = F*T/(G(SG-1)D50)

F=(1/0.047)=21.3 for flat slopes with Reynolds No. < 500

F=(1/0.062)=16.1 for 500 < Reynolds No. < 40,000

F=varies from (1/0.062)=16.1 for Reynolds = 40,000 to

(1/0.25)=4 for Reynolds No. = 500,000 or larger

F for Smin:	12.5
F for Smax:	9.09

SFb = (Cos a tan b)/(sin a + Nb tan b)

Tmax= K*G*d*S

Set K=0.75 for 1.5:1 slope, 0.76 for 2:1 slope, and 0.85 for 3:1 slope

K: 0.85

Ns = F*Tmax/(G(SG-1)D)

A = Atan(1/m)

B = Atan(Cos(Ar)/(2Sin(A)/NsTan)Ar))+Sin(Ar))

n = Ns(1+Sin(Ar+B)/2)

SFs = Cos(A)Tan(Ar)/(nTan(Ar)+Sin(A)Cos(B))

	Smin	Smax	
D50	2.00	2.00	feet
T	3.77	11.93	lb/ft2
Nb	0.23	0.53	
Tmax	3.21	10.14	lb/ft2
Ns	0.19	0.45	
m Critical	3.00	3.00	
A (m crit)	18.44	18.44	degrees
B	14.92	30.80	degrees
Nsp	0.12	0.35	
SFb	4.13	1.71	
SFs	2.00	1.44	

HA&L ENGINEERING

CLIENT Laidlaw
PROJECT Lone Mtn. Storm Drainage
FEATURE Hydrology - Channel Design
PROJECT NO. 64.163.100

SHEET 37 OF
COMPUTED M.A.
CHECKED KCS
DATE 4/30/98

F- Run-on Channel No. 5

The upper reach of Run-on Channel No. 5 was originally designed for a peak flow rate of 540 cfs and the lower reach for a peak flow rate of 1130 cfs. Due to modifications in tributary areas, design event, etc. the peak flow rate from the 25 yr, 24-hr event is only 342 cfs for the upper reach and 633 cfs for the lower reach.

Since the channel was designed for a higher flow rate, no modifications to the original design are necessary.

See Attachment 8 for original calculations based on 540 cfs for the upper reach and 1130 cfs for the lower reach.

5 - Culverts

A - Culvert C2A-1

Culvert C2A-1 is the outlet to Run-on Detention Pond No. 2. Flow characteristics of this culvert are addressed in Section 3A of these calculations - sheet 7.

B - Culvert C3G-1 and C3H-1.

Flow characteristics of these two culverts are addressed in Section 3C of these calculations associated with Run-on Detention Pond No. 1.

C - Culvert C4B-1

This culvert was originally designed for a peak flow rate of 45 cfs. Due to modifications in the tributary areas, design event, etc. the design peak flow rate from the 25-yr 24 hr event is only 12 cfs.

Since the culvert was designed for a larger flow rate, no modifications to the original design are necessary.

See Attachment 9 for original calculations based on a flow rate of 45 cfs.

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CLIENT Laidlaw
PROJECT Lone Mtn - Storm Drainage Rev.
FEATURE Hydrology - Channel Design
PROJECT NO. 64.63.100

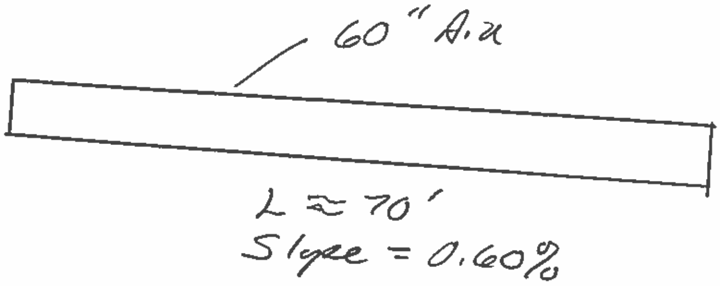
SHEET 39 OF
COMPUTED
CHECKED
DATE 4/30/98

D- Culvert C56-1

Culverts C56-1 consist of 4 parallel 60-inch diameter culverts. TOT

25yr 24-hr peak = 522 cfs

Culvert Section:



=3.27 ft.

Check requirements for inlet; outlet control Using "Hydraulic Charts for Selection of Highway Culverts" HEC 5, Federal Highway Administration.

Assume the tailwater depth is equal to the normal flow depth in the channel downstream at 522 cfs. See attached solution to Manning's equation for normal flow depth.

$y_0 = 2.21$ ft.

See attached printout for solution to culvert headwater (HW) determination.

Required HW = 5.61 feet which is slightly above the top of the culvert. Therefore, culverts have sufficient capacity to pass the 25-yr 24-hr event.

Trapezoidal Channel Flow Calculations using Mannings Equation

Client :	LAIDLAW/ECDC	Date :	30-Apr-98
Project No. :	64.63.100	Time :	09:39 PM
Channel Section:	RUNON CHANNEL NO. 5 LOWER	Computed	MEA

			UNITS
GENERAL CRITERIA:	Design Flow:	522.00	cfs
	Bottom Width:	40.0	feet
	Side Slope1:	3.0	1/m1
	Side Slope2:	3.0	1/m2
	Friction Factor:		
	Assumed D50:	0.50	feet
	If X=1, n=0.0395(D50)^1/6		
	If X=2, n=0.0456(D50*S)^0.159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	AT X=3 APPLICABLE FOR R/D50 > 0.5 ONLY		
	If X=4, n=0.39(S^0.38)(R^-0.16)		
	If X=5, Input n value		
	X:	1	
	Input n value for X=5:	0.030	
	Min. Bottom Slope:	0.0060	ft/ft
	Max. Bottom Slope:	0.0060	ft/ft
	Freeboard:	1.00	feet
CALCULATION:	Depth (Min. S):	2.21	feet
(Channel Depth)			
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.035	
	Required Depth:	3.21	feet
	Area:	103.29	ft2
	Perimeter:	54.01	feet
	Hydraulic Radius (R):	1.91	feet
	Velocity:	5.05	ft/sec
	Froude Number:	0.64	
CALCULATION:	Depth (Max. S):	2.21	feet
(Velocity Check)			
	Q-1.49AR(2/3)S(1/2)/n=	-0.000	Accuracy
	Calc n Value	0.035	
	Required Depth:	2.71	feet
	Area:	103.29	ft2
	Perimeter:	54.01	feet
	Hydraulic Radius (R):	1.91	feet
	Velocity:	5.05	ft/sec
	Froude Number:	0.64	

DESIGN CRITERIA:	Bottom Width:	40.0	feet
	Side Slope 1:	3.0	1/m1
	Side Slope 2:	3.0	1/m2
	Min. Bottom Slope:	0.6	%
	Max. Bottom Slope:	0.6	%
	Min Channel Depth:	3.21	feet

LAIDLAW ENVIRONMENTAL SERVICES - LONE MOUNTAIN
STORM DRAINAGE REVISIONS
April 24, 1998

COMPARES INLET VERSUS OUTLET CONDITIONS
Inlet Control Uses U.S. D.O.T. Hydraulic Charts for the Selection of Highway Culverts
Outlet Control - Assumes Full Flowing Pipe with the following:

Ke = Entrance Loss Coefficient = 0.9 for projecting from fill, no headwall, 0.5 for headwall condition
H = (1 + Ke + (29*n^2*L)/(R^1.33))*V^2/2g
HW = H +ho - LSo

Assume: All culverts have projecting entrance types, no headwall
All culverts are CMP

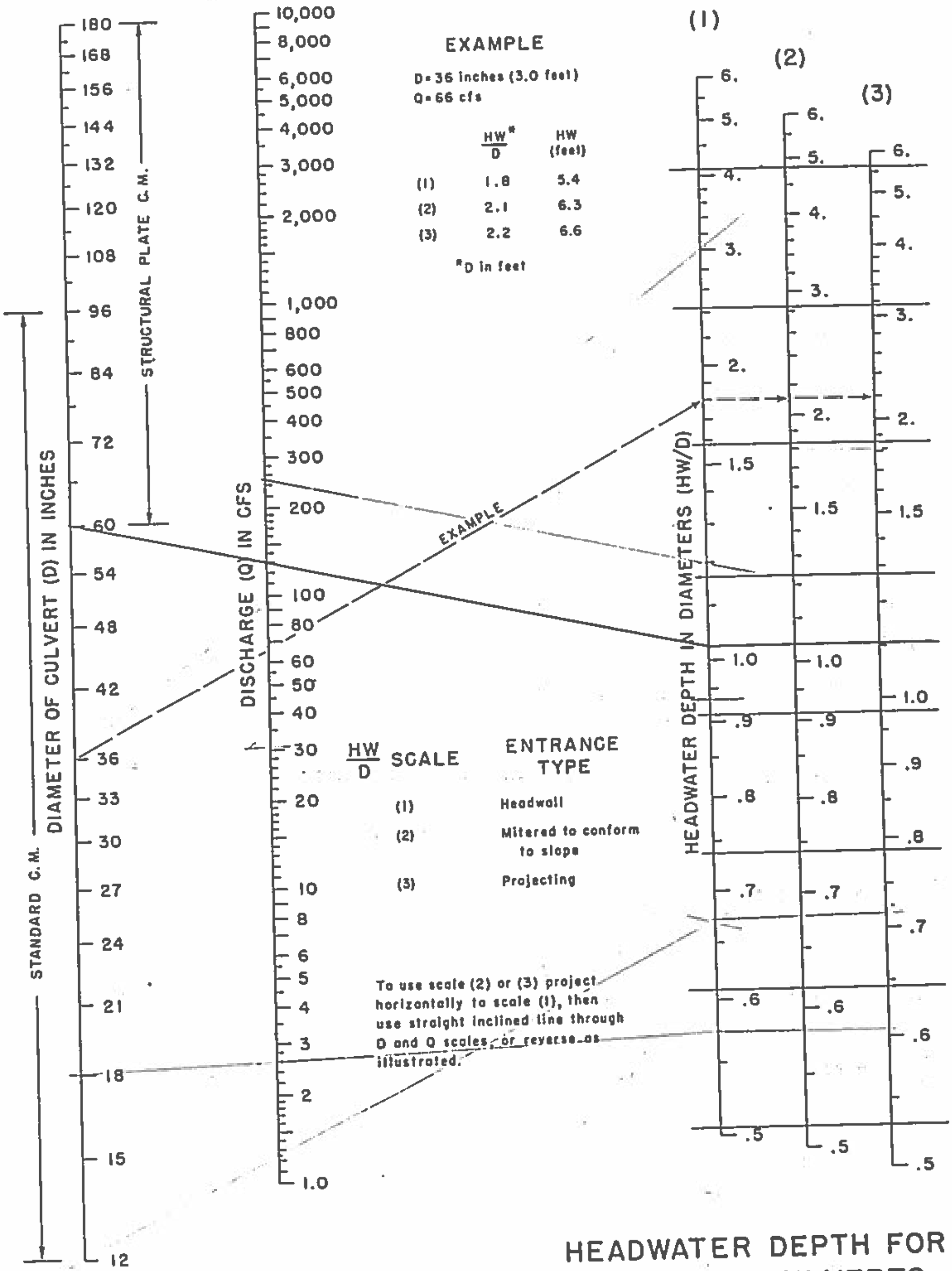
			INLET CONTROL		OUTLET CONTROL																
CULVERT NO.	CULVERT DIAMETER ft	DISCHARGE cfs	HW/D	HW ft	Ke	Manning's n	Flow Area A ft2	Wetted Perimeter P ft	Hydraulic Radius R ft	Velocity Full Pipe V fps	Culvert Length L ft	Culvert Slope So %	H ft	Critical Depth dc ft	(dc+D)/2 ft	Tailwater Depth TW ft	ho ft	LSo ft	HW ft	CONTROLLING HW ft	OUTLET VELOCITY fps
*C5G-1	5	130.5	1.1	5.5	0.9	0.024	19.63	15.71	1.25	6.65	70	0.6	1.90	3.27	4.135	2.21	4.14	0.42	5.61	5.61	6.65

* Has FOUR 5.0-foot diameter culverts. Thus, each culvert carries one fourth of discharge (i.e. 522/4 = 130.5 cfs).

41/

421

CHART 5



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

+ 10
BUREAU OF PUBLIC ROADS JAN. 1963

HA&L ENGINEERING

CLIENT Laidlaw
PROJECT Lone Mtn. Storm Drainage Rev
FEATURE Hydrology - Channel Design
PROJECT NO. 64.63.100

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CHECKED
DATE 4/30/9?

6. Drop Structure (Concrete) into Pond 3

The concrete drop inlet structure into the southwest corner of pond 3 was originally designed for a flow rate of 1133 cfs. Due to modifications to tributary areas, design event, etc. the peak flow rate from the 25-yr 24-hr event is only 613 cfs.

Since the structure was designed for a larger flow rate, no modifications are necessary to the original design.

See Attachment 10 for original calculations based on 1133 cfs.

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PROJECT Lone Mtn. - Storm Drainage
FEATURE Hydrology - Channel Design
PROJECT NO. 64.63.100

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COMPUTED [signature]
CHECKED [signature]
DATE 4/30/98

ATTACHMENT 1A

HEC-1 PRINTOUT

25-YR 24-HR

ALTERNATIVE 1 FOR

RUNON DETENTION POND NO. 1

```
HF  S/N: 0134300778       HMVersion: 6.33    Data File: LM2524.hc1

*****************************************                    ****************************************
*                                       *                    *                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                    *   U.S. ARMY CORPS OF ENGINEERS       *
*              MAY   1991               *                    *   HYDROLOGIC ENGINEERING CENTER      *
*           VERSION 4.0.1E              *                    *         609 SECOND STREET            *
*                                       *                    *       DAVIS, CALIFORNIA 95616        *
*  RUN DATE  04/30/1998  TIME  15:13:08 *                    *         (916) 756-1104               *
*                                       *                    *                                      *
*****************************************                    ****************************************


                         X     X  XXXXXXX   XXXXX           X
                         X     X  X        X     X         XX
                         X     X  X        X                X
                         XXXXXXX  XXXX     X         XXXXX  X
                         X     X  X        X                X
                         X     X  X        X     X          X
                         X     X  XXXXXXX   XXXXX          XXX


                      :::::::::::::::::::::::::::::::::::::::::::
                      :::::::::::::::::::::::::::::::::::::::::::
                      :::                                     :::
                      :::   Full Microcomputer Implementation :::
                      :::                 by                  :::
                      :::         Haestad Methods, Inc.       :::
                      :::                                     :::
                      :::::::::::::::::::::::::::::::::::::::::::
                      :::::::::::::::::::::::::::::::::::::::::::

            37 Brookside Road * Waterbury, Connecticut  06708 * (203) 755-1666


THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM
```

```
LINE     ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

   1     ID   LAIDLAW - LONE MOUNTAIN FACILITY
   2     ID   STORM DRAINAGE STUDY
   3     ID    25YR 24HR PRECIPITATION EVENT, SCS TYPE II RAINFALL DISTRIBUTION
   4     ID     FOR EVALUATION OF DITCHES, CHANNELS, CULVERTS AND PONDS
   5     ID     HANSEN, ALLEN & LUCE, INC APR 1998 - MEA
         *DIAGRAM
   6     IT       3       0       0    2000
   7     IO       5

   8     KK     5-A   ****BASIN 5-A ************************
   9     BA  .01801
  10     PB    6.00
  11     IN      30
  12     PI       0   0.005    .006    .006    .006    .006    .006    .007    .007    .007
  13     PI    .008    .008    .009    .009     .01     .01     .01    .012    .015    .016
  14     PI    .018    .023    .033    .046     .38    .072    .037    .027    .023    .018
  15     PI    .015    .013    .012    .011    .011     .01    .009    .009    .008    .008
  16     PI    .008    .008    .006    .006    .006    .005    .005    .005    .005
  17     LS       0      89       0
  18     UD    .080

  19     KK     5-B  ******* BASIN 5-B  ***********
  20     BA  .01086
  21     LS       0    88.1       0
  22     UD    0.13

  23     KK     5-C  ******* BASIN 5-C  ***********
  24     BA  .00696
  25     LS       0    92.0       0
  26     UD    0.11

  27     KK    COMB  COMBINE 5A, 5B, AND 5C
  28     HC       3

  29     KK     5-E  ******* BASIN 5-E  ***********
  30     BA  .00365
  31     LS       0    83.7       0
  32     UD    0.18

  33     KK     5-D  ******* BASIN 5-D  ***********
  34     BA  .00468
  35     LS       0    86.0       0
  36     UD    0.14

  37     KK    COMB  COMBINE 5E AND 5D
  38     HC       2

  39     KK    COMB  COMBINE 5E & 5D WITH 5A-5C
  40     HC       2
```

```
LINE        ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 41         KK     5-J  ******* BASIN 5-J  ***********
 42         BA  .00238
 43         LS       0    76.0       0
 44         UD    0.17

 45         KK   C5F-1  CULVERT
 46         RD    200.    .010    .024            CIRC     2.0

 47         KK    COMB  COMBINE 5J WITH 5A-5E
 48         HC       2

 49         KK   D5F-1  CHANNEL D5F-1
 50         RD    700.    .004    .035            TRAP       4     2.0

 51         KK     5-F  ******* BASIN 5-F  ***********
 52         BA  .01168
 53         LS       0    92.0       0
 54         UD    0.14

 55         KK    COMB  COMBINE 5F WITH 5A-5E & 5J
 56         HC       2

 57         KK     1-A  ******* BASIN 1-A  ***********
 58         BA  .00440
 59         LS       0    76.0       0
 60         UD    0.18

 61         KK     1-B  ******* BASIN 1-B  ***********
 62         BA  .00473
 63         LS       0    89.2       0
 64         UD    0.10

 65         KK    COMB  COMBINE 1A AND 1B
 66         HC       2

 67         KK    RO-1  RUNON CHANNEL NO. 1
 68         RD    800.    .010    .035            TRAP       6     3.0

 69         KK     1-C  ******* BASIN 1-C  ***********
 70         BA  .00991
 71         LS       0    92.0       0
 72         UD    0.14

 73         KK    COMB  COMBINE 1C WITH 1A AND 1B
 74         HC       2

 75         KK    COMB  COMBINE 1A-1C WITH 5A-5F AND 5J
 76         HC       2
```

```
 LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

   77          KK     2-A  ******* BASIN 2-A  ***********
   78          BA  .02530
   79          LS       0    81.5       0
   80          UD    0.19

   81          KK      P2 *** ROUTE FLOW THROUGH POND NO. 2 *****
   82          RS       1    ELEV  1388.3
   83          KO       0
   84          SV       0    0.41    1.87    4.10    6.87   10.21
   85          SE  1388.3  1390.0  1392.0  1394.0  1396.0  1398.0
   86          SQ       0     32.     43.     51.     82.     95.    110.    139.    172.
   87          SE  1388.3  1390.5  1391.0  1391.3  1392.3  1392.8  1393.3  1394.3  1396.3

   88          KK     2-C  ******* BASIN 2-C ***********
   89          BA  .00291
   90          LS       0    83.1       0
   91          UD    0.10

   92          KK    COMB  COMBINE 2A AND 2C
   93          HC       2

   94          KK    RO-2  RUNON CHANNEL NO. 2
   95          RD    800.    .009    .035            TRAP      10     3.0

   96          KK     2-B  ******* BASIN 2-B  ***********
   97          BA  .01204
   98          LS       0    77.5       0
   99          UD    0.18

  100          KK    COMB  COMBINE 2B WITH 2A AND 2C
  101          HC       2

  102          KK    COMB  COMBINE 2A-2C WITH 1A-1C, 5A-5F, & 5J
  103          HC       2

  104          KK   RO-5U  RUNON CHANNEL NO. 5 UPPER SECTION
  105          RD   1250.    .009    .035            TRAP      16     3.0

  106          KK     5-G  ******* BASIN 5-G  ***********
  107          BA  .03765
  108          LS       0    82.0       0
  109          UD    0.13

  110          KK    COMB  COMBINE 5G WITH 2A-2C, 1A-1C, 5A-5F, & 5J
  111          HC       2

  112          KK     5-I  ******* BASIN 5-I  ***********
  113          BA  .08594
  114          LS       0    89.0       0
  115          UD    0.31
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 116          KK    COMB  COMBINE 5I WITH 2A-2C, 1A-1C, 5A-5F, & 5J
 117          HC       2

 118          KK   RO-5L  RUNON CHANNEL NO. 5 LOWER SECTION
 119          RD   2200.    .006    .035            TRAP      40     3.0

 120          KK     5-H  ******* BASIN 5-H  ***********
 121          BA  .06130
 122          LS       0    80.8       0
 123          UD    0.15

 124          KK    COMB  COMBINE 5H WITH 2A-2C, 1A-1C, 5A-5F, 5I & 5J
 125          HC       2

 126          KK     3-J  ******* BASIN 3-J  ***********
 127          BA  .01103
 128          LS       0    91.3       0
 129          UD    0.09

 130          KK     3-A  ******* BASIN 3-A  ***********
 131          BA  .01511
 132          LS       0    89.8       0
 133          UD    0.07

 134          KK    COMB  COMBINE 3J AND 3A
 135          HC       2

 136          KK   D3E-1  CHANNEL D3E-1
 137          RD   1300.    .005    .035            TRAP       2     2.0

 138          KK     3-E  ******* BASIN 3-E  ***********
 139          BA  .01001
 140          LS       0    92.0       0
 141          UD    0.08

 142          KK    COMB  COMBINE 3E WITH 3A AND 3J
 143          HC       2

 144          KK     3-D  ******* BASIN 3-D  ***********
 145          BA  .00300
 146          LS       0    92.0       0
 147          UD    0.15

 148          KK    COMB  COMBINE 3D WITH 3A, 3E, AND 3J
 149          HC       2

 150          KK     3-B  ******* BASIN 3-B  ***********
 151          BA  .01662
 152          LS       0    83.8       0
 153          UD    0.21
```

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LINE       ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

154        KK     3-C  ******* BASIN 3-C  ***********
155        BA  .00961
156        LS       0    92.0       0
157        UD    0.20

158        KK    COMB  COMBINE 3C, 3B, WITH 3A, 3D, 3E, 3J
159        HC       3

160        KK     3-F  ******* BASIN 3-F  ***********
161        BA  .01148
162        LS       0    92.0       0
163        UD    0.05

164        KK     3-G  ******* BASIN 3-G  ***********
165        BA  .02695
166        LS       0    91.6       0
167        UD    0.14

168        KK    COMB  COMBINE 3F, 3G, WITH 3A-3E & 3J
169        HC       3

170        KK      P1 *** ROUTE FLOW THROUGH POND NO. 1 *********
171        RS       1    ELEV  1389.0
172        KO       0
173        SV       0    1.57    4.99    8.81   13.01   17.90
174        SE  1389.0  1390.0  1392.0  1394.0  1396.0  1398.0
175        SQ       0      0.     40.     80.    120.
176        SE  1388.8  1390.4 1391.71 1393.96 1397.53

177        KK     3-H  ******* BASIN 3-H ***********
178        BA  .03653
179        LS       0    90.4       0
180        UD    0.18

181        KK    COMB  COMBINE 3H WITH 3A-3G, & 3J
182        HC       2

183        KK   P3H-1 *** ROUTE FLOW THROUGH CHANNEL D3H-1 *********
184        RS       1    ELEV  1386.9
185        KO       0
186        SV       0    0.02    0.16    0.44    1.00    1.99    3.45
187        SE  1386.9  1388.0  1390.0  1392.0  1394.0  1396.0  1398.0
188        SQ       0     40.     80.    120.    160.    200.    240.
189        SE  1386.9  1388.9 1390.02 1391.14 1392.82 1396.04 1399.99

190        KK     3-I  ******* BASIN 3-I  ***********
191        BA  .04346
192        LS       0    84.8       0
193        UD    0.19
```

```
LINE           ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 194           KK    COMB  COMBINE 3I WITH 3A-3H & 3J
 195           HC       2

 196           KK     4-A  ******* BASIN 4-A  ***********
 197           BA  .24421
 198           LS       0    90.1       0
 199           UD    0.21

 200           KK     4-B  ******* BASIN 4-B  ***********
 201           BA  .00478
 202           LS       0    89.0       0
 203           UD    0.19

 204           KK     4-C  ******* BASIN 4-C  ***********
 205           BA  .01879
 206           LS       0    96.5       0
 207           UD    0.18

 208           KK    COMB  COMBINE 4A, 4B, 4C WITH 3A-3J - POND 3 INFLOW
 209           HC       4

 210           KK      P3 *** ROUTE FLOW THROUGH POND NO. 3 *****
 211           RS       1    ELEV    1383
 212           KO       0
 213           SV       0    6.08    12.3    25.3    38.9    53.1    68.0
 214           SE  1380.0  1381.0  1382.0  1384.0  1386.0  1388.0  1390.0
 215           SQ       0     54.    169.    344.    580.   1251.    2212
 216           SE  1383.0  1384.0  1385.0  1386.0  1387.0  1389.0  1391.0

 217           KK   RO-4U  RUNON CHANNEL NO. 4 UPPER SECTION
 218           RD    800.   .0117    .035            TRAP      18     3.0

 219           KK     4-D  ******* BASIN 4-D ***********
 220           BA  .02522
 221           LS       0    88.0       0
 222           UD    0.20

 223           KK    COMB  COMBINE 4D WITH POND 3 OUTFLOW
 224           HC       2

 225           KK   RO-4L  RUNON CHANNEL NO. 4 LOWER SECTION
 226           RD   1600.   .0117    .035            TRAP      18     3.0

 227           KK     4-E  ******* BASIN 4-E ***********
 228           BA  .04316
 229           LS       0    81.9       0
 230           UD    0.19

 231           KK    COMB  COMBINE 4E WITH 4D AND POND 3 OUTFLOW
 232           HC       2
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 233          KK    COMB  COMBINE 4A-4E, 3A-3J WITH 5A-5J, 1A-1C, & 2A-2C
 234          HC       2
 235          ZZ
```

```
                    SCHEMATIC DIAGRAM OF STREAM NETWORK
 INPUT
  LINE     (V) ROUTING        (--->) DIVERSION OR PUMP FLOW

   NO.     (.) CONNECTOR      (<---) RETURN OF DIVERTED OR PUMPED FLOW

     8       5-A
               .
               .
    19         .         5-B
               .           .
               .           .
    23         .           .         5-C
               .           .           .
               .           .           .
    27        COMB.....................
               .
               .
    29         .         5-E
               .           .
               .           .
    33         .           .         5-D
               .           .           .
               .           .           .
    37         .          COMB.........
               .           .
               .           .
    39        COMB.........
               .
               .
    41         .         5-J
               .           V
               .           V
    45         .        C5F-1
               .           .
               .           .
    47        COMB.........
               V
               V
    49       D5F-1
               .
               .
    51         .         5-F
               .           .
               .           .
    55        COMB.........
               .
               .
    57         .         1-A
               .           .
               .           .
    61         .           .         1-B
               .           .           .
               .           .           .
    65         .          COMB.........
               .           V
               .           V
    67         .         RO-1
```

```
                 .         .
  69             .         .         1-C
                 .         .           .
                 .         .           .
  73             .       COMB...........
                 .         .
                 .         .
  75           COMB.........
                 .
                 .
  77             .        2-A
                 .         V
                 .         V
  81             .        P2
                 .         .
                 .         .
  88             .         .         2-C
                 .         .           .
                 .         .           .
  92             .       COMB...........
                 .         V
                 .         V
  94             .       RO-2
                 .         .
                 .         .
  96             .         .         2-B
                 .         .           .
                 .         .           .
 100             .       COMB...........
                 .         .
                 .         .
 102           COMB.........
                 V
                 V
 104          RO-5U
                 .
                 .
 106             .        5-G
                 .         .
                 .         .
 110           COMB.........
                 .
                 .
 112             .        5-I
                 .         .
                 .         .
 116           COMB.........
                 V
                 V
 118          RO-5L
                 .
                 .
 120             .        5-H
                 .         .
                 .         .
 124           COMB.........
                 .
                 .
```

```
           .      3-J
           .       .
130        .       .      3-A
           .       .       .
134        .     COMB.......
           .       V
           .       V
136        .    D3E-1
           .       .
138        .       .      3-E
           .       .       .
142        .     COMB.......
           .       .
144        .       .      3-D
           .       .       .
148        .     COMB.......
           .       .
150        .       .      3-B
           .       .       .
154        .       .       .      3-C
           .       .       .       .
158        .     COMB...............
           .       .
160        .       .      3-F
           .       .       .
164        .       .       .      3-G
           .       .       .       .
168        .     COMB...............
           .       V
           .       V
170        .      P1
           .       .
177        .       .      3-H
           .       .       .
181        .     COMB.......
           .       V
           .       V
183        .    P3H-1
           .       .
190        .       .      3-I
           .       .       .
194        .     COMB.......
           .       .
```

```
                            4-A

200                                     4-B

204                                                 4-C

208                COMB
                    V
                    V
210                 P3
                    V
                    V
217               RO-4U

219                         4-D

223                COMB
                    V
                    V
225               RO-4L

227                         4-E

231                COMB

233       COMB
```

(***) RUNOFF ALSO COMPUTED AT THIS LOCATION

```
HF  S/N: 0134300778       HMVersion: 6.33   Data File: LM2524.hc1

*****************************************                          ****************************************
*                                       *                          *                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                          *   U.S. ARMY CORPS OF ENGINEERS       *
*             MAY   1991                *                          *   HYDROLOGIC ENGINEERING CENTER      *
*          VERSION 4.0.1E               *                          *        609 SECOND STREET             *
*                                       *                          *     DAVIS, CALIFORNIA 95616          *
* RUN DATE  04/30/1998  TIME  15:13:08  *                          *         (916) 756-1104               *
*                                       *                          *                                      *
*****************************************                          ****************************************


                       LAIDLAW - LONE MOUNTAIN FACILITY
                       STORM DRAINAGE STUDY
                        25YR 24HR PRECIPITATION EVENT, SCS TYPE II RAINFALL DISTRIBUTION
                         FOR EVALUATION OF DITCHES, CHANNELS, CULVERTS AND PONDS
                         HANSEN, ALLEN & LUCE, INC APR 1998 - MEA

  7 IO         OUTPUT CONTROL VARIABLES
                     IPRNT           5  PRINT CONTROL
                     IPLOT           0  PLOT CONTROL
                     QSCAL          0.  HYDROGRAPH PLOT SCALE

    IT         HYDROGRAPH TIME DATA
                      NMIN           3  MINUTES IN COMPUTATION INTERVAL
                     IDATE      1    0  STARTING DATE
                     ITIME        0000  STARTING TIME
                        NQ        2000  NUMBER OF HYDROGRAPH ORDINATES
                    NDDATE      5    0  ENDING DATE
                    NDTIME        0357  ENDING TIME
                     ICENT          19  CENTURY MARK

                 COMPUTATION INTERVAL    0.05 HOURS
                      TOTAL TIME BASE   99.95 HOURS

          ENGLISH UNITS
               DRAINAGE AREA          SQUARE MILES
               PRECIPITATION DEPTH    INCHES
               LENGTH, ELEVATION      FEET
               FLOW                   CUBIC FEET PER SECOND
               STORAGE VOLUME         ACRE-FEET
               SURFACE AREA           ACRES
               TEMPERATURE            DEGREES FAHRENHEIT


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

            **************
            *            *
 81 KK      *      P2    *     *** ROUTE FLOW THROUGH POND NO. 2 *****
            *            *
            **************
```

```
 KO         OUTPUT CONTROL VARIABLES
                  IPRNT           5  PRINT CONTROL
                  IPLOT           0  PLOT CONTROL
                  QSCAL          0.  HYDROGRAPH PLOT SCALE


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


            **************
            *            *
 170 KK     *      P1    *      *** ROUTE FLOW THROUGH POND NO. 1 *********
            *            *
            **************

 172 KO         OUTPUT CONTROL VARIABLES
                  IPRNT           5  PRINT CONTROL
                  IPLOT           0  PLOT CONTROL
                  QSCAL          0.  HYDROGRAPH PLOT SCALE


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


            **************
            *            *
 183 KK     *    P3H-1   *      *** ROUTE FLOW THROUGH CHANNEL D3H-1 *********
            *            *
            **************

 185 KO         OUTPUT CONTROL VARIABLES
                  IPRNT           5  PRINT CONTROL
                  IPLOT           0  PLOT CONTROL
                  QSCAL          0.  HYDROGRAPH PLOT SCALE


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


            **************
            *            *
 210 KK     *      P3    *      *** ROUTE FLOW THROUGH POND NO. 3 *****
            *            *
            **************

 212 KO         OUTPUT CONTROL VARIABLES
                  IPRNT           5  PRINT CONTROL
                  IPLOT           0  PLOT CONTROL
                  QSCAL          0.  HYDROGRAPH PLOT SCALE
```

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	5-A	49.	12.50	7.	2.	1.	0.02		
HYDROGRAPH AT	5-B	28.	12.50	4.	1.	0.	0.01		
HYDROGRAPH AT	5-C	19.	12.50	3.	1.	0.	0.01		
3 COMBINED AT	COMB	97.	12.50	14.	5.	2.	0.04		
HYDROGRAPH AT	5-E	8.	12.55	1.	0.	0.	0.00		
HYDROGRAPH AT	5-D	12.	12.50	2.	1.	0.	0.00		
2 COMBINED AT	COMB	20.	12.50	3.	1.	0.	0.01		
2 COMBINED AT	COMB	117.	12.50	17.	6.	2.	0.04		
HYDROGRAPH AT	5-J	5.	12.55	1.	0.	0.	0.00		
ROUTED TO	C5F-1	5.	12.55	1.	0.	0.	0.00		
2 COMBINED AT	COMB	121.	12.50	18.	6.	2.	0.05		
ROUTED TO	D5F-1	119.	12.50	18.	6.	2.	0.05		
HYDROGRAPH AT	5-F	32.	12.50	5.	2.	1.	0.01		
2 COMBINED AT	COMB	151.	12.50	23.	7.	2.	0.06		
HYDROGRAPH AT	1-A	8.	12.55	1.	0.	0.	0.00		
HYDROGRAPH AT	1-B	13.	12.50	2.	1.	0.	0.00		
2 COMBINED AT	COMB	21.	12.50	3.	1.	0.	0.01		

ROUTED TO	RO-1	21.	12.55	3.		0.	0.01		
HYDROGRAPH AT	1-C	27.	12.50	4.	1.	0.	0.01		
2 COMBINED AT	COMB	47.	12.50	7.	2.	1.	0.02		
2 COMBINED AT	COMB	198.	12.50	30.	10.	3.	0.08		
HYDROGRAPH AT	2-A	55.	12.55	9.	3.	1.	0.03		
ROUTED TO	P2	37.	12.70	9.	3.	1.	0.03	1390.71	12.70
HYDROGRAPH AT	2-C	7.	12.50	1.	0.	0.	0.00		
2 COMBINED AT	COMB	39.	12.65	10.	3.	1.	0.03		
ROUTED TO	RO-2	39.	12.70	10.	3.	1.	0.03		
HYDROGRAPH AT	2-B	24.	12.55	4.	1.	0.	0.01		
2 COMBINED AT	COMB	61.	12.60	13.	4.	1.	0.04		
2 COMBINED AT	COMB	256.	12.50	43.	14.	5.	0.12		
ROUTED TO	RO-5U	256.	12.55	43.	14.	5.	0.12		
HYDROGRAPH AT	5-G	87.	12.50	13.	4.	1.	0.04		
2 COMBINED AT	COMB	342.	12.55	56.	18.	6.	0.16		
HYDROGRAPH AT	5-I	188.	12.65	34.	11.	4.	0.09		
2 COMBINED AT	COMB	522.	12.55	91.	29.	10.	0.24		
ROUTED TO	RO-5L	519.	12.65	90.	29.	10.	0.24		
HYDROGRAPH AT	5-H	136.	12.50	20.	6.	2.	0.06		
2 COMBINED AT									

	COMB	633.	12.60	111.		12.	0.30		
HYDROGRAPH AT	3-J	31.	12.50	5.	1.	0.	0.01		
HYDROGRAPH AT	3-A	42.	12.50	6.	2.	1.	0.02		
2 COMBINED AT	COMB	72.	12.50	11.	3.	1.	0.03		
ROUTED TO	D3E-1	71.	12.50	11.	3.	1.	0.03		
HYDROGRAPH AT	3-E	28.	12.50	4.	1.	0.	0.01		
2 COMBINED AT	COMB	99.	12.50	15.	5.	2.	0.04		
HYDROGRAPH AT	3-D	8.	12.50	1.	0.	0.	0.00		
2 COMBINED AT	COMB	108.	12.50	16.	5.	2.	0.04		
HYDROGRAPH AT	3-B	37.	12.55	6.	2.	1.	0.02		
HYDROGRAPH AT	3-C	25.	12.55	4.	1.	0.	0.01		
3 COMBINED AT	COMB	168.	12.50	26.	8.	3.	0.07		
HYDROGRAPH AT	3-F	32.	12.50	5.	2.	1.	0.01		
HYDROGRAPH AT	3-G	73.	12.50	11.	4.	1.	0.03		
3 COMBINED AT	COMB	274.	12.50	42.	14.	5.	0.10		
ROUTED TO	P1	93.	12.80	41.	12.	4.	0.10	1395.14	12.80
HYDROGRAPH AT	3-H	94.	12.55	15.	5.	2.	0.04		
2 COMBINED AT	COMB	179.	12.55	56.	17.	6.	0.14		
ROUTED TO	P3H-1	165.	12.65	56.	17.	6.	0.14	1393.20	12.65
HYDROGRAPH AT									

	3-I	101.	12.55	16.	2.	2.	0.04		
2 COMBINED AT	COMB	261.	12.55	72.	22.	7.	0.18		
HYDROGRAPH AT	4-A	613.	12.55	99.	32.	11.	0.24		
HYDROGRAPH AT	4-B	12.	12.55	2.	1.	0.	0.00		
HYDROGRAPH AT	4-C	52.	12.50	8.	3.	1.	0.02		
4 COMBINED AT	COMB	937.	12.55	181.	58.	19.	0.45		
ROUTED TO	P3	616.	12.75	176.	57.	19.	0.45	1387.11	12.75
ROUTED TO	RO-4U	614.	12.80	176.	57.	19.	0.45		
HYDROGRAPH AT	4-D	62.	12.55	10.	3.	1.	0.03		
2 COMBINED AT	COMB	646.	12.75	186.	61.	20.	0.48		
ROUTED TO	RO-4L	647.	12.80	186.	61.	20.	0.48		
HYDROGRAPH AT	4-E	94.	12.55	15.	5.	2.	0.04		
2 COMBINED AT	COMB	691.	12.80	200.	65.	22.	0.52		
2 COMBINED AT	COMB	1257.	12.65	310.	100.	33.	0.82		

```
                      SUMMARY OF KINEMATIC WAVE - MU    GUM-CUNGE ROUTING
                        (FLOW IS DIRECT RUNOFF WITHOUT BASE FLOW)
                                                                  INTERPOLATED TO
                                                               COMPUTATION INTERVAL
      ISTAQ    ELEMENT      DT       PEAK    TIME TO     VOLUME       DT      PEAK    TIME TO      VOLUME
                                               PEAK                                      PEAK

                          (MIN)     (CFS)     (MIN)       (IN)      (MIN)     (CFS)    (MIN)        (IN)

        C5F-1  MANE        0.78      4.57    753.84       3.38      3.00      4.57    753.00        3.38

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.4291E+00 EXCESS=0.0000E+00 OUTFLOW=0.4290E+00 BASIN STORAGE=0.4148E-04 PERCENT ERROR=   0.0

        D5F-1  MANE        2.68    119.07    749.77       4.61      3.00    119.07    750.00        4.61

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.1145E+02 EXCESS=0.0000E+00 OUTFLOW=0.1145E+02 BASIN STORAGE=0.6528E-03 PERCENT ERROR=   0.0

         RO-1  MANE        3.00     20.76    753.00       4.09      3.00     20.76    753.00        4.09

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.1993E+01 EXCESS=0.0000E+00 OUTFLOW=0.1993E+01 BASIN STORAGE=0.5792E-03 PERCENT ERROR=   0.0

         RO-2  MANE        3.00     39.26    762.00       3.95      3.00     39.26    762.00        3.95

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.5947E+01 EXCESS=0.0000E+00 OUTFLOW=0.5946E+01 BASIN STORAGE=0.6920E-03 PERCENT ERROR=   0.0

        RO-5U  MANE        3.00    256.05    753.00       4.39      3.00    256.05    753.00        4.39

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.2749E+02 EXCESS=0.0000E+00 OUTFLOW=0.2748E+02 BASIN STORAGE=0.1426E-02 PERCENT ERROR=   0.0

        RO-5L  MANE        3.00    518.83    759.00       4.45      3.00    518.83    759.00        4.45

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.5720E+02 EXCESS=0.0000E+00 OUTFLOW=0.5718E+02 BASIN STORAGE=0.5910E-02 PERCENT ERROR=   0.0

        D3E-1  MANE        3.00     71.25    750.00       4.89      3.00     71.25    750.00        4.89

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.6823E+01 EXCESS=0.0000E+00 OUTFLOW=0.6820E+01 BASIN STORAGE=0.8179E-03 PERCENT ERROR=   0.0

        RO-4U  MANE        1.52    614.39    766.65       4.74      3.00    614.23    768.00        4.74

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.1142E+03 EXCESS=0.0000E+00 OUTFLOW=0.1142E+03 BASIN STORAGE=0.8328E-03 PERCENT ERROR=   0.0

        RO-4L  MANE        3.00    646.89    768.00       4.74      3.00    646.89    768.00        4.74
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CONTINUITY SUMMARY (AC-FT) - INFLOW=0.1205E+03 EXCESS=0.0000E+00 OUTFLOW=0.1205E+03 BASIN STORAGE=0.1649E-02 PERCENT ERROR=   0.0


*** NORMAL END OF HEC-1 ***
```

HA&L ENGINEERING

CLIENT Laidlaw
PROJECT Lone Mtn. Storm Drainage
FEATURE Hydrology - Channel Design
PROJECT NO. 64.631.100

SHEET ___ OF ___
COMPUTED [illegible]
CHECKED ___
DATE 9/17/99

ATTACHMENT 1B

HEC-1 PRINTOUT

25-YR 24-HR

ALTERNATIVE 2 FOR

RUNON DETENTION POND NO. 2

```
HEC1 S/N:  300778        HMVersion: 6.33    Data File: lm2524A.hc1

*****************************************                          *****************************************
*                                       *                          *                                       *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                          *   U.S. ARMY CORPS OF ENGINEERS        *
*              MAY   1991               *                          *   HYDROLOGIC ENGINEERING CENTER       *
*           VERSION 4.0.1E              *                          *         609 SECOND STREET             *
*                                       *                          *      DAVIS, CALIFORNIA 95616          *
*  RUN DATE  08/26/1999  TIME  08:27:44 *                          *          (916) 756-1104               *
*                                       *                          *                                       *
*****************************************                          *****************************************


                         X     X  XXXXXXX   XXXXX          X
                         X     X  X        X     X        XX
                         X     X  X        X               X
                         XXXXXXX  XXXX     X       XXXXX   X
                         X     X  X        X               X
                         X     X  X        X     X         X
                         X     X  XXXXXXX   XXXXX         XXX


                     :::::::::::::::::::::::::::::::::::::::::::
                     :::::::::::::::::::::::::::::::::::::::::::
                     :::                                     :::
                     :::  Full Microcomputer Implementation  :::
                     :::                 by                  :::
                     :::        Haestad Methods, Inc.        :::
                     :::                                     :::
                     :::::::::::::::::::::::::::::::::::::::::::
                     :::::::::::::::::::::::::::::::::::::::::::

           37 Brookside Road * Waterbury, Connecticut  06708 * (203) 755-1666



THIS PROGRAM REPLACES ALL PREVIOUS VERSIONS OF HEC-1 KNOWN AS HEC1 (JAN 73), HEC1GS, HEC1DB, AND HEC1KW.

THE DEFINITIONS OF VARIABLES -RTIMP- AND -RTIOR- HAVE CHANGED FROM THOSE USED WITH THE 1973-STYLE INPUT STRUCTURE.
THE DEFINITION OF -AMSKK- ON RM-CARD WAS CHANGED WITH REVISIONS DATED 28 SEP 81. THIS IS THE FORTRAN77 VERSION
NEW OPTIONS: DAMBREAK OUTFLOW SUBMERGENCE , SINGLE EVENT DAMAGE CALCULATION, DSS:WRITE STAGE FREQUENCY,
DSS:READ TIME SERIES AT DESIRED CALCULATION INTERVAL   LOSS RATE:GREEN AND AMPT INFILTRATION
KINEMATIC WAVE: NEW FINITE DIFFERENCE ALGORITHM

                                          HEC-1 INPUT                                       PAGE  1

LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  1           ID   LAIDLAW - LONE MOUNTAIN FACILITY
  2           ID   STORM DRAINAGE STUDY
  3           ID    25YR 24HR PRECIPITATION EVENT, SCS TYPE II RAINFALL DISTRIBUTION
```

```
ID     FOR EVALUATION OF DITCHES, CHANNELS, CULVERTS AN[illegible]NDS (WITHOUT POND 1)
ID     HANSEN, ALLEN & LUCE, INC AUG 1999 - MEA
*DIAGRAM
IT       3       0       0    2000
IO       5

KK     5-A   ****BASIN 5-A ***********************
BA  .01801
PB    6.00
IN      30
PI       0   0.005    .006    .006    .006    .006    .006    .007    .007    .007
PI    .008    .008    .009    .009     .01     .01     .01    .012    .015    .016
PI    .018    .023    .033    .046     .38    .072    .037    .027    .023    .018
PI    .015    .013    .012    .011    .011     .01    .009    .009    .008    .008
PI    .008    .008    .006    .006    .006    .005    .005    .005    .005
LS       0      89       0
UD    .080

KK     5-B  ******* BASIN 5-B  ***********
BA  .01086
LS       0    88.1       0
UD    0.13

KK     5-C  ******* BASIN 5-C  ***********
BA  .00696
LS       0    92.0       0
UD    0.11

KK    COMB  COMBINE 5A, 5B, AND 5C
HC       3

KK     5-E  ******* BASIN 5-E  ***********
BA  .00365
LS       0    83.7       0
UD    0.18

KK     5-D  ******* BASIN 5-D  ***********
BA  .00468
LS       0    86.0       0
UD    0.14

KK    COMB  COMBINE 5E AND 5D
HC       2

KK    COMB  COMBINE 5E & 5D WITH 5A-5C
HC       2
```

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LINE        ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 41         KK     5-J  ******* BASIN 5-J  ***********
 42         BA  .00238
 43         LS       0     76.0       0
 44         UD    0.17

 45         KK   C5F-1  CULVERT
 46         RD    200.     .010    .024            CIRC     2.0

 47         KK    COMB  COMBINE 5J WITH 5A-5E
 48         HC       2

 49         KK   D5F-1  CHANNEL D5F-1
 50         RD    700.     .004    .035            TRAP       4     2.0

 51         KK     5-F  ******* BASIN 5-F  ***********
 52         BA  .01168
 53         LS       0     92.0       0
 54         UD    0.14

 55         KK    COMB  COMBINE 5F WITH 5A-5E & 5J
 56         HC       2

 57         KK     1-A  ******* BASIN 1-A  ***********
 58         BA  .00440
 59         LS       0     76.0       0
 60         UD    0.18

 61         KK     1-B  ******* BASIN 1-B  ***********
 62         BA  .00473
 63         LS       0     89.2       0
 64         UD    0.10

 65         KK    COMB  COMBINE 1A AND 1B
 66         HC       2

 67         KK    RO-1  RUNON CHANNEL NO. 1
 68         RD    800.     .010    .035            TRAP       6     3.0

 69         KK     1-C  ******* BASIN 1-C  ***********
 70         BA  .00991
 71         LS       0     92.0       0
 72         UD    0.14

 73         KK    COMB  COMBINE 1C WITH 1A AND 1B
 74         HC       2

 75         KK    COMB  COMBINE 1A-1C WITH 5A-5F AND 5J
 76         HC       2
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```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

  77          KK     2-A  ******* BASIN 2-A  ***********
  78          BA  .02530
  79          LS       0    81.5       0
  80          UD    0.19

  81          KK      P2 *** ROUTE FLOW THROUGH POND NO. 2 *****
  82          RS       1    ELEV  1388.3
  83          KO       0
  84          SV       0    0.41    1.87    4.10    6.87   10.21
  85          SE  1388.3  1390.0  1392.0  1394.0  1396.0  1398.0
  86          SQ       0     32.     43.     51.     82.     95.    110.    139.    172.
  87          SE  1388.3  1390.5  1391.0  1391.3  1392.3  1392.8  1393.3  1394.3  1396.3

  88          KK     2-C  ******* BASIN 2-C ***********
  89          BA  .00291
  90          LS       0    83.1       0
  91          UD    0.10

  92          KK    COMB  COMBINE 2A AND 2C
  93          HC       2

  94          KK    RO-2  RUNON CHANNEL NO. 2
  95          RD    800.    .009    .035            TRAP      10     3.0

  96          KK     2-B  ******* BASIN 2-B  ***********
  97          BA  .01204
  98          LS       0    77.5       0
  99          UD    0.18

 100          KK    COMB  COMBINE 2B WITH 2A AND 2C
 101          HC       2

 102          KK    COMB  COMBINE 2A-2C WITH 1A-1C, 5A-5F, & 5J
 103          HC       2

 104          KK   RO-5U  RUNON CHANNEL NO. 5 UPPER SECTION
 105          RD   1250.    .009    .035            TRAP      16     3.0

 106          KK     5-G  ******* BASIN 5-G  ***********
 107          BA  .03765
 108          LS       0    82.0       0
 109          UD    0.13

 110          KK    COMB  COMBINE 5G WITH 2A-2C, 1A-1C, 5A-5F, & 5J
 111          HC       2

 112          KK     5-I  ******* BASIN 5-I  ***********
 113          BA  .08594
 114          LS       0    89.0       0
 115          UD    0.31
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 116          KK    COMB  COMBINE 5I WITH 2A-2C, 1A-1C, 5A-5F, & 5J
 117          HC       2

 118          KK   RO-5L  RUNON CHANNEL NO. 5 LOWER SECTION
 119          RD   2200.    .006    .035            TRAP      40     3.0

 120          KK     5-H  ******* BASIN 5-H  ***********
 121          BA  .06130
 122          LS       0    80.8       0
 123          UD    0.15

 124          KK    COMB  COMBINE 5H WITH 2A-2C, 1A-1C, 5A-5F, 5I & 5J
 125          HC       2

 126          KK     3-J  ******* BASIN 3-J  ***********
 127          BA  .01103
 128          LS       0    91.3       0
 129          UD    0.09

 130          KK     3-A  ******* BASIN 3-A  ***********
 131          BA  .01511
 132          LS       0    89.8       0
 133          UD    0.07

 134          KK    COMB  COMBINE 3J AND 3A
 135          HC       2

 136          KK   D3E-1  CHANNEL D3E-1
 137          RD   1300.    .005    .035            TRAP       2     2.0

 138          KK     3-E  ******* BASIN 3-E  ***********
 139          BA  .01001
 140          LS       0    92.0       0
 141          UD    0.08

 142          KK    COMB  COMBINE 3E WITH 3A AND 3J
 143          HC       2

 144          KK     3-D  ******* BASIN 3-D  ***********
 145          BA  .00300
 146          LS       0    92.0       0
 147          UD    0.15

 148          KK    COMB  COMBINE 3D WITH 3A, 3E, AND 3J
 149          HC       2

 150          KK     3-B  ******* BASIN 3-B  ***********
 151          BA  .01662
 152          LS       0    83.8       0
 153          UD    0.21
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 154          KK     3-C  ******* BASIN 3-C  ***********
 155          BA  .00961
 156          LS       0    92.0       0
 157          UD    0.20

 158          KK    COMB  COMBINE 3C, 3B, WITH 3A, 3D, 3E, 3J
 159          HC       3

 160          KK     3-F  ******* BASIN 3-F  ***********
 161          BA  .01148
 162          LS       0    92.0       0
 163          UD    0.05

 164          KK     3-G  ******* BASIN 3-G  ***********
 165          BA  .02695
 166          LS       0    91.6       0
 167          UD    0.14

 168          KK    COMB  COMBINE 3F, 3G, WITH 3A-3E & 3J
 169          HC       3

 170          KK     3-H  ******* BASIN 3-H ***********
 171          BA  .03653
 172          LS       0    90.4       0
 173          UD    0.18

 174          KK    COMB  COMBINE 3H WITH 3A-3G, & 3J
 175          HC       2

 176          KK   P-1 *** ROUTE FLOW THROUGH POND-1 *********
 177          RS       1    ELEV  1386.9
 178          KO       0
 179          SV       0    0.02    0.17    0.47    1.22    3.50   10.43
 180          SE  1386.9  1388.0  1390.0  1392.0  1394.0  1396.0  1398.0
 181          SQ       0     40.     80.    120.    160.    200.    240.
 182          SE  1386.9  1388.9 1390.02 1391.14 1392.82 1396.04 1399.99

 183          KK     3-I  ******* BASIN 3-I  ***********
 184          BA  .04346
 185          LS       0    84.8       0
 186          UD    0.19

 187          KK    COMB  COMBINE 3I WITH 3A-3H & 3J
 188          HC       2

 189          KK     4-A  ******* BASIN 4-A  ***********
 190          BA  .24421
 191          LS       0    90.1       0
 192          UD    0.21
```

```
LINE          ID.......1.......2.......3.......4.......5.......6.......7.......8.......9......10

 193          KK     4-B  ******* BASIN 4-B  ***********
 194          BA  .00478
 195          LS       0    89.0       0
 196          UD    0.19

 197          KK     4-C  ******* BASIN 4-C  ***********
 198          BA  .01879
 199          LS       0    96.5       0
 200          UD    0.18

 201          KK    COMB  COMBINE 4A, 4B, 4C WITH 3A-3J - POND 3 INFLOW
 202          HC       4

 203          KK      P3 *** ROUTE FLOW THROUGH POND NO. 3 *****
 204          RS       1    ELEV    1383
 205          KO       0
 206          SV       0    6.08    12.3    25.3    38.9    53.1    68.0
 207          SE  1380.0  1381.0  1382.0  1384.0  1386.0  1388.0  1390.0
 208          SQ       0     54.    169.    344.    580.   1251.    2212
 209          SE  1383.0  1384.0  1385.0  1386.0  1387.0  1389.0  1391.0

 210          KK   RO-4U  RUNON CHANNEL NO. 4 UPPER SECTION
 211          RD    800.   .0117    .035            TRAP      18     3.0

 212          KK     4-D  ******* BASIN 4-D ***********
 213          BA  .02522
 214          LS       0    88.0       0
 215          UD    0.20

 216          KK    COMB  COMBINE 4D WITH POND 3 OUTFLOW
 217          HC       2

 218          KK   RO-4L  RUNON CHANNEL NO. 4 LOWER SECTION
 219          RD   1600.   .0117    .035            TRAP      18     3.0

 220          KK     4-E  ******* BASIN 4-E ***********
 221          BA  .04316
 222          LS       0    81.9       0
 223          UD    0.19

 224          KK    COMB  COMBINE 4E WITH 4D AND POND 3 OUTFLOW
 225          HC       2

 226          KK    COMB  COMBINE 4A-4E, 3A-3J WITH 5A-5J, 1A-1C, & 2A-2C
 227          HC       2
 228          ZZ
```

```
                   SCHEMATIC DIAGRAM OF STREAM NETWORK
INPUT
 LINE      (V) ROUTING          (--->) DIVERSION OR PUMP FLOW

  NO.      (.) CONNECTOR        (<---) RETURN OF DIVERTED OR PUMPED FLOW

   8         5-A
              .
              .
  19          .         5-B
              .          .
              .          .
  23          .          .         5-C
              .          .          .
              .          .          .
  27        COMB.......................
              .
              .
  29          .         5-E
              .          .
              .          .
  33          .          .         5-D
              .          .          .
              .          .          .
  37          .        COMB...........
              .          .
              .          .
  39        COMB...........
              .
              .
  41          .         5-J
              .          V
              .          V
  45          .        C5F-1
              .          .
              .          .
  47        COMB...........
              V
              V
  49       D5F-1
              .
              .
  51          .         5-F
              .          .
              .          .
  55        COMB...........
              .
              .
  57          .         1-A
              .          .
              .          .
  61          .          .         1-B
              .          .          .
              .          .          .
  65          .        COMB...........
              .          V
              .          V
  67          .        RO-1
```

```
         .         .
 69      .         .        1-C
         .         .          .
         .         .          .
 73      .       COMB...........
         .         .
         .         .
 75    COMB...........
         .
         .
 77      .        2-A
         .         V
         .         V
 81      .         P2
         .         .
         .         .
 88      .         .        2-C
         .         .          .
         .         .          .
 92      .       COMB...........
         .         V
         .         V
 94      .       RO-2
         .         .
         .         .
 96      .         .        2-B
         .         .          .
         .         .          .
100      .       COMB...........
         .         .
         .         .
102    COMB...........
         V
         V
104   RO-5U
         .
         .
106      .        5-G
         .         .
         .         .
110    COMB...........
         .
         .
112      .        5-I
         .         .
         .         .
116    COMB...........
         V
         V
118   RO-5L
         .
         .
120      .        5-H
         .         .
         .         .
124    COMB...........
         .
         .
```

```
126   .    3-J
      .     .
      .     .
130   .     .        3-A
      .     .         .
      .     .         .
134   .   COMB...........
      .     V
      .     V
136   .   D3E-1
      .     .
      .     .
138   .     .        3-E
      .     .         .
      .     .         .
142   .   COMB...........
      .     .
      .     .
144   .     .        3-D
      .     .         .
      .     .         .
148   .   COMB...........
      .     .
      .     .
150   .     .        3-B
      .     .         .
      .     .         .
154   .     .         .        3-C
      .     .         .         .
      .     .         .         .
158   .   COMB.......................
      .     .
      .     .
160   .     .        3-F
      .     .         .
      .     .         .
164   .     .         .        3-G
      .     .         .         .
      .     .         .         .
168   .   COMB.......................
      .     .
      .     .
170   .     .        3-H
      .     .         .
      .     .         .
174   .   COMB...........
      .     V
      .     V
176   .    P-1
      .     .
      .     .
183   .     .        3-I
      .     .         .
      .     .         .
187   .   COMB...........
      .     .
      .     .
189   .     .        4-A
      .     .         .
```

```
193         .          .          .        4-B
            .          .          .         .
197         .          .          .         .         4-C
            .          .          .         .          .
201         .        COMB...............................
            .          V
203         .         P3
            .          V
210         .      RO-4U
            .          .
212         .          .        4-D
            .          .          .
216         .        COMB..........
            .          V
218         .      RO-4L
            .          .
220         .          .        4-E
            .          .          .
224         .        COMB..........
            .          .
226       COMB...........
```

(***) RUNOFF ALSO COMPUTED AT THIS LOCATION

```
HEC1 S/N: 300778        HMVersion: 6.33    Data File: lm2524A.hc1

*****************************************                  ****************************************
*                                       *                  *                                      *
*   FLOOD HYDROGRAPH PACKAGE  (HEC-1)   *                  *   U.S. ARMY CORPS OF ENGINEERS       *
*              MAY   1991               *                  *   HYDROLOGIC ENGINEERING CENTER      *
*           VERSION 4.0.1E              *                  *       609 SECOND STREET              *
*                                       *                  *     DAVIS, CALIFORNIA 95616          *
*  RUN DATE  08/26/1999  TIME  08:27:44 *                  *         (916) 756-1104               *
*                                       *                  *                                      *
*****************************************                  ****************************************


                    LAIDLAW - LONE MOUNTAIN FACILITY
                    STORM DRAINAGE STUDY
                     25YR 24HR PRECIPITATION EVENT, SCS TYPE II RAINFALL DISTRIBUTION
                      FOR EVALUATION OF DITCHES, CHANNELS, CULVERTS AND PONDS (WITHOUT POND 1)
                      HANSEN, ALLEN & LUCE, INC AUG 1999 - MEA

  7 IO          OUTPUT CONTROL VARIABLES
                      IPRNT           5  PRINT CONTROL
                      IPLOT           0  PLOT CONTROL
                      QSCAL          0.  HYDROGRAPH PLOT SCALE

    IT          HYDROGRAPH TIME DATA
                       NMIN           3  MINUTES IN COMPUTATION INTERVAL
                      IDATE      1    0  STARTING DATE
                      ITIME        0000  STARTING TIME
                         NQ        2000  NUMBER OF HYDROGRAPH ORDINATES
                     NDDATE      5    0  ENDING DATE
                     NDTIME        0357  ENDING TIME
                      ICENT          19  CENTURY MARK

                 COMPUTATION INTERVAL    0.05 HOURS
                      TOTAL TIME BASE   99.95 HOURS

         ENGLISH UNITS
              DRAINAGE AREA          SQUARE MILES
              PRECIPITATION DEPTH    INCHES
              LENGTH, ELEVATION      FEET
              FLOW                   CUBIC FEET PER SECOND
              STORAGE VOLUME         ACRE-FEET
              SURFACE AREA           ACRES
              TEMPERATURE            DEGREES FAHRENHEIT


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


            **************
            *            *
 81 KK      *       P2   *     *** ROUTE FLOW THROUGH POND NO. 2 *****
            *            *
            **************
```

```
 83 KO        OUTPUT CONTROL VARIABLES
                    IPRNT           5  PRINT CONTROL
                    IPLOT           0  PLOT CONTROL
                    QSCAL          0.  HYDROGRAPH PLOT SCALE


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

            ***************
            *             *
176 KK      *     P3H-1   *       *** ROUTE FLOW THROUGH CHANNEL D3H-1 *********
            *             *
            ***************

178 KO        OUTPUT CONTROL VARIABLES
                    IPRNT           5  PRINT CONTROL
                    IPLOT           0  PLOT CONTROL
                    QSCAL          0.  HYDROGRAPH PLOT SCALE


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

            ***************
            *             *
203 KK      *        P3   *       *** ROUTE FLOW THROUGH POND NO. 3 *****
            *             *
            ***************

205 KO        OUTPUT CONTROL VARIABLES
                    IPRNT           5  PRINT CONTROL
                    IPLOT           0  PLOT CONTROL
                    QSCAL          0.  HYDROGRAPH PLOT SCALE
```

RUNOFF SUMMARY
FLOW IN CUBIC FEET PER SECOND
TIME IN HOURS, AREA IN SQUARE MILES

OPERATION	STATION	PEAK FLOW	TIME OF PEAK	AVERAGE FLOW FOR MAXIMUM PERIOD 6-HOUR	24-HOUR	72-HOUR	BASIN AREA	MAXIMUM STAGE	TIME OF MAX STAGE
HYDROGRAPH AT	5-A	49.	12.50	7.	2.	1.	0.02		
HYDROGRAPH AT	5-B	28.	12.50	4.	1.	0.	0.01		
HYDROGRAPH AT	5-C	19.	12.50	3.	1.	0.	0.01		
3 COMBINED AT	COMB	97.	12.50	14.	5.	2.	0.04		
HYDROGRAPH AT	5-E	8.	12.55	1.	0.	0.	0.00		
HYDROGRAPH AT	5-D	12.	12.50	2.	1.	0.	0.00		
2 COMBINED AT	COMB	20.	12.50	3.	1.	0.	0.01		
2 COMBINED AT	COMB	117.	12.50	17.	6.	2.	0.04		
HYDROGRAPH AT	5-J	5.	12.55	1.	0.	0.	0.00		
ROUTED TO	C5F-1	5.	12.55	1.	0.	0.	0.00		
2 COMBINED AT	COMB	121.	12.50	18.	6.	2.	0.05		
ROUTED TO	D5F-1	119.	12.50	18.	6.	2.	0.05		
HYDROGRAPH AT	5-F	32.	12.50	5.	2.	1.	0.01		
2 COMBINED AT	COMB	151.	12.50	23.	7.	2.	0.06		
HYDROGRAPH AT	1-A	8.	12.55	1.	0.	0.	0.00		
HYDROGRAPH AT	1-B	13.	12.50	2.	1.	0.	0.00		
2 COMBINED AT	COMB	21.	12.50	3.	1.	0.	0.01		

R[illegible]D TO	RO-1	21.	12.55	3.	1.	0.	0.01		
HYDROGRAPH AT	1-C	27.	12.50	4.	1.	0.	0.01		
2 COMBINED AT	COMB	47.	12.50	7.	2.	1.	0.02		
2 COMBINED AT	COMB	198.	12.50	30.	10.	3.	0.08		
HYDROGRAPH AT	2-A	55.	12.55	9.	3.	1.	0.03		
ROUTED TO	P2	37.	12.70	9.	3.	1.	0.03	1390.71	12.70
HYDROGRAPH AT	2-C	7.	12.50	1.	0.	0.	0.00		
2 COMBINED AT	COMB	39.	12.65	10.	3.	1.	0.03		
ROUTED TO	RO-2	39.	12.70	10.	3.	1.	0.03		
HYDROGRAPH AT	2-B	24.	12.55	4.	1.	0.	0.01		
2 COMBINED AT	COMB	61.	12.60	13.	4.	1.	0.04		
2 COMBINED AT	COMB	256.	12.50	43.	14.	5.	0.12		
ROUTED TO	RO-5U	256.	12.55	43.	14.	5.	0.12		
HYDROGRAPH AT	5-G	87.	12.50	13.	4.	1.	0.04		
2 COMBINED AT	COMB	342.	12.55	56.	18.	6.	0.16		
HYDROGRAPH AT	5-I	188.	12.65	34.	11.	4.	0.09		
2 COMBINED AT	COMB	522.	12.55	91.	29.	10.	0.24		
ROUTED TO	RO-5L	519.	12.65	90.	29.	10.	0.24		
HYDROGRAPH AT	5-H	136.	12.50	20.	6.	2.	0.06		
2 COMBINED AT									

	COMB	633.	12.60	111.	35.	12.	0.30		
HYDROGRAPH AT	3-J	31.	12.50	5.	1.	0.	0.01		
HYDROGRAPH AT	3-A	42.	12.50	6.	2.	1.	0.02		
2 COMBINED AT	COMB	72.	12.50	11.	3.	1.	0.03		
ROUTED TO	D3E-1	71.	12.50	11.	3.	1.	0.03		
HYDROGRAPH AT	3-E	28.	12.50	4.	1.	0.	0.01		
2 COMBINED AT	COMB	99.	12.50	15.	5.	2.	0.04		
HYDROGRAPH AT	3-D	8.	12.50	1.	0.	0.	0.00		
2 COMBINED AT	COMB	108.	12.50	16.	5.	2.	0.04		
HYDROGRAPH AT	3-B	37.	12.55	6.	2.	1.	0.02		
HYDROGRAPH AT	3-C	25.	12.55	4.	1.	0.	0.01		
3 COMBINED AT	COMB	168.	12.50	26.	8.	3.	0.07		
HYDROGRAPH AT	3-F	32.	12.50	5.	2.	1.	0.01		
HYDROGRAPH AT	3-G	73.	12.50	11.	4.	1.	0.03		
3 COMBINED AT	COMB	274.	12.50	42.	14.	5.	0.10		
HYDROGRAPH AT	3-H	94.	12.55	15.	5.	2.	0.04		
2 COMBINED AT	COMB	368.	12.50	57.	18.	6.	0.14		
ROUTED TO	P-1	206.	12.70	57.	18.	6.	0.14	1396.61	12.70
HYDROGRAPH AT	3-I	101.	12.55	16.	5.	2.	0.04		
2 COMBINED AT	COMB	304.	12.55	73.	23.	8.	0.18		

HYDROGRAPH AT	4-A	613.	12.55	99.	32.	11.	0.24		
HYDROGRAPH AT	4-B	12.	12.55	2.	1.	0.	0.00		
HYDROGRAPH AT	4-C	52.	12.50	8.	3.	1.	0.02		
4 COMBINED AT	COMB	981.	12.55	182.	59.	20.	0.45		
ROUTED TO	P3	682.	12.75	179.	59.	20.	0.45	1387.30	12.75
ROUTED TO	RO-4U	677.	12.80	179.	59.	20.	0.45		
HYDROGRAPH AT	4-D	62.	12.55	10.	3.	1.	0.03		
2 COMBINED AT	COMB	714.	12.75	188.	62.	21.	0.48		
ROUTED TO	RO-4L	713.	12.80	188.	62.	21.	0.48		
HYDROGRAPH AT	4-E	94.	12.55	15.	5.	2.	0.04		
2 COMBINED AT	COMB	758.	12.75	203.	66.	22.	0.52		
2 COMBINED AT	COMB	1318.	12.65	313.	102.	34.	0.82		

SUMMARY OF KINEMATIC WAVE - MUSKINGUM-[illegible]E ROUTING
(FLOW IS DIRECT RUNOFF WITHOUT BASE FLOW)

ISTAQ	ELEMENT	DT	PEAK	TIME TO PEAK	VOLUME	INTERPOLATED TO COMPUTATION INTERVAL DT	PEAK	TIME TO PEAK	VOLUME
		(MIN)	(CFS)	(MIN)	(IN)	(MIN)	(CFS)	(MIN)	(IN)
C5F-1	MANE	0.78	4.57	753.84	3.38	3.00	4.57	753.00	3.38

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.4291E+00 EXCESS=0.0000E+00 OUTFLOW=0.4290E+00 BASIN STORAGE=0.4148E-04 PERCENT ERROR= 0.0

D5F-1	MANE	2.68	119.07	749.77	4.61	3.00	119.07	750.00	4.61

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.1145E+02 EXCESS=0.0000E+00 OUTFLOW=0.1145E+02 BASIN STORAGE=0.6528E-03 PERCENT ERROR= 0.0

RO-1	MANE	3.00	20.76	753.00	4.09	3.00	20.76	753.00	4.09

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.1993E+01 EXCESS=0.0000E+00 OUTFLOW=0.1993E+01 BASIN STORAGE=0.5792E-03 PERCENT ERROR= 0.0

RO-2	MANE	3.00	39.26	762.00	3.95	3.00	39.26	762.00	3.95

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.5947E+01 EXCESS=0.0000E+00 OUTFLOW=0.5946E+01 BASIN STORAGE=0.6920E-03 PERCENT ERROR= 0.0

RO-5U	MANE	3.00	256.05	753.00	4.39	3.00	256.05	753.00	4.39

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.2749E+02 EXCESS=0.0000E+00 OUTFLOW=0.2748E+02 BASIN STORAGE=0.1426E-02 PERCENT ERROR= 0.0

RO-5L	MANE	3.00	518.83	759.00	4.45	3.00	518.83	759.00	4.45

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.5720E+02 EXCESS=0.0000E+00 OUTFLOW=0.5718E+02 BASIN STORAGE=0.5910E-02 PERCENT ERROR= 0.0

D3E-1	MANE	3.00	71.25	750.00	4.89	3.00	71.25	750.00	4.89

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.6823E+01 EXCESS=0.0000E+00 OUTFLOW=0.6820E+01 BASIN STORAGE=0.8179E-03 PERCENT ERROR= 0.0

RO-4U	MANE	1.48	679.41	767.27	4.84	3.00	677.31	768.00	4.84

CONTINUITY SUMMARY (AC-FT) - INFLOW=0.1165E+03 EXCESS=0.0000E+00 OUTFLOW=0.1165E+03 BASIN STORAGE=0.8295E-03 PERCENT ERROR= 0.0

RO-4L	MANE	2.91	713.62	767.75	4.83	3.00	712.90	768.00	4.83

```
CONTINUITY SUMMARY (AC-FT) - INFLOW=0.1227E+03 EXCESS=0.0000E+00 OUTFLOW=0.1227E+03 BASIN STORAGE=0.1655E-02 PERCENT ERROR=   0.0


*** NORMAL END OF HEC-1 ***
```

HA&L ENGINEERING

CLIENT Laidlaw
PROJECT Lyne Mtn - Storm Drainage
FEATURE Hydrology - Channel Design
PROJECT NO. 64.63.100

SHEET ___ OF ___
COMPUTED MA
CHECKED VLS
DATE 4/30/98

ATTACHMENT 2

RUNON DETENTION POND NO. 2

STAGE - DISCHARGE

HA&L ENGINEERING

CLIENT USPCI
PROJECT Lone Mountain Facilities
FEATURE Run-on Detention Pond No. 2
PROJECT NO. 64-

SHEET 2 OF 3
COMPUTED GJP
CHECKED
DATE June 199

Stage-Discharge with 54" CMP

Approach: Assume inlet control to conservatively assess the effect of the available detention storage on discharge and then use the combined peak pond discharge, and the flow from the SW½ of cell 11 to conservatively compute the required culvert Head water depth.

54" CMP w/ steel inlet section

h	STAGE	HW/D	Q
0	1388.3	0	0
2.25	1390.5	0.5	32
~~2.7~~	~~1391.0~~	~~0.6~~	~~43~~
3	1391.3	0.666	51
4	1392.3	.888	82
4.5	1392.8	1	95
5	1393.3	1.11	110
6	1394.3	1.33	139
8	1396.3	1.77	172

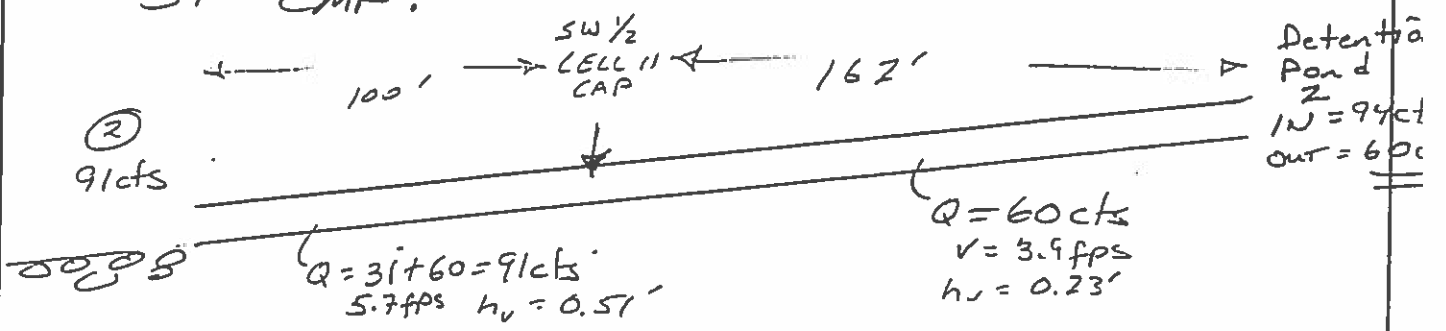
HA&L ENGINEERING

CLIENT USPCI
PROJECT Lone Mtn Facilities
FEATURE Run On Detention Pond No 2
PROJECT NO. 64-

SHEET 3 OF 3
COMPUTED CJP
CHECKED
DATE June 1990

Culvert hydraulics : (see HEC 1 printout)

54" CMP:



SW ½ of Cell 11 CAP

$$\text{Area} = \tfrac{1}{2}\,650 \times 650 / 43560 = 4.8 \text{ acres}$$

$$Q_{100\,yr\,24hr} = \frac{4.8}{8}(52\text{cfs}) = \underline{31\text{ cfs}}$$

$$EGL_{②} = EGL_{①} - \Sigma h_{LOSS}$$

Σh_{LOSS} = inlet loss (60cfs) + 100' 54" w/91cfs + 162' 54" w/60cfs + outlet loss + bend loss

$$= 0.3\frac{V_{in}^2}{2g} + 100\left(\frac{91}{25.63/.024}\right)^2 + 162\left(\frac{60}{25.63/.024}\right)^2 + \frac{V_{out}^2}{2g} + \frac{1.5\,V^2}{2g}$$

$$= 0.3(.23) + .73 + .51 + .51 + .76$$

$$\underline{\Sigma h_{LOSS} = 2.6'}$$

$$\therefore EGL_{②} = 1386.45_{\text{invert}} + 1.6'_{TW} + \frac{4.3^2}{2g} = 1388.34$$

$$EGL_{①} = EGL_{②} + \Sigma h_{LOSS} = 1388.34 + 2.6 = \underline{1390.94'}$$

say 1391.0

1391.0 is less than 1391.6 obtained for inlet flow conditions, therefore inlet flow governs and required Headwater elevation is 1391.6 (or Hw = 1391.6 - 1388.3 = 3.3 feet)

ATTACHMENT 3

RUNON DETENTION POND 3

STAGE-CAPACITY

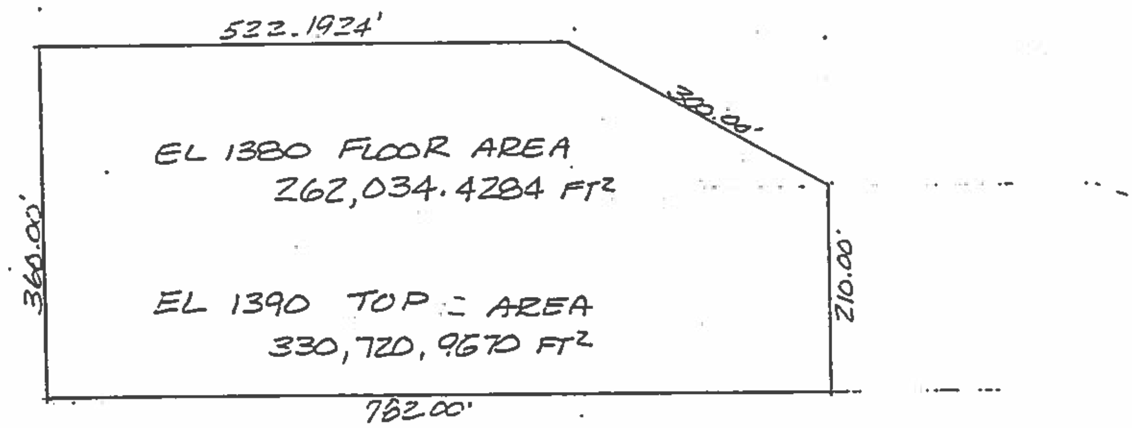
&

STAGE-DISCHARGE DATA

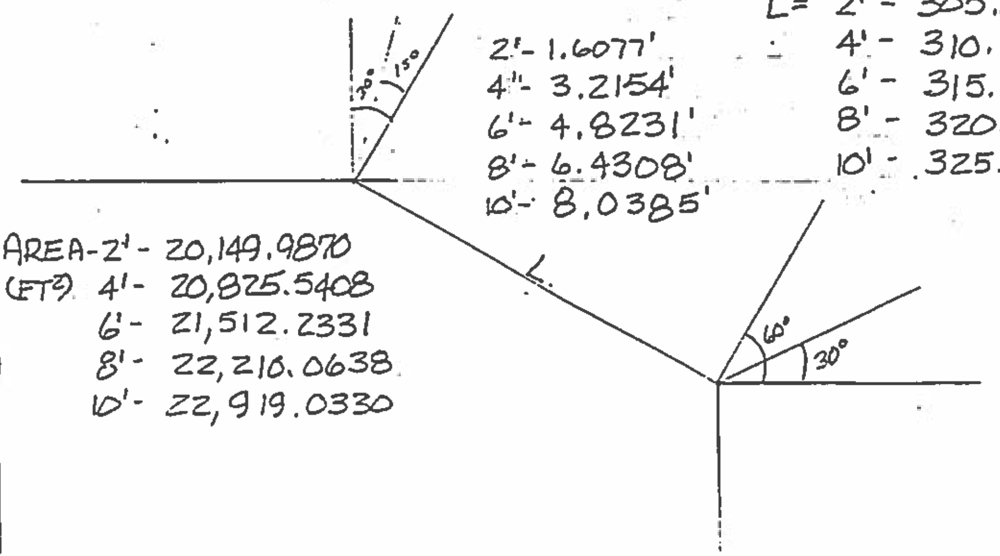
HA&L ENGINEERING

CLIENT USPCI
PROJECT [illegible]
FEATURE DETENTION POND NO 3 CAPACITY
PROJECT NO. 64.25.100

SHEET 1 OF 3
COMPUTED P
CHECKED
DATE 21 JUN 90



STAGE	ELEVATION	AREA (FT²)	AVERAGE AREA (FT²)	VOLUME (AF)	ΣVOL (AF)
0	1380	262,034.4284			
			268,626.2207	12.3336	12.
2	1382	275,218.0130			
			281,948.2361	12.9453	25.
4	1384	288,678.4592			
			295,547.1131	13.5693	38
6	1386	302,415.7669			
			309,422.8516	14.2067	53.
8	1388	316,429.9362			
			323,575.4516	14.8565	67.
10	1390	330,720.9670			



2' - 1.6077'
4' - 3.2154'
6' - 4.8231'
8' - 6.4308'
10' - 8.0385'

L = 2' - 305.0718'
4' - 310.1436'
6' - 315.2154'
8' - 320.2872'
10' - 325.3590'

2' - 3.4641'
4' - 6.9282'
6' - 10.3923'
8' - 13.8564'
10' - 17.3205'

AREA (FT²) - 2' - 20,149.9870
4' - 20,825.5408
6' - 21,512.2331
8' - 22,210.0638
10' - 22,919.0330

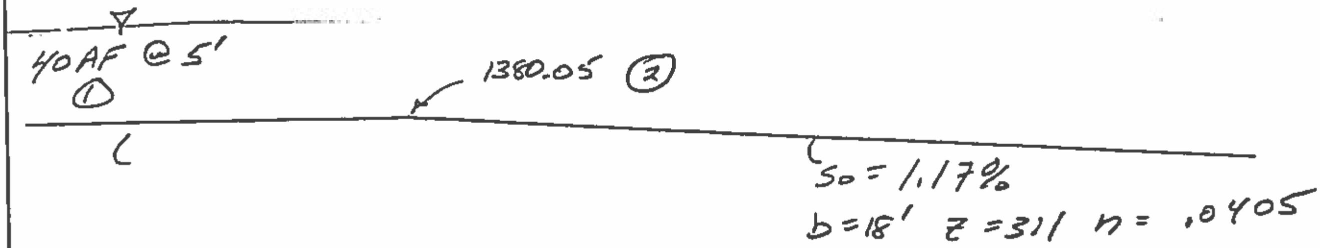
HA&L ENGINEERING

CLIENT: USPCI
PROJECT: Lone Mountain Facilities
FEATURE: Run-on Detention Pond No. 3
PROJECT NO.: 64-75-100

SHEET 2 OF 3
COMPUTED: GP
CHECKED:
DATE: 6/21/90

Detention Basin Stage-Discharge

Basin discharge problem to subcritical open channel



mild channel (Fr = 0.8) ∴ @ pt ②

mannings $Q = \frac{1.49}{n} A \left(\frac{A}{P}\right)^{2/3} \sqrt{S_f}$

energy $E = Y + \frac{V^2}{2g}$ = lake elevation

USPCI Lone Mountain Facility
RUN ON CHANNEL 4 INLET STAGE DISCHARGE RELATIONSHIP

GRADUAL VARIED FLOW PROFILE IN CONCRETE CHUTE
STEP METHOD (REF. HENDERSON, "OPEN CHANNEL FLOW" 1966, p. 128)

Q CFS	B FT	Y FT	AREA FT2	FR2	P FT	V FPS	E FT	Sf FT/FT
0	18	0	0.00	ERR	18.000	ERR	ERR	ERR
100	18	1.29	23.22	0.447	20.580	4.307	1.578	0.01166511
200	18	2	36.00	0.479	22.000	5.556	2.479	0.0118
300	18	2.61	46.98	0.485	23.220	6.386	3.243	0.0118
400	18	3.17	57.06	0.481	24.340	7.010	3.933	0.0117
500	18	3.68	66.24	0.481	25.360	7.548	4.565	0.0117
600	18	4.17	75.06	0.476	26.340	7.994	5.162	0.0117
700	18	4.64	83.52	0.470	27.280	8.381	5.731	0.0117
800	18	5.1	91.80	0.462	28.200	8.715	6.279	0.0116
900	18	5.53	99.54	0.459	29.060	9.042	6.799	0.0117
1000	18	5.95	107.10	0.455	29.900	9.337	7.304	0.0117
1100	18	6.38	114.84	0.447	30.760	9.579	7.805	0.0117
1200	18	6.8	122.40	0.439	31.600	9.804	8.292	0.0117

See new calcs, attached.

Reservoir stage = E + invert elev of channel.

HA&L ENGINEERING

CLIENT USPCI
PROJECT Lone Mountain Facilities
FEATURE Run ON Detention Pond No. 3
PROJECT NO. 64-25-100

SHEET 3 OF 3
COMPUTED LSP
CHECKED
DATE June 1990

Run-ON Detention Pond No. 3 will be totally excavated and will not have an embankment. Existing ground surface on the east side of the pond is about elev. 1400, the access road top elevation will be cut to an elevation of 1390 feet. The 100yr 24 hr peak stage is 1386.1 feet (see HEC-1 printout). Therefore freeboard to the access road will be about 4'. This is ample freeboard to include wave height and run up.

HA&L ENGINEERING

CLIENT: Laidlaw
PROJECT: Lone Mtn - Storm Drainage Rev.
FEATURE: Runoff Pond 3 - Stage Discharge
PROJECT NO.: 64.63.100

SHEET 1 OF 3
COMPUTED: [illegible]
CHECKED:
DATE: 4/30/98

Laidlaw raised the outlet elevation of pond 3 by 3', by filling the outlet channel with 3 feet of riprap.

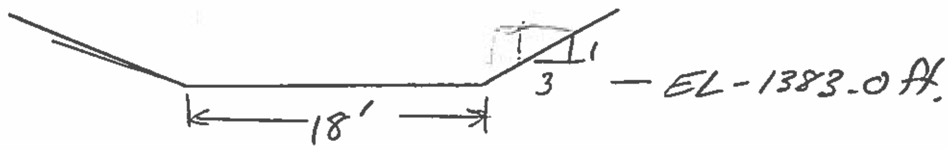
Determine stage discharge relationship. Due to drop from 3' rise in channel grade to the existing channel, the outlet should function as a broadcrested weir.

According to Brater and King "Handbook of Hydraulics", McGraw-Hill 1976, a broad crested weir flow can be determined from.

$$Q = CLH^{3/2}$$

where C = weir coefficient
Use 2.63 for 15' breadth of crest.
L = weir length ft
H = head in feet.

Original Channel Section



This accounts only for the 18' rectangular portion of the channel. To account for the triangular portion of the trapezoidal channel, assume L and H for the two ~~triangular~~ portions to be the top width and average depth of the triangular portion, and then add that portion to the rectangular.

See the table below

2/3

RECTANGULAR SECTION HEAD H FT	L FT	Q CFS	TRIANGULAR SECTIONS AVE H FT	L DR	Q CFS	SUM. Q CFS	SUM Q 2 SIDES CFS	TOTAL Q CFS

LAIDLAW ENVIRONMENTAL SERVICES
LONE MOUNTAIN FACILITY
STORM WATER REVISIONS

April 30, 1998

OUTFLOW FROM RUNON POND 3 - BROAD CRESTED WEIR

Q = C*L*H^1.5 C = 2.63 L=18 ft for rectangular channel portion

Triangular channel sections of trapezoidal channelfollow the same equation, but with H assumed to be the ave
Determine triangular portion in 1-foot horizontal increments

RECTANGULAR SECTION HEAD H FT	L FT	Q CFS	TRIANGULAR SECTIONS AVE H FT	L DR	Q CFS	SUM. Q CFS	SUM Q 2 SIDES CFS	TOTAL Q CFS
0	18	0						
1	18	47	0.83	1	2			
			0.5	1	1			
			0.17	1	0	3	6	54
2	18	134	1.83	1	7			
			1.5	1	5			
			1.16	1	3			
			0.83	1	2			
			0.5	1	1			
			0.16	1	0	18	35	169
3	18	246	2.83	1	13			
			2.5	1	10			
			2.16	1	8			
			1.83	1	7			
			1.5	1	5			
			1.16	1	3			
			0.83	1	2			
			0.5	1	1			
			0.16	1	0	49	98	344
4	18	379	3.83	1	20			
			3.5	1	17			
			3.16	1	15			
			2.83	1	13			
			2.5	1	10			
			2.16	1	8			
			1.83	1	7			
			1.5	1	5			
			1.16	1	3			
			0.83	1	2			
			0.5	1	1			
			0.16	1	0	101	201	580
6	18	696	5.83	1	37			
			5.5	1	34			
			5.16	1	31			
			4.83	1	28			
			4.5	1	25			
			4.16	1	22			
			3.83	1	20			
			3.5	1	17			
			3.16	1	15			
			2.83	1	13			
			2.5	1	10			
			2.16	1	8			
			1.83	1	7			
			1.5	1	5			
			1.16	1	3			
			0.83	1	2			
			0.5	1	1			
			0.16	1	0	278	556	1251

RECTANGULAR SECTION			TRIANGULAR SECTIONS					
HEAD H FT	L FT	Q CFS	AVE H FT	L DR	Q CFS	SUM. Q CFS	SUM Q 2 SIDES CFS	TOTAL Q CFS
8	18	1071	7.83	1	58			
			7.5	1	54			
			7.16	1	50			
			6.83	1	47			
			6.5	1	44			
			6.16	1	40			
			5.83	1	37			
			5.5	1	34			
			5.16	1	31			
			4.83	1	28			
			4.5	1	25			
			4.16	1	22			
			3.83	1	20			
			3.5	1	17			
			3.16	1	15			
			2.83	1	13			
			2.5	1	10			
			2.16	1	8			
			1.83	1	7			
			1.5	1	5			
			1.16	1	3			
			0.83	1	2			
			0.5	1	1			
			0.16	1	0	571	1141	2212

Table 5-3. Values of C in the Formula $Q = CLH^{3/2}$ for Broad-crested Weirs

Measured head in feet, H	Breadth of crest of weir in feet										
	0.50	0.75	1.00	1.50	2.00	2.50	3.00	4.00	5.00	10.00	15.00
0.2	2.80	2.75	2.69	2.62	2.54	2.48	2.44	2.38	2.34	2.49	2.68
0.4	2.92	2.80	2.72	2.64	2.61	2.60	2.58	2.54	2.50	2.56	2.70
0.6	3.08	2.89	2.75	2.64	2.61	2.60	2.68	2.69	2.70	2.70	2.70
0.8	3.30	3.04	2.85	2.68	2.60	2.60	2.67	2.68	2.68	2.69	2.64
1.0	3.32	3.14	2.98	2.75	2.66	2.64	2.65	2.67	2.68	2.68	2.63
1.2	3.32	3.20	3.08	2.86	2.70	2.65	2.64	2.67	2.66	2.69	2.64
1.4	3.32	3.26	3.20	2.92	2.77	2.68	2.64	2.65	2.65	2.67	2.64
1.6	3.32	3.29	3.28	3.07	2.89	2.75	2.68	2.66	2.65	2.64	2.63
1.8	3.32	3.32	3.31	3.07	2.88	2.74	2.68	2.66	2.65	2.64	2.63
2.0	3.32	3.31	3.30	3.03	2.85	2.76	2.72	2.68	2.65	2.64	2.63
2.5	3.32	3.32	3.31	3.28	3.07	2.89	2.81	2.72	2.67	2.64	2.63
3.0	3.32	3.32	3.32	3.32	3.20	3.05	2.92	2.73	2.66	2.64	2.63
3.5	3.32	3.32	3.32	3.32	3.32	3.19	2.97	2.76	2.68	2.64	2.63
4.0	3.32	3.32	3.32	3.32	3.32	3.32	3.07	2.79	2.70	2.64	2.63
4.5	3.32	3.32	3.32	3.32	3.32	3.32	3.32	2.88	2.74	2.64	2.63
5.0	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.07	2.79	2.64	2.63
5.5	3.32	3.32	3.32	3.32	3.32	3.32	3.32	3.32	2.88	2.64	2.63

Table 5-4. Values of C in the Formula $Q = CLH^{3/2}$ for Models of Broad-crested Weirs with Rounded Upstream Corner

Name of experimenter	Radius of curve in feet	Breadth of weir in feet, B	Height of weir in feet, P	Head in feet, H									
				0.4	0.6	0.8	1.0	1.5	2.0	2.5	3.0	4.0	5.0
Bazin..........	0.33	2.62	2.46	2.93	2.97	2.96	3.01	3.04					
Bazin..........	0.33	6.56	2.46	2.70	2.82	2.87	2.89	2.92					
U. S. Deep Waterways...	0.33	2.62	4.57	....	2.77	2.80	2.83	2.92	3.00	3.08	3.17	3.34	3.50
U. S. Deep Waterways...	0.33	6.56	4.56	....	....	2.83	2.83	2.83	2.82	2.82	2.82	2.82	2.81

HA&L ENGINEERING

CLIENT Laidlaw
PROJECT Lone Mtn - Storm Drainage
FEATURE Hydrology - Channel Design
PROJECT NO. 64-63.100

SHEET ___ OF ___
COMPUTED MJF
CHECKED KCS
DATE 4/30/98

ATTACHMENT 4

RUNON CHANNEL NO. 1

ORIGINAL DESIGN CALCULATIONS

B. Hydraulic Design of each channel section.

I. Culvert Outlet

Using the procedures for outlet protection found in "Urban Storm Drainage - Criteria Manual", DRCOG

1- Calculate the tailwater elevation in the channel downstream from the culvert.

$Q_p = 155$ cfs
$n = .035$ (assumed for $D_{50} = 6"$)
$S = .007$
$b = 6$ ft
$m = 3:1$ $\Rightarrow y = 2.46$ ft, $V = 4.72$ fps, $Fr = 0.66$
$A = 32.85$ ft^2, $P = 21.54$ ft, $R = 1.53$ ft

TW = 2.45 ft immediately downstream from the culvert

2- Calculate the flow characteristics in the culvert

$Q_p = 155$ cfs
$n = .024$
$S = .014$
$d_o = 5$ ft $\Rightarrow y = 3.8$ ft, $V = 9.68$ fps, $Fr = 0.88$, $T = 4.27$ f
$A = 16.02$ f^2, $P = 10.59$ f, $R = 1.51$ f, $\theta = 242.718°$
4.23623 rad

3- Calculate the diameter of a pipe flowing full; $A = Q/V = \frac{155}{9.68} = 16.02$ f^2

$A = \pi r^2 = 16.02$ $\therefore$ $r = 2.258$ f & $D = 4.52$ f $= 54.19$ in

Applying procedures in sect. 5.6 of DRCOG's "Drainage Criteria Manual"

Using Fig 5-7 on the following Page

$Q/D^{1.5} = \frac{155}{4.52^{1.5}} = 16.13$ & $\frac{y_t}{D} = \frac{2.46}{4.52} = 0.544$

Type H riprap, $D_{50} = 12"$

Using the above procedures itterate to a solution using the proper riprap size for n to calculate y_t

assumed D_{50}	y_t	A_t	V_t	$\frac{y_t}{D}$	D_{50} from Fig 5-7	
12"	2.62	36.25	4.28	0.58	9" type L	n = .040
9"	2.54	34.66	4.47	0.56	9" type L	n = .0377, P = 22.08 f, R = 1.57 Fr = 0.62

VAUGHN HANSEN ASSOCIATES

CLIENT USPCI
PROJECT Lancifill Cell 10-15
FEATURE Erosion Conveyance Channel No. 1
PROJECT NO. 4-2-2

SHEET 44 OF 47
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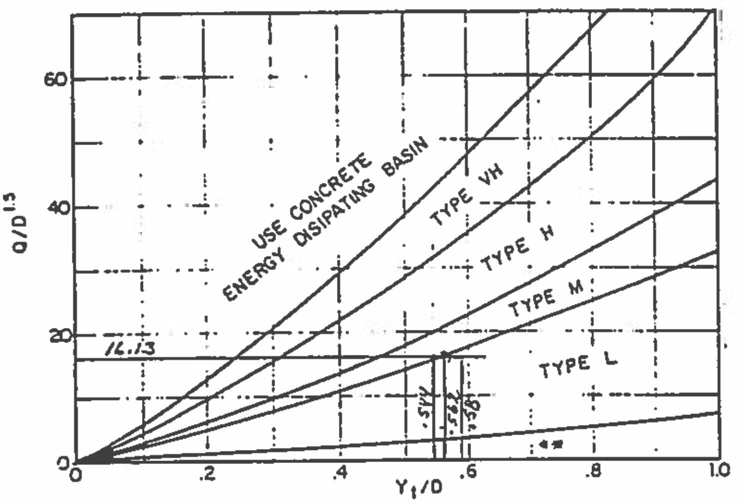
DATE Feb 86

Culvert Outlet Continued



Use D_a instead of D whenever flow is supercritical in the barrel.
** Use Type L for a distance of 3D downstream.

FIGURE 5-7. RIPRAP EROSION PROTECTION AT CIRCULAR CONDUIT OUTLET.

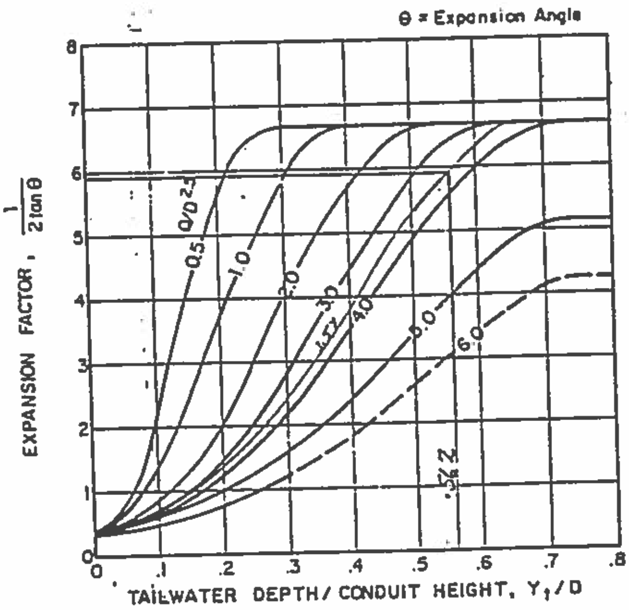


FIGURE 5-9. EXPANSION FACTOR FOR CIRCULAR CONDUITS

$L = (1/\tan\theta)\left(\frac{A_t}{Y_t} - w\right)$, from Fig 5-9 above $1/\tan\theta = 5.9$

$L = .59\left(\frac{34.66}{2.54} - 5\right) = 50.9$

Use $L = 50$ ft. beyond the end Section

Since the solution is between 12" and 9" riprap

Use $D_{50} = 12"$

II. Diversion Channel Design

Normal Channel Downstream from Culvert

$Q = 155$ cfs, $n = 0.0395\, D_{50}^{1/6}$, $S = .007$, $b = 6$ ft, $m = 3H:1V$

D_{50} (in:f)	n	y (f)	A (sf)	P (f)	R (f)	V (fps)	Fr	τ_o (psf)	τ_c (psf)	FS
6:0.50	0.035	2.46	32.85	21.54	1.53	4.72	0.661	0.67	2.421	3.61
4:0.33	0.033	2.39	31.45	21.11	1.49	4.93	0.698	0.65	1.614	2.48
3:0.25	0.0313	2.33	30.29	20.74	1.46	5.12	0.733	0.64	1.210	1.90

where:

Use $D_{50} = 4"$

$\tau_o = \gamma R S$, $\tau_c = 0.047(\gamma_s - \gamma) D_{50}$

$FS = \frac{\tau_c}{\tau_o}$

Hydraulic Design - Continued

III - first Bend - Sta 5+55 to 6+03

Curve Data: $\Delta = 7°$, $R = 400'$, to ℄, channel $b = 6$ ft, $T = 24.47'$, $L = 48.87'$

For $y = 2.39$ ft, topwidth of the water surface is:

$$T = b + 2ym = 6 + 2(2.39)(3) = 20.34 \text{ ft}$$

From "Design of Stable Channels With Flexible Linings", by FHA

$$R_d = 400 + \left(\frac{20.34+6}{4}\right) = 406.59'$$

superelevation $\Delta y = \frac{V^2 T}{g R_o} = \frac{(4.93)^2(20.34)}{(32.2)(400)} = 0.04$ ft

$\therefore$ highest depth $= 2.39 + .04 = 2.43$ ft use 2.5 ft
and with 2' FB, total riprapped channel depth = 4.5 ft

$$\Delta_c = \cos^{-1}\frac{R_o}{R_d} = \cos^{-1}\frac{400}{406.59} = 10.33 > \Delta = 7° \quad \therefore \text{ use short bend procedures}$$

From Chart 33: $\frac{V^2}{R_d} = \frac{(4.93)^2}{406.59} = 0.0598$ use 0.06

and $K_3 = 1.20$

From Chart 34: $\frac{\Delta}{\Delta_c} = \frac{7}{10.33} = 0.678$

$K_3' = 1.136$

For SF = 2 (interpolated)

D_{50}(bend) $= 1.136 \cdot D_{50}$ (straight) $= 1.136\,(\approx 3.2") = 3.64$ in.

use a continuous $d_{50} = 4"$ continued from the straight channel section.

VAUGHN HANSEN ASSOCIATES

CLIENT: USPCI
PROJECT: Landfill Cells K-15
FEATURE: Perim. Conveyance Channel No. 1
PROJECT NO.: 4-2-7

SHEET 46 OF 47
COMPUTED: KCS
CHECKED:
DATE: Feb. 87

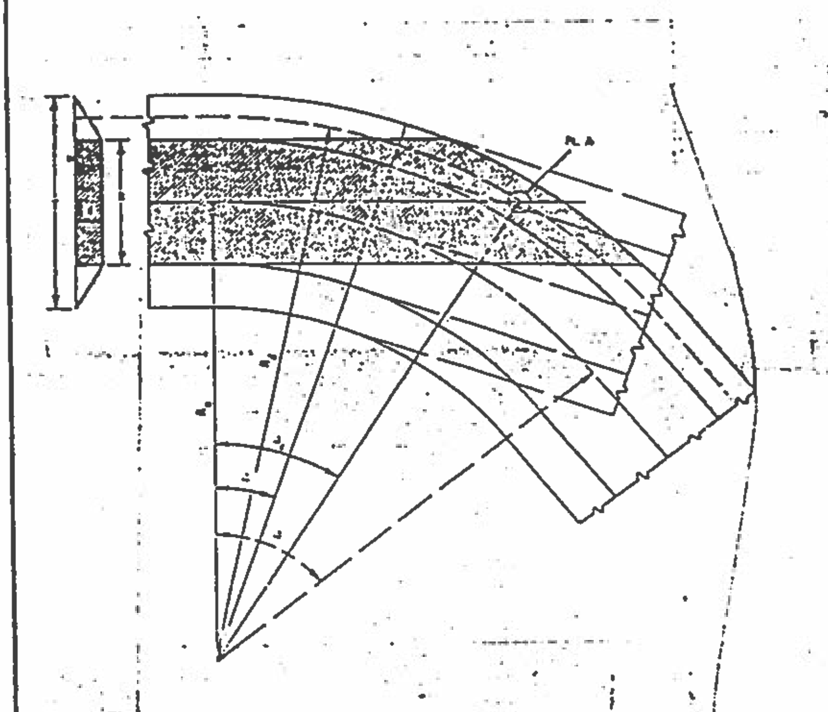
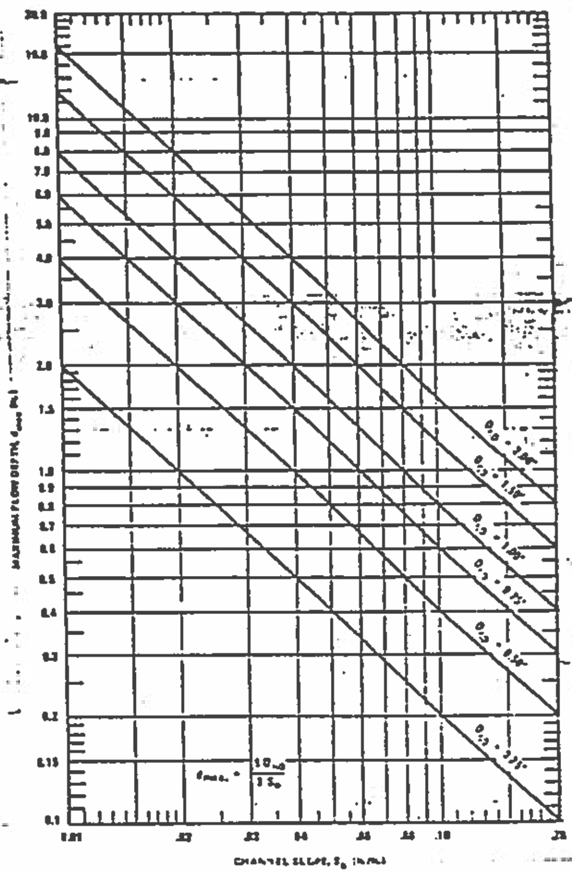


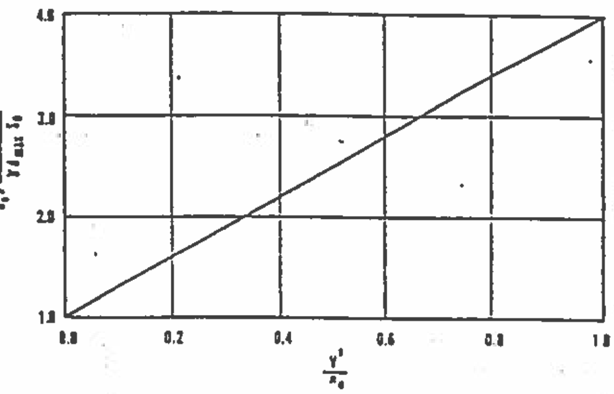
Figure 2. DEFINITION SKETCH FOR FLOW IN BENDS

Chart 27



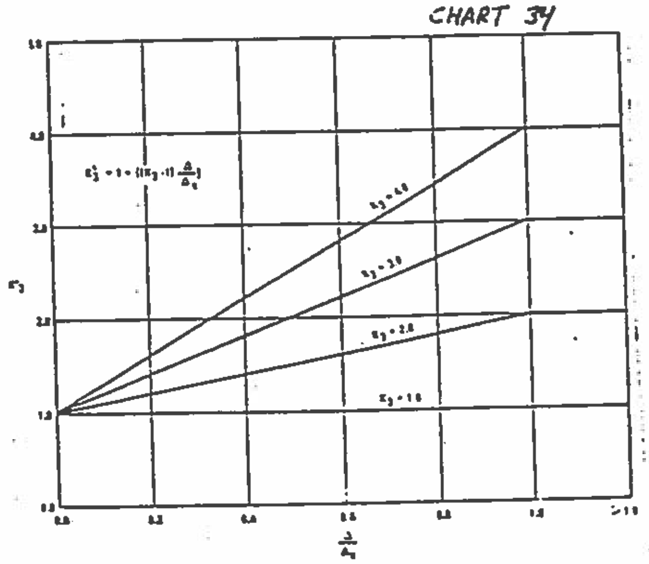
MAXIMUM PERMISSIBLE DEPTH OF FLOW (d_{max})
FOR CHANNELS LINED WITH ROCK RIPRAP

Chart 33



RATIO OF MAXIMUM BOUNDARY SHEAR IN BENDS
TO MAXIMUM BOTTOM SHEAR IN STRAIGHT REACH

CHART 34



RATIO OF MAXIMUM BOUNDARY SHEAR IN SHORT BENDS
TO MAXIMUM BOTTOM SHEAR IN STRAIGHT REACH

Hydraulic Design - Continued

IV Second Bend, see the following Page for the curve layout

Curve Data $\begin{cases} \Delta = 92^\circ \\ R = 200' \\ T = 207.1061' \\ L = 321.1406' \end{cases}$ to ℄ of channel, $b = 6$ ft

For $y = 2.39$ ft, top width $T = 20.34$ ft

$$R_d = R_o + \left(\frac{T+b}{4}\right) = 200 + \left(\frac{20.34+6}{4}\right) = 206.585 \text{ ft}$$

$$\Delta y = \frac{V^2 T}{g R_o} = \frac{(4.93)^2 (20.34)}{32.2 (200)} = 0.077 \text{ ft}$$ ∴ the max flowdepth including superelevation $= 2.39 + .077 = 2.47'$

channel Depth below the top of the riprap is ; $2.47 + 2(FB) = 4.5$ ft

$$\Delta_c = \cos^{-1} \frac{200}{206.59} = 14.51^\circ < \Delta = 90^\circ$$ ∴ use long bend procedures

From Chart 33, $\frac{V^2}{R_d} = \frac{(4.93)^2}{206.59} = 0.118$

and $K_3 = 1.36$

d_{50} (bend) $= 1.36\ D_{50}$ (straight) for $SF = 2$ D_{50} (straight) $= 3.2''$

$= 1.36 (3.2) = 4.4''$

use $D_{50} = 6''$ for bend

HA&L ENGINEERING

CLIENT Laidlaw
PROJECT Lone Mtn - Storm Drainage
FEATURE Hydrology - Channel Design
PROJECT NO. 64.63.100

SHEET ___ OF ___
COMPUTED DLK
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DATE 4/30/98

ATTACHMENT 5

RUNON CHANNEL NO. 2

ORIGINAL DESIGN CALCULATIONS

VAUGHN HANSEN ASSOCIATES

CLIENT: USPCI | SHEET 11 OF 25
PROJECT: [illegible] | COMPUTED: KCS
FEATURE: Runoff Control - upper Channel No. 2 | CHECKED:
PROJECT NO.: 14-2-2 | DATE: Feb. 27

Hydraulic Design Continued

III. Perminant Channel Design below Culvert.

Two channel reaches will be designed as follows:

1- The culvert outlet
2- The straight channel reaches

1- Culvert Outlet
Using the procedures for outlet protection found in The "Urban Storm Drainage - Criteria Manual" by The Denver Regional Council of Governments.

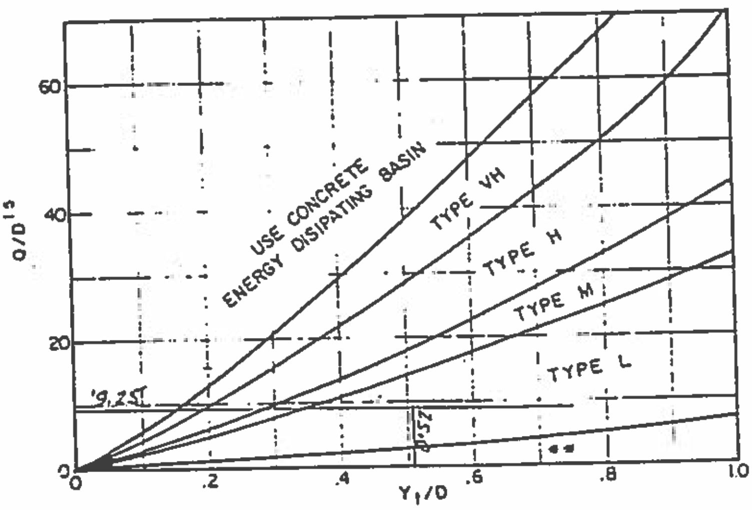
a- determine the flow characteristics in the culvert using mannings equation.

$D = 4.5'$, $n = .024$, $Q = 65$, $S = .007$
$y = 2.85$ ft, $A = 10.6$ ft², $P = 8.28$ f, $R = 1.28$, $V = 6.13$ fps, $Fr = 0.69$
$\theta = 210.774°$, $T = 4.34$ ft

b- using the calculated velocity, adjust the pipe diameter to a full-flowing pipe.

$A = Q/v = 65/6.13 = 10.60 = \pi r^2$ and $d = 2r$
$\therefore d = 3.67$ ft

c- Using Figure 5-7 shown below, illerate into a riprap size.



Use D_a instead of D whenever flow is supercritical in the barrel.
** Use Type L for a distance of 3D downstream.

FIGURE 5-7. RIPRAP EROSION PROTECTION AT CIRCULAR CONDUIT OUTLET.

$Q/D^{1.5} = 65/3.67^{1.5} = 9.25$

Q for the tail water = 109 cfs

Assumed D_{50} (in : f)	n	y_t (f)	A_t (sf)	V_t (fps)	$\frac{y_t}{D}$	Fig. 5-7 Riprap Type	D_{50} (in : f)
9 : .75	.038	1.90	26.30	4.14	.519	L	9 : 1

therefore 9" D_{50} is OK as assumed and the culvert design also proves to be adequate.

d - from the equation $L = (1/2\tan\theta)(\frac{A_t}{y_t} - W)$
and the figure below determine the length of 9" riprap to be used.

$Q/D^{2.5} = \frac{65}{4.5^{2.5}} = 1.51$

$\frac{A_t}{y_t} = \frac{26.3}{1.9} = 13.84$

$w = 4.5$

$\therefore L = 6.63(13.84 - 4.5)$

$L = 62$ ft

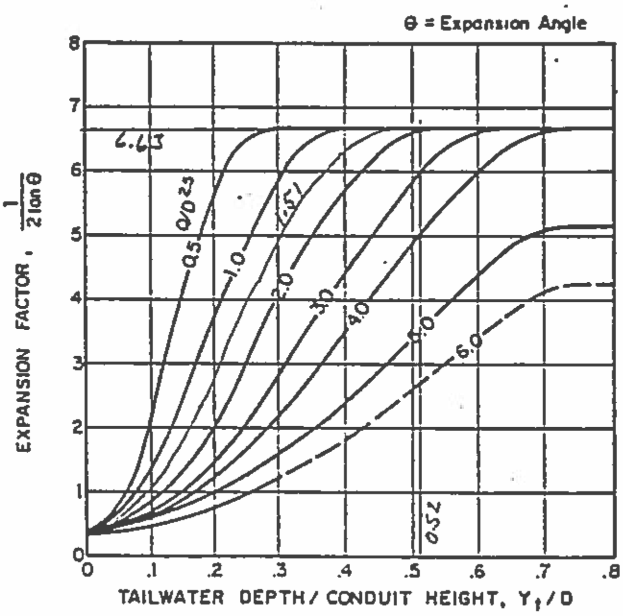


FIGURE 5-9. EXPANSION FACTOR FOR CIRCULAR CONDUITS

d - Check whether or not the outlet riprap needs to be sized up due to the sharp turn between the culvert outlet and the channel.

The degree of the sharp bend is:

$89°09'28'' - 80° = 9°09'28'' = 9.1578°$

Assume a tangent distance of about 15 ft

$\therefore\ R_i = \dfrac{15}{\tan \frac{9.1578}{2}} = 187\ ft$ use $190\ ft = R_o$

for $y = 1.9\ ft$ the top width of the channel is

$$T = b + 2my = 10 + 2(2)(1.9) = 17.6\ ft$$

$$R_d = 190 + \left(\frac{17.6 + 10}{4}\right) = 196.9$$

$\Delta_c = \cos^{-1} \dfrac{190}{196.9} = 15.2130^\circ > 9.1578^\circ$ $\therefore$ Short bend.

From Chart 33

$$\frac{V^2}{R_d} = \frac{4.14^2}{196.9} = 0.087$$

$$K_3 = 1.26$$

From Chart 34

$$\frac{\Delta}{\Delta_c} = \frac{9.1578}{15.2130} = 0.602$$

$$K_3' = 1.16$$

D_{50} (bend) $= 1.16\ D_{50}$ (straight) $= 9(1.16) = 10.4''$

$\therefore$ use $D_{50} = 12''$

with $D_{50} = 12''$ the length of the culvert outlet reach should be reduced.

For the larger flowrate produced in the runon control channel the riprap was extended for 50 ft.

$\therefore$ use $D_{50} = 12''$ for $L = 50\ ft$

VAUGHN HANSEN ASSOCIATES

CLIENT USPCI
PROJECT Lemi fill Cells IC & II Eng. [illegible]
FEATURE Runoff Control - Upper Channel No. 2
PROJECT NO. 114-2-2

SHEET 20 OF 25
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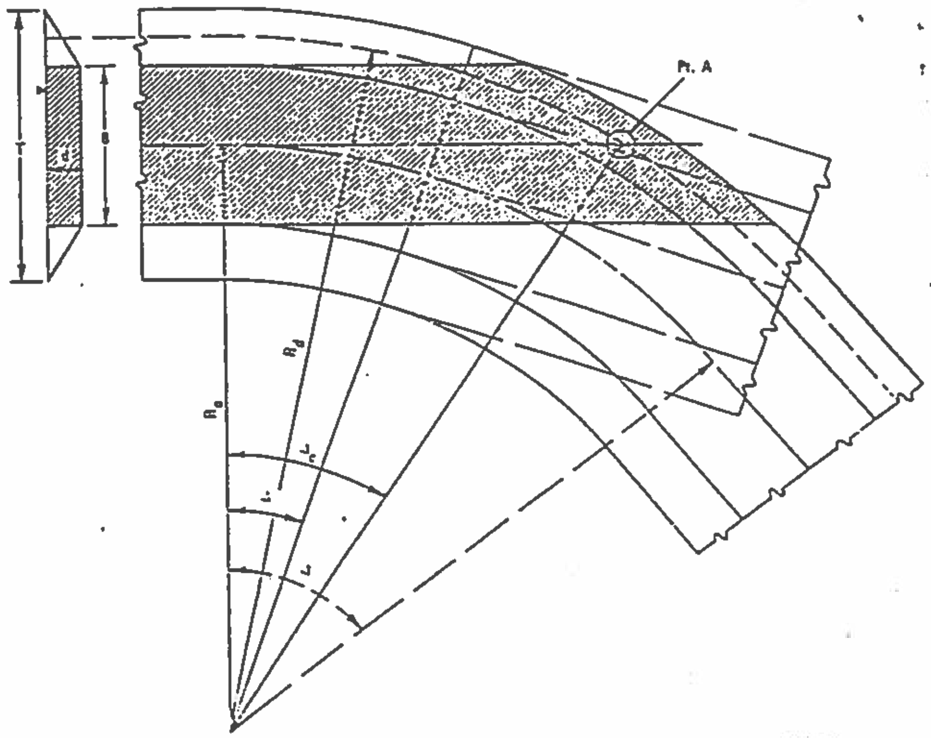

Figure 2. DEFINITION SKETCH FOR FLOW IN BENDS

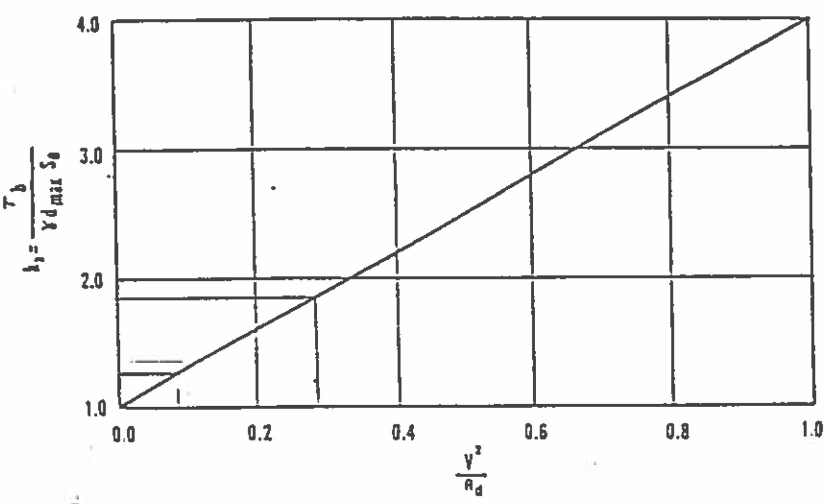

Chart 33 RATIO OF MAXIMUM BOUNDARY SHEAR IN BENDS TO MAXIMUM BOTTOM SHEAR IN STRAIGHT REACH

VAUGHN HANSEN ASSOCIATES

CLIENT USPCI

PROJECT Landfill Cells 1C & 11 Lone Mtn

FEATURE Runoff Control - Upper Channel No. 2

PROJECT NO. 114-2-2

SHEET 21 OF 25

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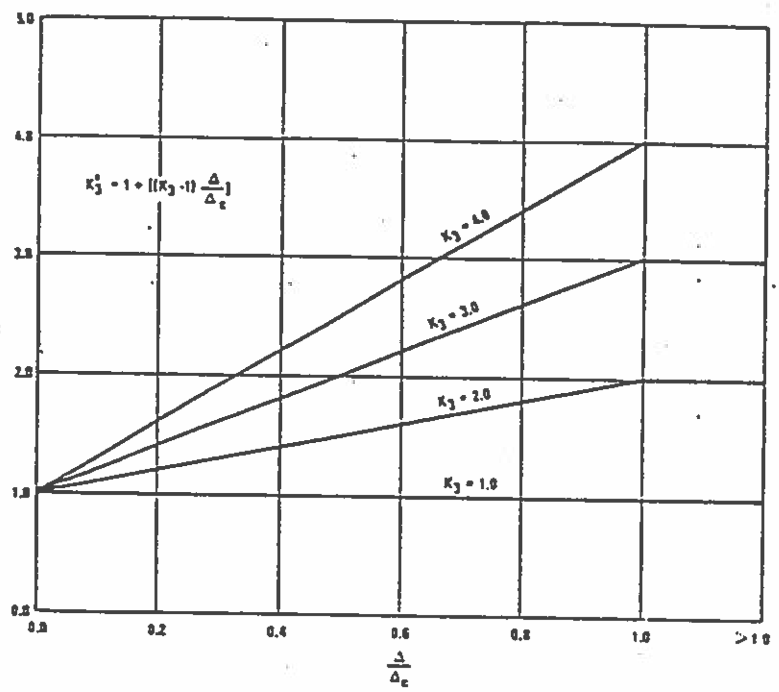
DATE Feb. 87

CHART 35



RATIO OF MAXIMUM BOUNDARY SHEAR IN SHORT BENDS TO MAXIMUM BOTTOM SHEAR IN STRAIGHT REACH

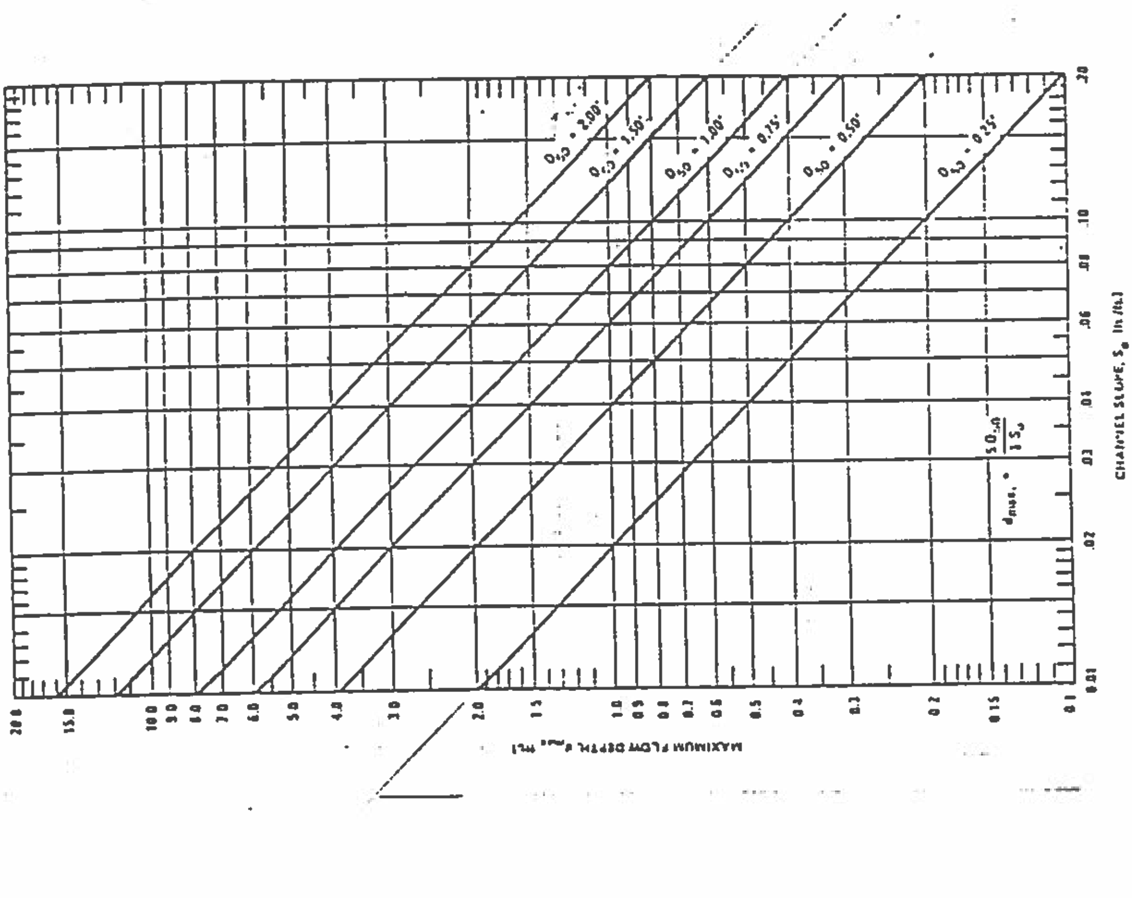


Chart 27

MAXIMUM PERMISSIBLE DEPTH OF FLOW (d_{max}) FOR CHANNELS LINED WITH ROCK RIPRAP

Hydraulic Design Continued

2. Straight Channel Reaches

Design the riprap for the straight channel reaches assuming:

$Q = 152$ cfs, $b = 10$, $m = 2$, $n = 0.0395\, D_{50}^{1/6}$
$S = 0.007$

D_{50} (in:f)	n	y (f)	A (sf)	P (f)	R (f)	V (fps)	Fr	τ_o (psf)	τ_c (psf)	FS
4:0.33	0.033	2.11	30.09	19.46	1.55	5.05	0.70	0.676	1.628	2.41 ←
3:0.25	0.0314	2.06	29.02	19.20	1.51	5.24	0.73	0.660	1.210	1.83

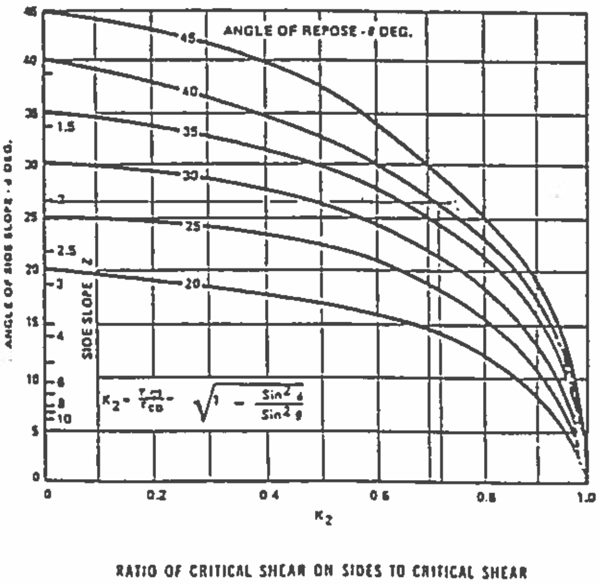
use d_{50} = 4 inch riprap on the straight sections

Find D_{50} for FS = 2 & R = 1.53

$\gamma R S (2) = .047(103)(D_{50})$ $\therefore$ $D_{50} = 0.28$ ft
$2(62.4)(1.53)(.007) = .047(103)(D_{50})$ $= 3.31$ in.

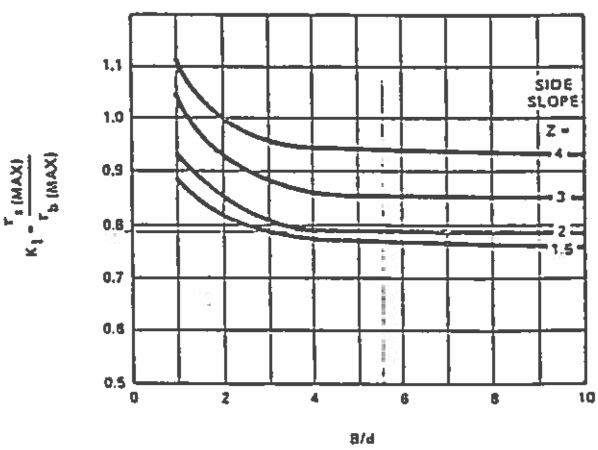
sizing for steep sideslopes:
assume an angle of repose of 40°

Chart 32



RATIO OF CRITICAL SHEAR ON SIDES TO CRITICAL SHEAR ON BOTTOM FOR NONCOHESIVE SEDIMENT

Chart 31



DISTRIBUTION OF BOUNDARY SHEAR AROUND WETTED PERIMETER OF TRAPEZOIDAL CHANNELS

Hydraulic Design Continued

Charts 31 and 32 on the preceding page are taken from "Design of Stable Channels with Flexible Linings" Federal Highway Administration

From Chart 31 $B/d = \frac{10}{2.1} = 4.76$

and $K_1 = 0.79$.

From Chart 32

$K_2 = 0.72$

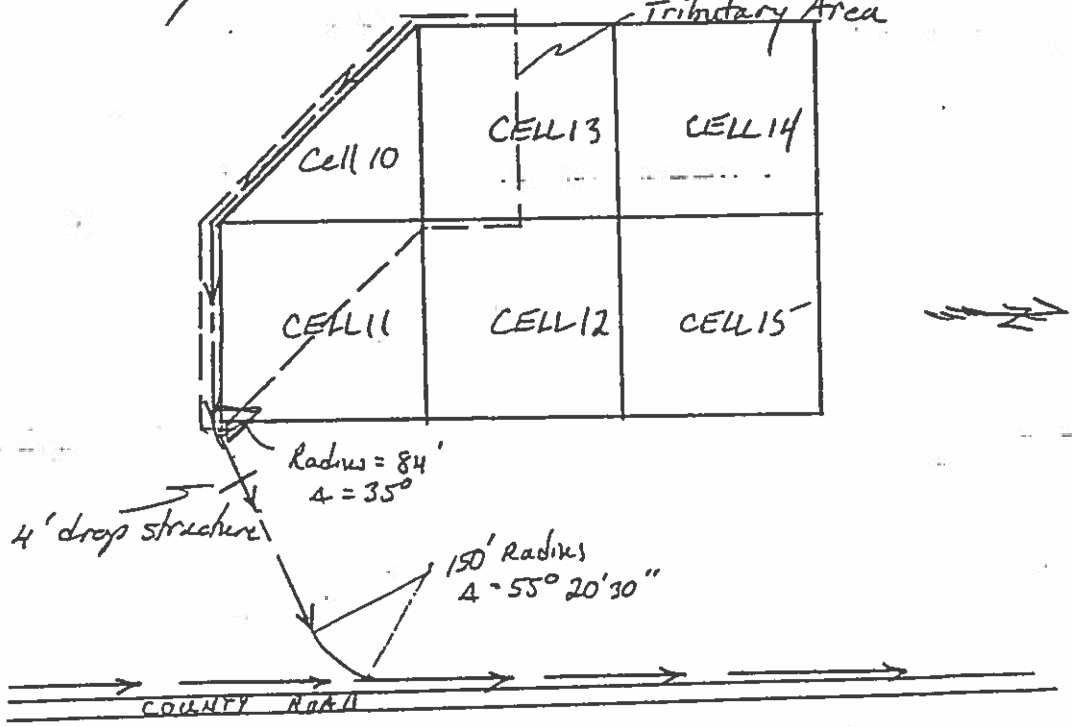
D_{50} (sides) $= \frac{K_1}{K_2} D_{50}$(Bottom) $= \frac{.79}{.72}(3.31) = 3.63$ in

use $D_{50} = 4$ inches for the whole channel section for all straight sections.

I- Design of the runoff conveyance channel which is located along the south side of Landfill Cell 11 and which will be rerouted to discharge into the existing drainage channel on the west side of the county road (now refered to as run-on channel No. 2).

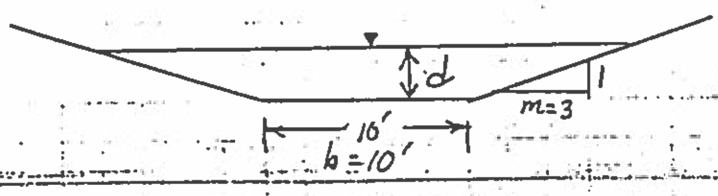
A- Design considerations and tributary area.

Note: The design of the runoff conveyance channel along the south side of Cell 11 is presented in the "Engineering Design Report, Landfill Cells 10 and 11, Lone Mountain Facility." The design presented herein is to extend or reroute this channel from the southeast corner of Cell 11 to the existing channel on the west side of the County Road. Presently, this channel turns to the north and runs along the east toe of Landfill Cell 11. The design flowrate of 152 cfs presented in the above referenced report is therefore applicable to the channel extension to the east into the existing channel along the County Road. Illustrated below is the tributary area to this rerouted channel.



B- Channel design configuration

• Channel cross-section



• Channel slope

Length = 427.8'
ΔH = 1382.46 - 1374.68 = 7.78'

$$Slope = \frac{\Delta H}{Length} = \frac{7.78}{427.8} = 0.0182\ ft/ft$$

• Check for lining requirement - If velocity of unlined channel is greater than 5 fps (which is the maximum permissible velocity for a stiff clay soil) then the channel must be lined.

Using mannings equation:

$$Q = \frac{1.486}{n} \frac{A^{5/3}}{P^{2/3}} S^{1/2}$$

with $n = 0.02$ for an unlined clay soil channel
$S = 0.0182$ ft/ft
$Q = 152$ cfs
$b = 10'$
$m = 3:1$

Area A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Velocity V fps	Flow Depth d ft	Froude Number
16.06	17.49	0.92	9.47	1.19	1.7

Since the velocity is much greater than 5 fps, the channel must be lined. Using Sheilds criteria to check the required size of riprap (from "Sediment Transport Technology", by Simons & Senturk, pg 450)

$$\tau_c = 0.047\,\gamma(SG-1)D_{50} \qquad \tau_o = \gamma . d . S$$

where τ_c = limiting tractive force on channel bottom
τ_o = tractive force on channel bottom
γ = Unit weight of water
SG = specific gravity of rock

d = flow depth in channel
S = Channel slope

on channel bed $\eta_0 = \frac{\tau_0}{\tau_c} = \frac{\gamma d S}{0.047\gamma(SG-1)D_{50}} = \frac{21.3 d S}{(SG-1)D_{50}}$

max shear stress on sideslopes

on channel bank where potential for failure is greatest $\eta = \frac{21.3\,\tau_{max}}{\gamma(SG-1)D_{50}}$ where $\tau_{max} = 0.85\gamma d S$ for 3:1 sideslopes

$\eta' = \eta\,\frac{1+\sin(\lambda+\beta)}{2}$ where λ = channel slope angle for uniform flow

$\beta = \tan^{-1}\left(\frac{\cos\lambda}{\frac{2\sin\alpha}{\eta\tan\phi} + \sin\lambda}\right)$

α = angle of the channel sideslope
ϕ = angle of repose for rock = 42° for angular rock

α = 18.4349° for 3:1 slopes
$\lambda = \tan^{-1}(0.0182\ ft/ft) = 1.0427$

Safety Factor against Failure $SF_{cs} = \frac{\cos\alpha\tan\phi}{\eta'\tan\phi + \sin\alpha\cos\beta}$

Using Mannings Equation with $n = 0.0395\,D_{50}^{1/6}$

D_{50} ft	Q cfs	n	S ft/ft	m	b ft	A ft^2	P ft	R ft	V fps	d ft	Fr	η	β degrees	η'	SF_{cs}
0.75	152	0.038	0.0182	3	10	25.20	20.60	1.22	6.03	1.70	0.95	0.45	32.305	0.35	1.5

Note: Procedure for riprap design or for any channel design recommends that the channel not have a Froude Number near 1. Design should have Fr less than 0.8 or greater than 1.2. Therefore, the slope must be flattened.

Design the channel with a 4' drop to be in a hydraulic condition with Fr < 0.8 or Fr > 1.2. This 4' drop could be accomplished with a vertical concrete drop structure.

- Design channel with a 4' Drop Structure.
  Channel Length = 427.8'

  Channel Slope = $\frac{7.78' - 4'}{427.8'}$ = 0.0088 ft/ft

Check requirement for channel lining on 0.0088 ft/ft slope
n = 0.025, S = 0.0088 ft/ft Q = 152 cfs, m = 3, b = 10'

Q = cfs	A ft^2	P ft	R ft	V fps	d ft	Fr
24.23	24.23	20.29	1.19	6.27	1.63	0.99

Since the velocity is greater than 5 fps, the channel must be lined. Using the same procedure as defined above determine the design D_{50}.

Mannings $n = 0.0395\, D_{50}^{1/6}$

D_{50} ft	Q cfs	n	S ft/ft	m	b ft	A ft²	P ft	R ft	V fps.	d ft	Fr	η'	B degrees	η	SF_{cs}
0.5	152	0.0352	0.0088	3	10	30.91	22.33	1.38	4.92	1.95	0.73	0.38	28.2984	0.28	1.6
0.33	152	0.0329	0.0088	3	10	29.45	21.90	1.34	5.16	1.88	0.77	0.55	37.8697	0.45	1.3

Use $D_{50} = 0.50$ at a slope of 0.0088 ft/ft

- Check required riprap size around bends, due to increased shear stress on rock around bends which is a function of the channel bend radius. Procedure used is from "Design of Stable Channels with Flexible Linings", 1975 by U.S. Dept. of Transportation.

There a two bends, one with R = 150 ft and the other with R = 84

Δ_c must be calculated to determine whether Δ of the bend is greater or less than Δ_c.
If $\Delta \geq \Delta_c$ use the long bend procedure
If $\Delta < \Delta_c$ use short bend procedure.

$$\Delta_c = \cos^{-1}\frac{R_o}{R_d}$$

$$R_d = R_o + \left(\frac{T+B}{4}\right)$$ and R_o, T, and B are illustrated on the figure below.

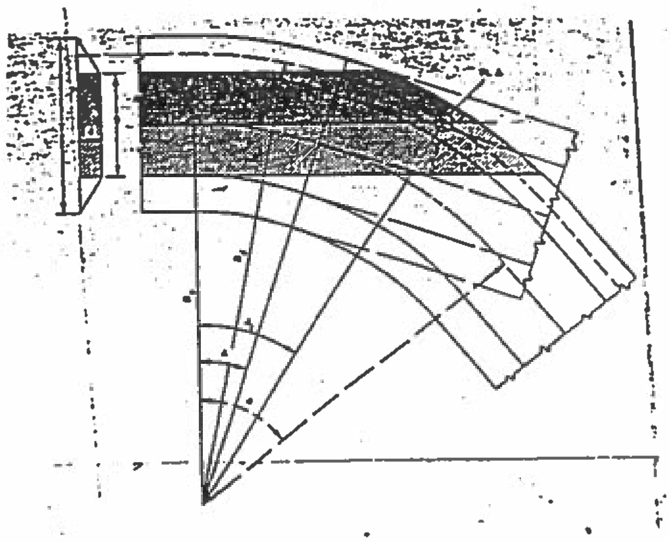


Figure 2. DEFINITION SKETCH FOR FLOW IN BENDS

∴ , $B = 10'$, and $T = 21.7'$ @ $d = 1.95'$ under design flow conditions.

For $R = 84'$ $R_d = 84' + \left(\frac{21.7+10}{4}\right) = 91.9'$

$\Delta_c = \cos^{-1} \frac{84}{91.9} = 23.93°$

$\Delta = 35°$,

~~Since $\Delta = 35° > \Delta_c = 23.9°$ use long bend procedure.~~

For $R = 150$ $R_d = 150 + \left(\frac{21.7+10}{4}\right) = 157.9'$

$\Delta_c = \cos^{-1} \frac{150}{157.9} = 18.2°$

$\Delta = 55.3417°$

since $\Delta = 55.34° > \Delta_c = 18.2°$ use long bend proc

From Chart 33 below determine "K_3", the ratio of maximum boundary shear in bends, to the maximum boundary shear in a straight reach, using V^2/R_d

$V = 4.9$ fps

For $R = 84'$, $R_d = 91.9'$, $\frac{V^2}{R_d} = \frac{4.9^2}{91.9} = 0.26$

$K_3 = 1.85$ $\tau_0 = 1.85\, \gamma d S$

For $R = 150'$, $\frac{V^2}{R_d} = \frac{4.9^2}{157.9} = 0.15$

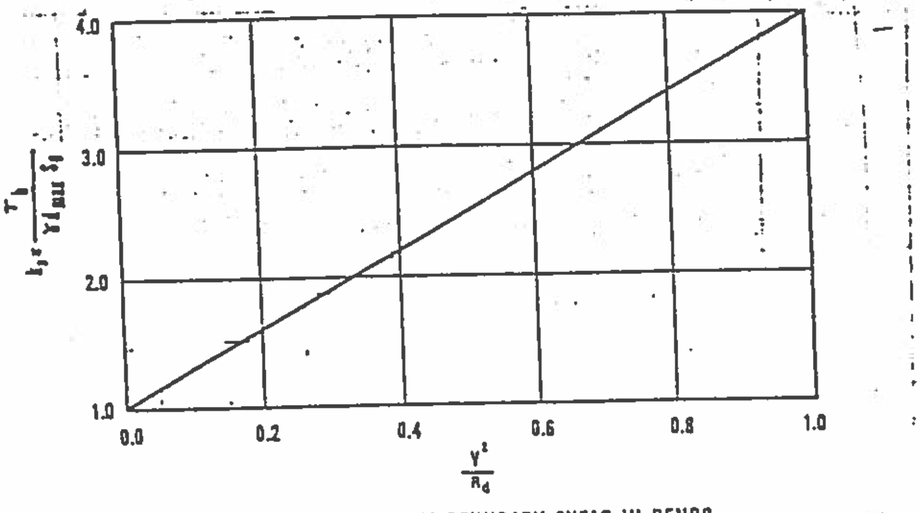
$K_3 = 1.5$ $\tau_0 = 1.5\, \gamma d S$

Then apply same procedure as before,

	D_{50} ft	Q cfs	n	S ft/ft	m	b ft	A ft²	P ft	R ft	V fps	d ft	Fr	η	β degrees	η'	SF
84' Radius →	1.0	152	0.0395	0.0088	3	10	33.57	23.09	1.45	4.53	2.07	0.65	0.44	31.9211	0.34	1.5 ← OK
150' Radius →	0.75	152	0.0377	0.0088	3	10	32.46	22.78	1.42	4.68	2.02	0.68	0.46	33.0685	0.36	1.5 ← OK

∴ Use $D_{50} = 1'$ for 84' Radius Bend

∴ Use $D_{50} = 0.75'$ for 150' Radius Bend.



RATIO OF MAXIMUM BOUNDARY SHEAR IN BENDS

II – Design 4' drop structure and riprap downstream of drop structure.

Using the equations and diagram below from "Open Channel Hydraulics" by Chow, L_d, y_p, y_1, and y_2 can be determined assuming a rectangular drop.

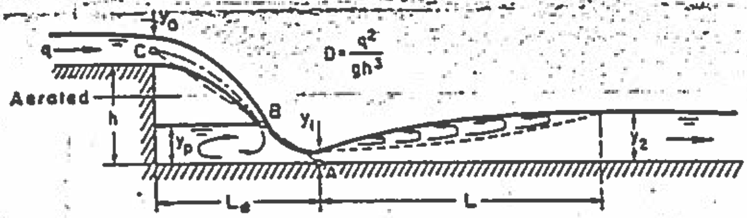


FIG. 15-18. Flow geometry of a straight drop spillway.

$$\frac{L_d}{h} = 4.30D^{0.27}$$
$$\frac{y_p}{h} = 1.00D^{0.22}$$
$$\frac{y_1}{h} = 0.54D^{0.425}$$
$$\frac{y_2}{h} = 1.66D^{0.27}$$

D = Drop number

q = discharge per unit width of crest overfall

g = accelleration due to gravity.

h = height of drop = 4'

$Q = 152$ cfs

Channel bottom width = rectangular opening width for drop = 10'

$$q = \frac{152}{10} = 15.2 \text{ cfs.}$$

$$D = \frac{q^2}{gh^3} = \frac{15.2^2}{32.2(4)^3} = 0.11$$

drop length $L_d = 4(4.3)(0.11)^{0.27} = 9.5'$

Pool depth under nappe $y_p = 1.00(0.11)^{0.22}(4) = 2.46'$

Depth of Toe of nappe $y_1 = 0.54(0.11)^{0.425}(4) = 0.85'$

Tailwater Depth $y_2 = 1.66(0.11)^{0.27}(4) = 3.65'$

$L = 4y_0 = 4(1.88) = 7.5'$

Basin Length $= L_d + L = 9.5 + 7.5 = 17'$

Use a 20' Basin Length of larger diameter riprap

• Check size of riprap required in drop basin

Using Shields criteria to determine point of incipient motion.

$$\tau_c = 0.047(\gamma_s - \gamma) D_{50}$$

$$\tau = \frac{1}{8} \rho f V^2$$

~~where τ = shear stress on particle~~
ρ = density of water
~~f = darcy weisbach~~ friction factor
V = flow velocity.

Setting $\tau_c = \tau$

V = velocity at toe of nappe $= \frac{q}{y_1} = \frac{15.2}{0.85}$
$= 17.9$ fps.

Assume riprap $D_{50} = 1.5'$. $n = 0.0395(1.5)^{1/6} = 0.0423$

$$f = 116 \frac{n^2}{y_0^{1/3}} = 116\left(\frac{0.0423^2}{1.88^{1/3}}\right) = 0.168$$

$$D_{50} = \frac{\frac{1}{8}\rho f V^2}{0.047(\gamma_s - \gamma)} = \frac{\frac{1}{8}(1.94)(0.168)(17.9)^2}{0.047(165.4 - 62.4)}$$

$$= 2.7'$$

Assuming no scour $\rightarrow D_{50\,Design} = 1.5(2.7) = 4'$ ← Impractical

Therefore design for a scour depth.

• In designing for a scour depth while sizing the riprap to accomodate that depth, there are several emperical techniques that can be employed. A couple of these techniques will be checked to compare results. The first two methods presented below are taken from "Sediment Transport Technology" by Simons & Sentürk.

Method 1 - Depth of scour proposed by Schoklitsch:

$$d_s = S + h_d = 4.75 \frac{H^{0.2} q^{0.5}}{D_{90}^{0.32}} \qquad (9.23)$$

where d_s is the distance from the deepest point of the scour hole to the downstream water surface - in meters
S is the depth of the scour hole - in meters
h_d is the downstream water depth - in meters
q is the water discharge per unit of width and
D_{90} is the particle size for which 90 percent of the material is finer
H is the vertical distance between the energy grade

VAUGHN HANSEN ASSOCIATES

CLIENT UCPCT
PROJECT Lone Mtn. Expansion Plan
FEATURE Conveyance Channel No. 2
PROJECT NO. 4-2-5

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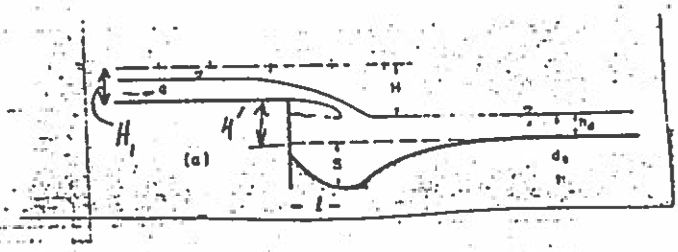
This formula is in metric units.



Assume a $D_{50} = 0.75'$ which would have a D_{90} of $\approx 1.3' = 0.41$ meters $= 410$ mm

$h_d = 1.88$ ft $= 0.57$ meters

H_1 = Energy Head upstream of the drop

$= Y_1 + \frac{V^2}{2g} = 1.88' + \frac{5.17^2}{64.4} = 2.3' = 0.7$ meters

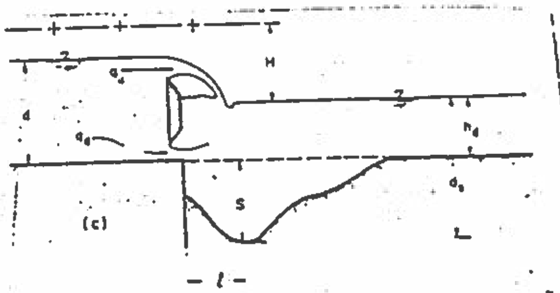
$H = H_1 + 4' - h_d = 2.3' + 4' - 1.88' = 4.42' = 1.35$ meters.

$q = 15.2 \frac{cfs}{ft} = 1.41 \frac{m^3/sec}{m}$

$d_s = 4.75 \frac{(1.35)^{0.2}(1.41)^{0.5}}{410^{0.32}} = 0.74$ m

$S = d_s - h_d = 0.74 - 0.57 = 0.17$ meters $= \underline{0.6 \text{ ft.}}$

Method 2 - Uses Jager's formula - which actually also assumes in addition to an overflow over a spillway, that a jet is issuing from the bottom of the spillway as well. See Figure below.



$$d_s = S + h_d = 6\, H^{0.25}\, q^{0.5}\, \left(\frac{h_d}{D_{90}}\right)^{1/3} \qquad (9.25)$$

In these relations C is a constant, d_s, H and h_d are in meters, D_{90} is in millimeters and q in m^3/sec-m

VAUGHN HANSEN ASSOCIATES

CLIENT: USPCI
PROJECT: Lone Mountain Expansion Plan
FEATURE: Conveyance Channel No. 2
PROJECT NO.: 4-2-5

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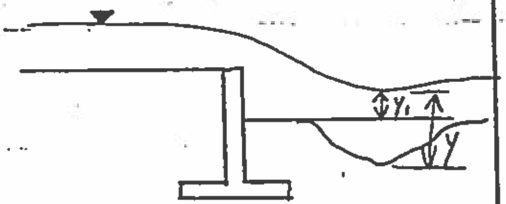
DATE: 7/13/87

$$d_s = 6(1.35)^{0.25}(1.41)^{0.5}\left(\frac{0.57}{410}\right)^{0.33} = 0.86\ m$$

$$S = 0.86 - 0.57 = 0.29 \text{ meters} = \underline{0.95\ ft.}$$

Method 3 - Uses Shields criteria to determine a critical velocity for the D_{50} size of riprap being checked and then calculates the required scour depth to provide sufficient cross sectional area for the given flowrate to obtain that velocity.

$S = Y - Y_1$ where



From Shields

$$V_c = \left[\frac{8(0.047)(\gamma_s - \gamma)(D_{50})}{\rho f}\right]^{1/2}$$

$$n = 0.0395(0.75)^{1/6} = 0.038$$

$$f = 116\frac{n^2}{Y_0^{1/3}} = 116 \times \frac{0.038^2}{1.88^{1/3}} = 0.1357$$

$$V_c = \left[\frac{8(0.047)(103)(0.75)}{1.94(0.1357)}\right]^{1/2} = 10.5\ fps.$$

$$Y = \frac{q}{V_c} = \frac{15.2}{10.5} = 1.45'$$

$$S = 1.45 - 0.85 = \underline{0.6\ ft}$$

Since all three methods are between 0.5 to 1', use a scour depth = 1 foot. Use a D_{50} for the riprap of 14" which would provide a safety factor against failure of:

$$S.F. = \frac{14"}{9"} = 1.6 \Leftarrow OK$$

Riprap design basin downstream of structure, provide 24" thickness on riprap for riprap itself, plus 12" for scour. Total Riprap thickness downstream of structure would therefore be 3'. The length of this basin and indicated by the previous calculations should be 20'.

HA&L ENGINEERING

CLIENT Laidlaw
PROJECT Lone Mtn. Storm Drainage
FEATURE Hydrology - Channel Design
PROJECT NO. 64.63.100

SHEET ___ OF ___
COMPUTED JMA
CHECKED ___
DATE 4/30/98

ATTACHMENT 6

RUN-ON CHANNEL NO. 3

ORIGINAL DESIGN CALCULATIONS

HA&L ENGINEERING

CLIENT USPCI
PROJECT Lone Mountain Facilities
FEATURE Run-on Conveyance Channel No. 3
PROJECT NO. 64-

COMPUTED GJP
CHECKED
DATE June 1990

Run-On Channel No 3 Upper Reach:

Of the 24 acres tributary to Channel No 3 from subbasin III-A, only 22 acres is tributary to the upper reach of the channel.

$Q_{100yr\ 24hr} = \frac{22ac}{24ac} * 153cfs = 140 cfs$ see HEC 1 model

channel slope = 1.4%

Bend $\Delta \cong 90°$ ref. "Design of Stable Channels" FHA, 1975

try $R_0 = 125'$, $b = 12' \Rightarrow Y_0 = 1.7'$ $T = 22'$

$\therefore R_d = R_0 + \left(\frac{22+12}{4}\right) = 133.5'$

$\Delta_c = \text{ARC} \cos \frac{R_0}{R_d} = \cos^{-1} \frac{125}{133.5} = 20°$

$\therefore$ use long bend procedure.

Y_0. w/ $D_{50} = 9'' \Rightarrow Y_0 = 1.58'$ $V_0 = 5.3 fps$

CHART 33 (see copy attached)

$\frac{V^2}{R_d} = \frac{5.3^2}{133.5} = 0.21 \Rightarrow K_3 = \left(\frac{.6}{.2}\right).21 + 1 = 1.63$

$\therefore$ design flow depth in bend for rock stability

$\Rightarrow Y_{design} = 1.58 (1.63) = 2.6$

riprap design
$\Rightarrow$ use 9" D_{50} through bend SF = 1.4 ok

superelevation in bend

$\Delta y = \frac{V^2 T}{g R_0} = \frac{5.6^2 (21')}{g\ 125} = 0.16'$

$\therefore$ use design channel depth as follows

straight reach $\Rightarrow b = 12'$, $D_{50} = 6''$
channel depth $= 1.53 + 1' \cong \underline{2.6'}$

$125' R_0$ Bend $\Rightarrow b = 12'$ $D_{50} = 9''$
channel depth $= 1.53 + .16 + 1 \cong \underline{2.7'}$

see saftely factor calculations Attached

Lower Reach of Channel 3
Below confluence w/ subbasins III-B and III-C

$Q_{100\,yr}$ = 205cfs (see HEC 1 model)
channel slope = 1.4%

SCS criteria (SCS Tech Release No. 59)
⇒ maximum design slope = 0.7 critical slope
∴ 1.4% OK w/ D_{50} = 1' and b = 12'.

use channel bottom width = 15' to facilitate pipe drops from III-B and III-C

straight reach:
b = 15', D_{50} = 1', S_o = 1.4% ⇒ Y_o = 1.81 V_o = 5.6 fps
SF = 1.8 OK

Bend R = 760'

CHART 33 (ref. "Design of stable channels ... FHA, 1975)

$$\frac{V^2}{R} = \frac{5.6^2}{760} = 0.0413 \Rightarrow K_3 = \left(\frac{.6}{.2}\right).0413 + 1 = 1.12$$

⇒ use flow depth for riprap design in bend of
$K_3 Y_o = 1.12(1.81) = 2.0'$

superelevation in bend

$$\Delta Y = \frac{V^2 T}{g R_o} = \frac{5.6^2\,(26)}{32.2\,(760)} = 0.03'$$

∴ use design channel depth = 1.81 + .03 + 1 = 2.8

USE 2.9' channel depth for both straight and bend

bottom width = 15'
side slopes 3H : 1V

HYDRAULICS TABLE 100-YR 24-HR STORM EVENT

NT: USPCI
CT: LONE MTN. FACILITY

	GIVEN CONDITIONS						HYDRAULIC COMPUTATIONS					
	IDENTIFICA	DESIGN FLOW (CFS)	SLOPE (ft/ft)	BOTTOM WIDTH (FT)	SIDE SLOPE (H/V)	MANNINGS N	FLOW DEPTH (FT)	COMPUTED FLOW (CFS)	FLOW AREA (FT2)	VELOCITY (FPS)	FLOW TOP WIDTH (ft)	FROUDE NO.
-3	CRITICAL S	140	0.020	12	3	0.038	1.44	141.289	23.50	6.01	20.64	0.99
3	UPPER	140	0.014	12	3	0.038	1.58	140.059	25.45	5.30	21.48	0.84
3	UPPER BEND	140	0.014	12	3	0.038	2.6	357.999	51.48	6.95	27.6	0.90
-3	LOWER (check critical)	205	0.020	12	3	0.040	1.81	205.116	31.55	6.50	22.86	0.98
3	LOWER (check critical)	205	0.020	15	3	0.040	1.64	206.262	32.67	6.31	24.84	0.97
-3	LOWER	205	0.014	15	3	0.040	1.81	206.358	36.98	5.58	25.86	0.82
H 3	LOWER BEND	205	0.014	15	3	0.040	2.01	249.994	42.27	5.91	27.06	0.83

H RIPRAP DESIGN TABLE

CI
ECT: LONE MTN. FACILITY

rock specific gravity = 2.6

CHANNEL ID	RIPRAP D50 (FT)	ANGLE OF REPOSE (DEGREES)	SFs	MANNING'S N	FLOW DEPTH (FT)	TBmax MAX. TRACTIVE FORCE (LBS/FT2)	CHANNEL BED STABILITY Ns	SAFTEY FACTOR FOR BED SFs	RATIO (TSmax/TBmax)	TSmax MAX. SIDE TRACTIVE FORCE (LBS/FT2)	n	BETA (RADIANS)	CHANNEL WALL STABILITY N's	SAFTEY FACTOR FOR SIDE SFs
CR	0.75	41	1.6	0.037551	1.44	1.79712	0.524	[illegible]	0.75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
UP	0.75	41	1.8	0.237651	1.58	1.380288	0.387	[illegible]	0.75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
UB	0.75	41	1.4	0.037551	2.6	2.27136	0.637	[illegible]	0.75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LO	1	41	1.6	0.0395	1.81	2.25888	0.475	[illegible]	0.75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LO	1	41	1.7	0.0395	1.64	2.04672	0.431	[illegible]	0.75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LO	1	41	1.8	0.0395	1.81	1.581216	0.333	2.27	0.75	[illegible]	[illegible]	[illegible]	0.169	[illegible]
LO	1	41	1.8	0.0395	2.01	1.755936	0.359	[illegible]	0.75	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ATTACHMENT NO. 7

RUNON CHANNEL NO. 4

ORIGINAL DESIGN CALCULATIONS

Run-On Conveyance Channel No 4:

Design Flow Rate:
100 yr 24 hr storm (see HEC-1 printout, Exhibit A)
Detention Pond No. 3 Peak Discharge = 890 cfs
combined w/ runoff from subbasin IV-F
Channel 4 design Flow = 965 cfs

Channel Design:

$Q_{100\,yr\ 24\,hr}$ = 965 cfs
channel slope = 1.17 %
Bend Radius = 1500'

References: ① Riprap design with saftey factor as presented in "Applied Hydrology and Sedimentology for Disturbed Areas" Barfield, Warner and Haan, Oklahoma State University, 1985

② "Design of stable channels with Flexible Linings" F.H.A. October 1975

Straight reach hydraulics: (see attached spread sheet)

D_{50} = 14" ⇒ Mannings n = .0405

Bottom width = 18' 3H : 1V SIDE SLOPES

⇒ normal depth = 4.05' ⇒ Channel Depth = 4.0 + 1 (FB) = $\boxed{5.0'}$
normal velocity = 7.9 fps
D_{50} = 14" ⇒ s.f. side slopes = 1.6 ok

BEND:
(see attached Chart 33 from "Design of Stable channels..." ref. ② above)

$$\frac{V^2}{R_c} = \frac{7.9^2}{1500} = 0.0416$$

CHART 33 ⇒ $K_3 = 1 + \frac{.6}{.2}(0.0416) = 1.125$

K_3 is a depth factor used to adjust straight reach flow depth to account for extra shear stress in bend

∴ bend analysis depth = $Y_o\,K_3$ = 4.05 (1.125) = 4.56'
The attached spread sheet shows that w/a depth of 4.56 feet the riprap S.F. is 1.5, therefore

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ANNEL HYDRAULICS TABLE

...: USPCI
...JECT: LONE MOUNTAIN FACILITY

...ANNEL IDENTIFICATION	DESIGN FLOW (CFS)	SLOPE (ft/ft)	BOTTOM WIDTH (FT)	SIDE SLOPE (H/V)	MANNINGS N	HYDRAULIC COMPUTATIONS DEPTH (FT)	COMPUTED FLOW (CFS)	FLOW AREA (FT2)	WETTED PERIMETER (FT)	HYDRAULIC RADIUS (FT)	VELOCITY (FPS)	TOP WIDTH (FT)	FR
CH 4 14" RIPRAP CHANNEL	965	0.0117	18	3	0.0405	4.051	965.050	122.15	43.62	2.80	7.90	42.306	0.82
CH 4 max. depth at benc	965	0.0117	18	3	0.0405	4.55	1217.204	144.46	46.84	3.08	8.43	45.36	0.83

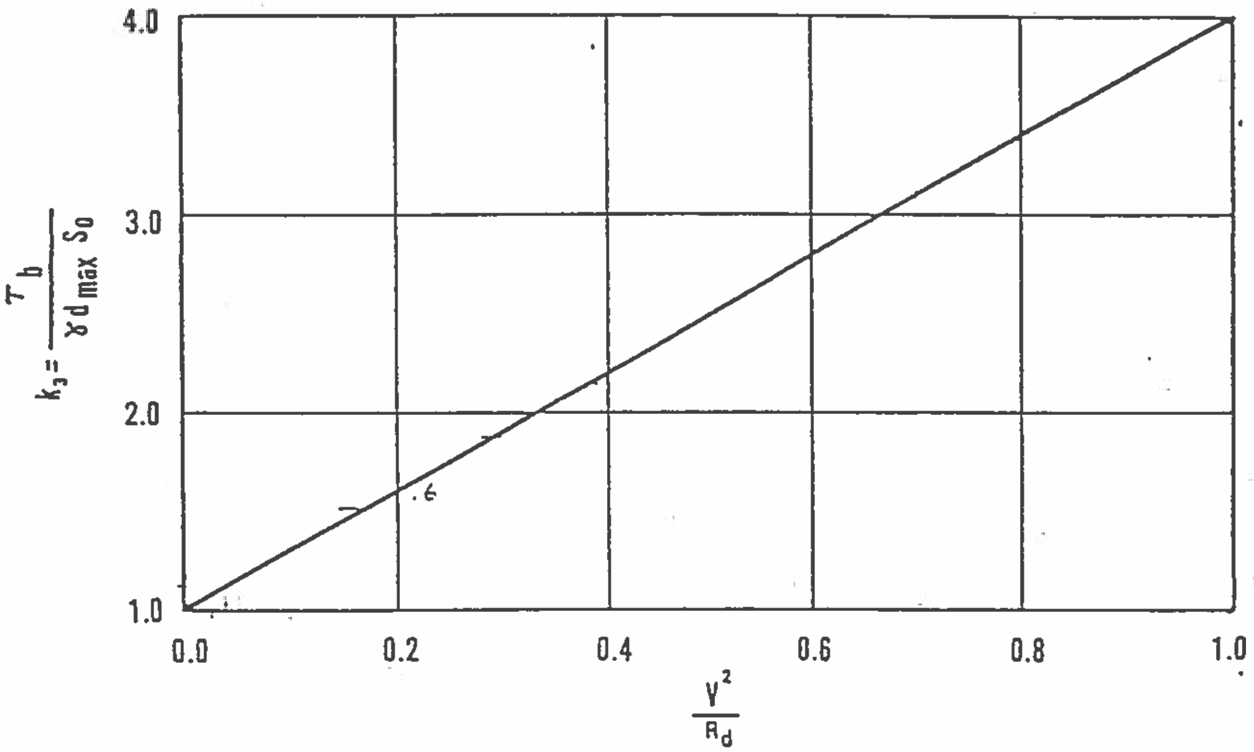
DITCH RIPRAP DESIGN TABLE

...IENT: USPCI
PROJECT:LONE MOUNTAIN FACILITY

...ANNEL IDENTIFICATION	RIPRAP D50 (FT)	ANGLE OF REPOSE (DEGREES)	FLOW DEPTH (FT)	MAX. TRACTIVE FORCE (LBS/FT2)	CHANNEL BED STABILITY η_0	SAFTEY FACTOR FOR BED SF_b	MAX. SIDE TRACTIVE FORCE (LBS/FT2)	η	BETA (RADIANS)	CHANNEL WALL STABILITY N'	SAFTEY FACTOR FOR SIDE SF_s
CH 4 14" RIPRAP CHAN	1.17	42	4.051	2.96	0.517	1.89	2.25	0.392	0.537	0.294	1.6
CH 4 max. depth at be	1.17	42	4.54	3.31	0.579	1.69	2.52	0.440	0.557	0.339	1.5

3/4

Chart 33



RATIO OF MAXIMUM BOUNDARY SHEAR IN BENDS
TO MAXIMUM BOTTOM SHEAR IN STRAIGHT REACH

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CLIENT USPCI
PROJECT Lone Mountain Facilities
FEATURE Run ON Conveyance Channel 4
PROJECT NO. 64–

COMPUTED GSP
CHECKED
DATE June 1990

Channel depth required in Bend

$$\text{superelevation} = \frac{V^2 T}{g R_o}$$

$$= \frac{7.9^2 \; 42.3}{g \; 1500} = \underline{0.05'}$$

∴ required channel depth = Yo + FB + superelev.

$$= 4.05' + 1' + 0.05'$$

$$= \underline{\underline{5.1'}}$$

CHANNEL DESIGN SUMMARY:

Design Flow = 965 cfs
channel slope = 1.17%

bottom width = 18'
side slopes 3H:1V
Riprap D_{50} = 14"

Channel Depth:
straight reach ⇒ 5.0'
bend 5.1'

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CLIENT Laidlaw
PROJECT Lone Mtn. Storm Drainage
FEATURE Hydrology - Channel Design
PROJECT NO. 64.63.100

SHEET ___ OF ___
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DATE 4/30/98

ATTACHMENT NO. 8

RUNON CHANNEL NO. 5

ORIGINAL DESIGN CALCULATIONS

HA&L ENGINEERING

CLIENT: USPCI
PROJECT: Lone Mountain Facilities
FEATURE: Run ON Conveyance Channel No. 5
PROJECT NO.: 64-

SHEET 1 OF 2
COMPUTED: GJF
CHECKED:
DATE: June 1990

Run on Conveyance channel No. 5 is located along the west side of the county road adjacent to cells 11, 12, and 15.

The upper reach of channel 5 recieves runoff from Subbasin V-A and Channels 1 & 2.

Channel 5 upper reach:

$Q_{100yr\ 24hr}$ = 540 cfs (see HEC 1 printout)
Channel slope = 0.9% (see sheet 16 of 23)
see attached spread sheet for riprap channel saftey factor design (ref. "Applied Hydrology and Sedimentology for Disturbed Areas" Barfield et al, Oklahoma Technical Press, 1985

Bottom width = 16 ft, 3H:1V side slopes
D_{50} = 9" ⇒ SF = 1.6 ok

Channel depth = normal flow depth + 1' Free board
= 3.2 + 1 = $\boxed{4.3 \text{ feet}}$

Lower channel 5
Near the souteast corner of section 28 runoff flows from Subbasin V-B and V-C confluence with channel 5.

$Q_{100yr\ 24hr}$ = 1130 cfs
channel slope = 0.6%

Channel Design (see attached spread sheet)

Bottom width = 40 feet
Side Slopes = 3H:1V
Riprap ⇒ D_{50} = 6" SF = 1.6 ok
Normal Flow depth = 3.5
Design channel Depth = 3.5' + 1' = $\boxed{4.5 \text{ feet}}$

NNEL HYDRAULICS TABLE

C: USPCI
JECT: LONE MOUNTAIN FACILITY

NNEL IDENTIFICATION	DESIGN FLOW (CFS)	SLOPE (ft/ft)	BOTTOM WIDTH (FT)	SIDE SLOPE (H/V)	MANNINGS N	HYDRAULIC COMPUTATIONS DEPTH (FT)	COMPUTED FLOW (CFS)	FLOW AREA (FT2)	WETTED PERIMETER (FT)	HYDRAULIC RADIUS (FT)	VELOCITY (FPS)	TOP WIDTH (FT)	FR
-5 upper (I-II-VA)	540	0.009	16	3	0.0377	3.24	542.540	83.33	36.49	2.28	6.51	35.44	0.75
-5 LOWER RIPRAP CHANNEL	1130	0.006	40	3	0.0352	3.45	1134.443	173.71	61.82	2.81	6.53	60.7	0.65
-5 LOWER earth CHANNEL	1130	0.001	40	3	0.0250	4.69	1131.003	253.59	69.66	3.64	4.46	68.14	0.41

DITCH RIPRAP DESIGN TABLE

IENT: USPCI
PROJECT:LONE MOUNTAIN FACILITY

CHANNEL IDENTIFICATION	RIPRAP D50 (FT)	ANGLE OF REPOSE (DEGREES)	FLOW DEPTH (FT)	MAX. TRACTIVE FORCE (LBS/FT2)	CHANNEL BED STABILITY Nb	SAFTEY FACTOR FOR BED SFb	MAX. SIDE TRACTIVE FORCE (LBS/FT2)	n	BETA (RADIANS)	CHANNEL WALL STABILITY N'	SAFTEY FACTOR FOR SIDE SFs
C-5 upper (I-II-VA)	0.75	42	3.24	1.820	0.495	1.98	1.38	0.28	0.490	0.28	1.61
-5 LOWER RIPRAP CHAN	0.50	42	3.45	1.292	0.527	1.87	0.98	0.40	0.517	0.30	1.57

ATTACHMENT NO. 9

CULVERT CHB-1 (Formerly IV-B Pipe Drop)

ORIGINAL DESIGN CALCULATIONS

Pipe drop for Subbasin IV-B into Detention Basin No 3

$Q_{100yr\,24hr} = 45$ cfs

try projecting entrance:

try 36" ϕ pipe $\Rightarrow$ $H_w/D = 1.15$ for groove end projecting
6.4 fps
$\Rightarrow H_{w\,min.} = 1.15(3) = 3.5'$

$\therefore$ required berm height = 4.5' (w/ 1' FB)

try 30" ϕ pipe $\Rightarrow H_w/D = 1.71 \Rightarrow H_{w\,min} = 4.3'$
$V_f = 9$ fps

$\therefore$ required berm height = 5.3'

if use concrete drop inlet w/ $V_{F\,max} = 12$ fps $\Rightarrow 27"\phi$

→ use 30" drop pipe w/ either concrete drop inlet or berm to 5.3' above inlet

Energy dissipation at outlet:

toe elev = 1377'
invert in elev = 1400'

GVF
30" CMP N = ~~.013~~ .024

3:1 slope $\Rightarrow$ $V_{out} = 23.7$ fps $Fr = 4.8$ OK
4:1 slope

$V_{out} = 21.6$ fps $Fr = 4.2$

Riprap basin:
$V_0 = 24$ fps, $Y_{out} = 1.03$

for no scour

$$D_{50} = \frac{1/8\, f \rho U^2}{.047(\gamma_s - \gamma)}$$ shields criteria

$$= \frac{1/8(1.113)\,1.936\,(24)^2}{.047(165.4 - 62.4)} = 3.25'$$

Largest available riprap = D_{50} = 14"

$$V_{allowable} = \left(\frac{.047\,(165.4 - 62.4)\,\frac{14}{12}\,/\,1.5\,SF}{\frac{1}{8}\;\;1.936\;\;.113} \right)^{1/2} = 11.7\,fps$$

non scour flow depth $= \frac{1.03\,(24)}{11.7} = 2.1'$

w/ $y = 1.03'$ $\quad y_s = 2.1 - 1.03' = \underline{1.1'}$

riprap thickness = $2' + 1.1$ say $\underline{3.5'}$

Riprap basin dimensions

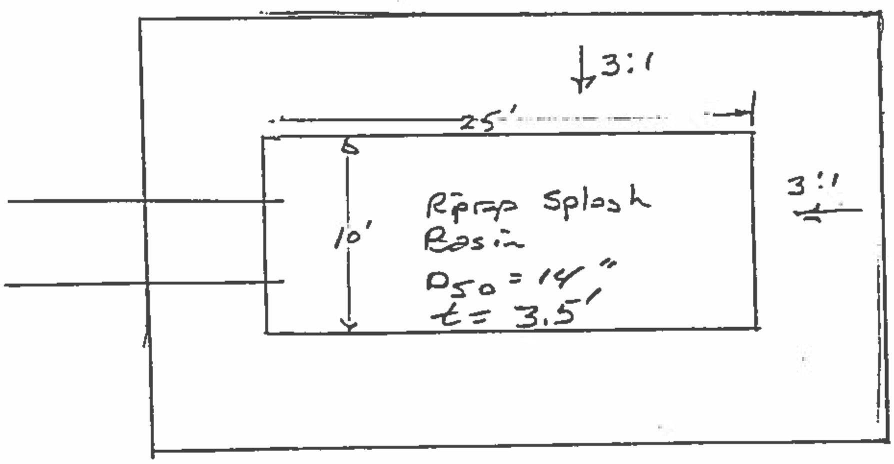
$D_{50} = 14"$

Basin width $= \frac{45\,cfs}{(5)\,(1.03)} = 9'$ say $\underline{\underline{10'}}$

Basin length $= 4\,y_2$:

$$y_2 = -\frac{y_1}{2} + \sqrt{\frac{y_1^2}{2} + \frac{2(24)^2\,y_1}{g}} = 5.6'$$

$\therefore$ basin length $= 4\,(5.6) = \underline{\underline{22'}}$ use $\underline{25'}$



3/4

SPCI LONE MOUNTAIN FACILTIES
IPE[illegible] SUBBASIN IV-B TO DETENTION BASIN NO. 3
30" CMP
ADUAL VARIED FLOW PROFILE IN CULVERT
TEP METHOD (REF. HENDERSON, "OPEN CHANNEL FLOW" 1966, p. 128)

CFS	D FT	Y FT	BETA RADIAN	THETA RADIANS	AREA FT2	TOP WID FT	FR2	P FT	V FPS	E FT	N	So FT/FT	Sf FT/FT	AVE Sf FT/FT	DELTA E FT	DELTA X FT	SUM X FT
45	2.5	2.2	2.434	4.868	4.575	1.625	1.067	6.085	9.836	3.702	0.024	0.333	0.037				
45	2.5	2.15	2.375	4.749	4.491	1.735	1.205	5.936	10.020	3.709	0.024	0.333	0.038	0.037	0.007	0.02	0.02
45	2.5	2.1	2.319	4.637	4.402	1.833	1.352	5.796	10.223	3.723	0.024	0.333	0.039	0.038	0.014	0.05	0.07
45	2.5	2.05	2.265	4.531	4.308	1.921	1.511	5.663	10.446	3.744	0.024	0.333	0.041	0.040	0.022	0.07	0.14
45	2.5	2	2.214	4.429	4.210	2.000	1.686	5.536	10.689	3.774	0.024	0.333	0.043	0.042	0.030	0.10	0.25
45	2.5	1.95	2.165	4.330	4.108	2.071	1.879	5.413	10.954	3.813	0.024	0.333	0.045	0.044	0.039	0.14	0.38
45	2.5	1.9	2.118	4.235	4.003	2.135	2.094	5.294	11.242	3.862	0.024	0.333	0.048	0.046	0.049	0.17	0.55
45	2.5	1.85	2.071	4.143	3.895	2.193	2.335	5.179	11.554	3.923	0.024	0.333	0.051	0.049	0.061	0.21	0.77
45	2.5	1.8	2.026	4.053	3.784	2.245	2.607	5.066	11.893	3.996	0.024	0.333	0.054	0.052	0.074	0.26	1.03
45	2.5	1.75	1.982	3.965	3.670	2.291	2.915	4.956	12.261	4.084	0.024	0.333	0.058	0.056	0.088	0.32	1.35
45	2.5	1.7	1.939	3.878	3.555	2.332	3.266	4.848	12.660	4.189	0.024	0.333	0.063	0.061	0.105	0.38	1.73
45	2.5	1.65	1.897	3.793	3.437	2.369	3.669	4.741	13.093	4.312	0.024	0.333	0.068	0.066	0.123	0.46	2.19
45	2.5	1.6	1.855	3.709	3.318	2.400	4.133	4.636	13.563	4.457	0.024	0.333	0.075	0.071	0.145	0.55	2.74
45	2.5	1.55	1.813	3.626	3.197	2.427	4.670	4.533	14.075	4.626	0.024	0.333	0.082	0.078	0.170	0.67	3.41
45	2.5	1.5	1.772	3.544	3.075	2.449	5.297	4.430	14.633	4.825	0.024	0.333	0.090	0.086	0.199	0.81	4.22
45	2.5	1.45	1.731	3.463	2.952	2.468	6.032	4.329	15.243	5.058	0.024	0.333	0.100	0.095	0.233	0.98	5.20
45	2.5	1.4	1.691	3.382	2.828	2.482	6.898	4.228	15.910	5.330	0.024	0.333	0.112	0.106	0.273	1.20	6.40
45	2.5	1.35	1.651	3.302	2.704	2.492	7.926	4.127	16.641	5.650	0.024	0.333	0.125	0.119	0.321	1.50	7.90
45	2.5	1.3	1.611	3.222	2.579	2.498	9.155	4.027	17.446	6.026	0.024	0.333	0.143	0.135	0.377	1.90	9.80
45	2.5	1.25	1.571	3.142	2.454	2.500	10.634	3.927	18.335	6.470	0.024	0.333	0.163	0.153	0.445	2.47	12.26
45	2.5	1.2	1.531	3.062	2.329	2.498	12.429	3.827	19.318	6.995	0.024	0.333	0.188	0.176	0.527	3.34	15.60
45	2.5	1.15	1.491	2.981	2.205	2.492	14.625	3.727	20.412	7.619	0.024	0.333	0.218	0.203	0.626	4.80	20.40
45	2.5	1.13	1.475	2.949	2.155	2.488	15.641	3.687	20.883	7.902	0.024	0.333	0.232	0.225	0.283	2.60	23.00
45	2.5	1.11	1.459	2.917	2.105	2.484	16.747	3.646	21.377	8.206	0.024	0.333	0.247	0.239	0.304	3.23	26.23
45	2.5	1.09	1.442	2.885	2.055	2.479	17.955	3.606	21.853	8.533	0.024	0.333	0.263	0.255	0.327	4.17	30.40
45	2.5	1.07	1.426	2.853	2.006	2.474	19.276	3.566	22.433	8.885	0.024	0.333	0.281	0.272	0.352	5.77	36.17
45	2.5	1.05	1.410	2.820	1.957	2.468	20.722	3.525	23.000	9.264	0.024	0.333	0.301	0.291	0.380	9.01	45.18
45	2.5	1.03	1.394	2.788	1.907	2.461	22.309	3.485	23.595	9.674	0.024	0.333	0.323	0.312	0.410	19.14	64.31
45	2.5	1.025	1.390	2.780	1.895	2.459	22.729	3.475	23.748	9.782	0.024	0.333	0.329	0.326	0.108	13.96	78.27

CT LONE MOUNTAIN FACILTIES
E SUBBASIN IV-B TO DETENTION BASIN NO. 3
30" CMP
AL VARIED FLOW PROFILE IN CULVERT
P METHOD (REF. HENDERSON. "OPEN CHANNEL FLOW" 1966, p. 128)

S	D FT	Y FT	BETA RADIAN	THETA RADIANS	AREA FT2	TOP WID FT	FR2	P FT	V FPS	E FT	N	So FT/FT	Sf FT/FT	AVE Sf FT/FT	DELTA E FT	DELTA X FT	SUM X FT
45	2.5	2.2	2.434	4.868	4.575	1.625	1.067	6.085	9.836	3.702	0.024	0.250	0.037				
45	2.5	2.1	2.319	4.637	4.402	1.833	1.352	5.796	10.223	3.723	0.024	0.250	0.039	0.038	0.021	0.10	0.10
[illegible]	2.5	2	2.214	4.429	4.210	2.000	1.686	5.536	10.689	3.774	0.024	0.250	0.043	0.041	0.052	0.25	0.35
[illegible]	2.5	1.9	2.118	4.235	4.003	2.135	2.094	5.294	11.242	3.862	0.024	0.250	0.048	0.045	0.089	0.43	0.78
45	2.5	1.8	2.026	4.053	3.784	2.245	2.607	5.066	11.893	3.996	0.024	0.250	0.054	0.051	0.135	0.68	1.46
[illegible]	2.5	1.7	1.939	3.878	3.555	2.332	3.266	4.848	12.660	4.189	0.024	0.250	0.063	0.059	0.194	1.01	2.47
[illegible]	2.5	1.6	1.855	3.709	3.318	2.400	4.133	4.636	13.563	4.457	0.024	0.250	0.075	0.069	0.270	1.49	3.96
45	2.5	1.5	1.772	3.544	3.075	2.449	5.297	4.430	14.633	4.825	0.024	0.250	0.090	0.083	0.371	2.22	6.18
45	2.5	1.4	1.691	3.382	2.828	2.482	6.898	4.228	15.910	5.330	0.024	0.250	0.112	0.101	0.510	3.43	9.61
[illegible]	2.5	1.3	1.611	3.222	2.579	2.498	9.155	4.027	17.446	6.026	0.024	0.250	0.143	0.128	0.703	5.74	15.35
45	2.5	1.25	1.571	3.142	2.454	2.500	10.634	3.927	18.335	6.470	0.024	0.250	0.163	0.153	0.445	4.59	19.94
45	2.5	1.2	1.531	3.062	2.329	2.498	12.429	3.827	19.318	6.995	0.024	0.250	0.188	0.176	0.527	7.07	27.01
[illegible]	2.5	1.15	1.491	2.981	2.205	2.492	14.625	3.727	20.412	7.619	0.024	0.250	0.218	0.203	0.626	13.25	40.27
[illegible]	2.5	1.1	1.451	2.901	2.080	2.482	17.338	3.626	21.632	8.366	0.024	0.250	0.255	0.236	0.749	54.55	94.82

ATTACHMENT 10

CONCRETE DROP STRUCTURE
INTO RUNON POND 3

ORIGINAL DESIGN CALCULATIONS

HA&L ENGINEERING

CLIENT USPCI
PROJECT Lone Mountain Facilities
FEATURE Basin 1U-A Drop Structure
PROJECT NO. 64-

COMPUTED GJP
CHECKED
DATE June 1990

Basin 1U-A Drop Structure into channel 4 inlet,
(Detention Basin No. 2)

Design Flowrate = 1133 cfs (see HEC1 printout)

Reference:
U.S.B.R. "Design of Small Dams", 1977, p. 411

Impact type drop basin:

Drop height $Y = 1392 - 1378 = 14'$

Effective length of crest $L = L' - 2(.2)\,H_e$

try $L' = 35'$ guess $L = 33' \Rightarrow q = \frac{1133}{33} = 34.3$

$\Rightarrow d_c = \sqrt[3]{\frac{34.3^2}{g}} = 3.3' \Rightarrow H_e = \frac{3}{2} Y_c = 5 \Rightarrow L = 35 - 2(.2)5 = 33.$

$\Rightarrow q = \frac{1133}{33} = \underline{34.3 \text{ cfs/ft}} \Rightarrow d_c = \sqrt[3]{\frac{34.3^2}{g}} = \underline{3.32'}$

$E_c = 5'$

USE $q = 34.3$ cfs/ft and $d_c = 3.32$ for design

Approach velocity > 5 fps use riprap upstream

Tailwater elev. = 1386' (see HEC 1 printout)

minimum tailwater depth = $d_{tw} = 2.15\,d_c = \underline{7.1'}$

∴ set floor such as to provide T_w

assume T_w elev = 1385.1 ⇒ Floor elev = 1385.1 − 7.1 = 1378' ok

Drop Number $= \frac{q^2}{g Y^3} = \frac{34.3^2}{g\, 14^3} = \underline{0.01332}$

$h_d = Y + H_e - T_w = 14 + 5' - 7.1 = 11.9'$

$\frac{h_d}{H_e} = \frac{11.9}{5} = 2.4$

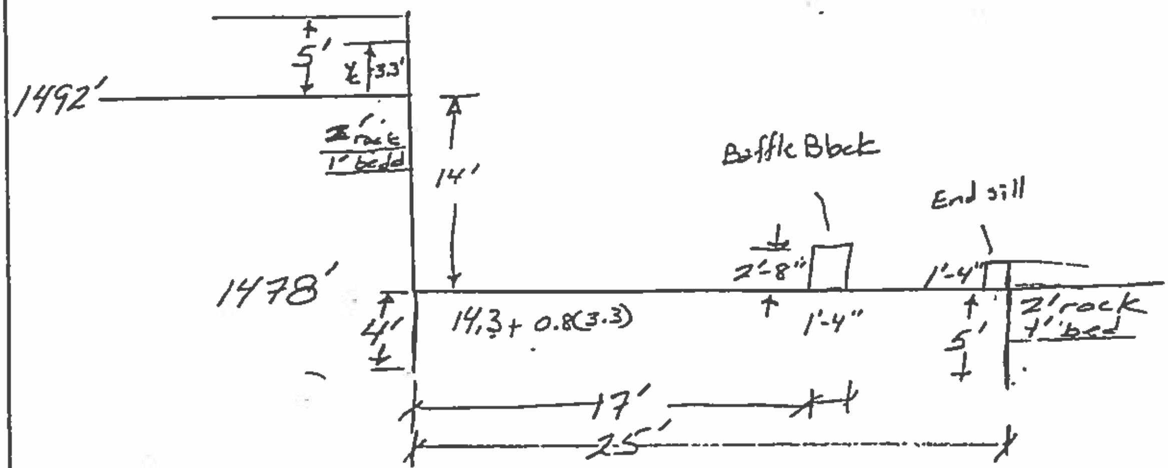
Fig 279 (see attached) $\Rightarrow \frac{L_p}{Y} = 1.2 \Rightarrow L_p = 14.3'$

HA&L ENGINEERING

CLIENT USPCI
PROJECT Lone Mountain Facilities
FEATURE Basin 10-A Drop Structure
PROJECT NO. 64-

SHEET 2 OF 3
COMPUTED GJP
CHECKED
DATE June 22, 199?

Basin 10-A Drop structure configuration:



optimum baffle block height $= 0.8 d_c = .8(3.32) = 2.66'$
use 2'-8"

width and spacing of baffle blocks $= 0.4(3.32)^{\pm} = 1.3'$
$\approx 1'4"$

Total length $= L_B = 14.3' + 2.55(3.32) = 22.7'$ use 25'

SEEPAGE ANALYSIS:
Lane's weighted creep

$L = CH$
$H = hd = 12'$
$C = 3$ (conservative hard clay or hardpan would be 1.6)
reduce by 20% for minor structure w/ weep holes
$\therefore L_{min} = 3(.8)12 = 29'$

$L = V + \frac{1}{3}H = (14-3) + \frac{25}{3} = 22'$ w/out cut off walls

$\therefore$ need cut off wall

check $L = (14-3) + 2(4) + \frac{25}{3} + 5 + 2 = \underline{\underline{34}}$ OK

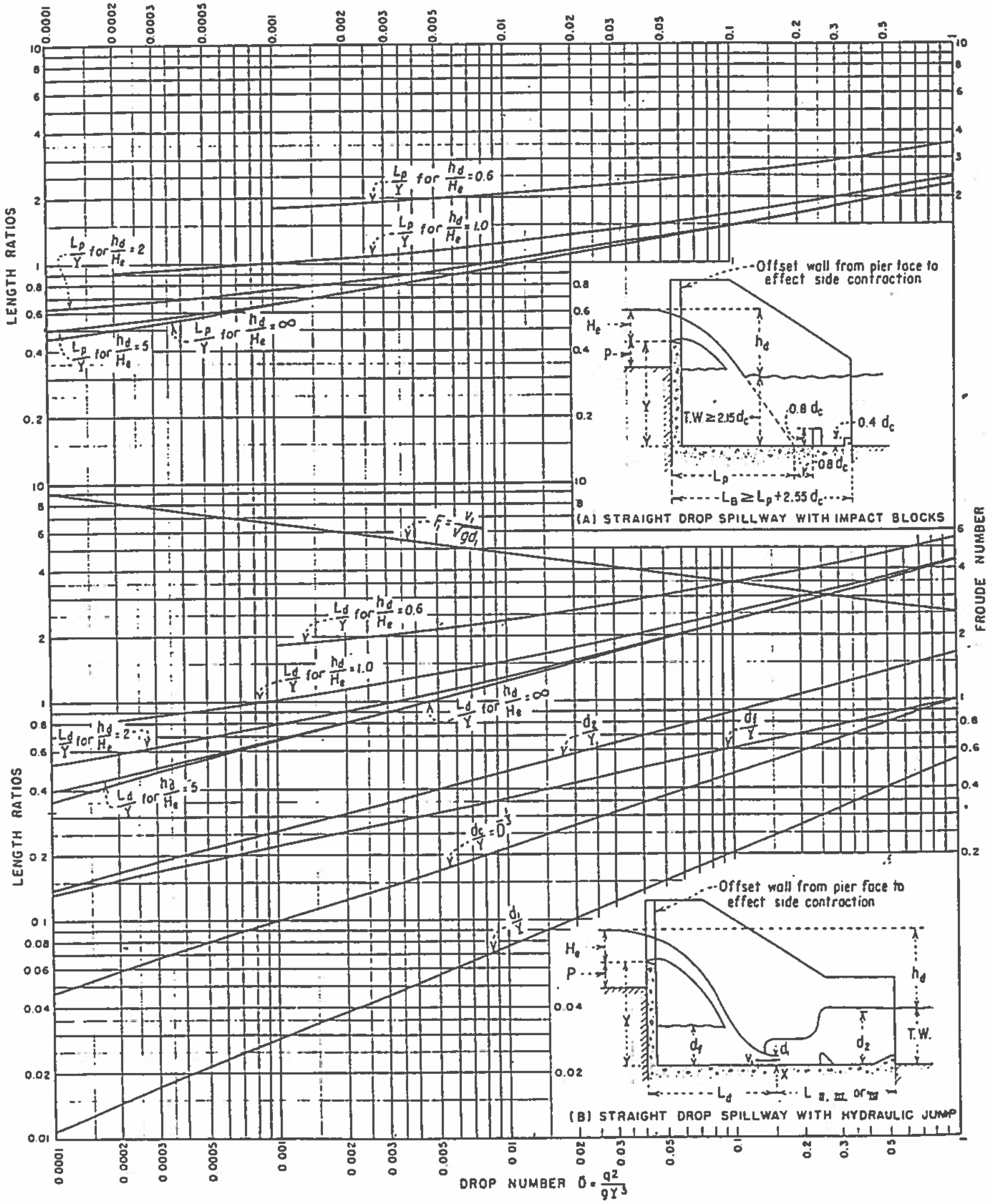
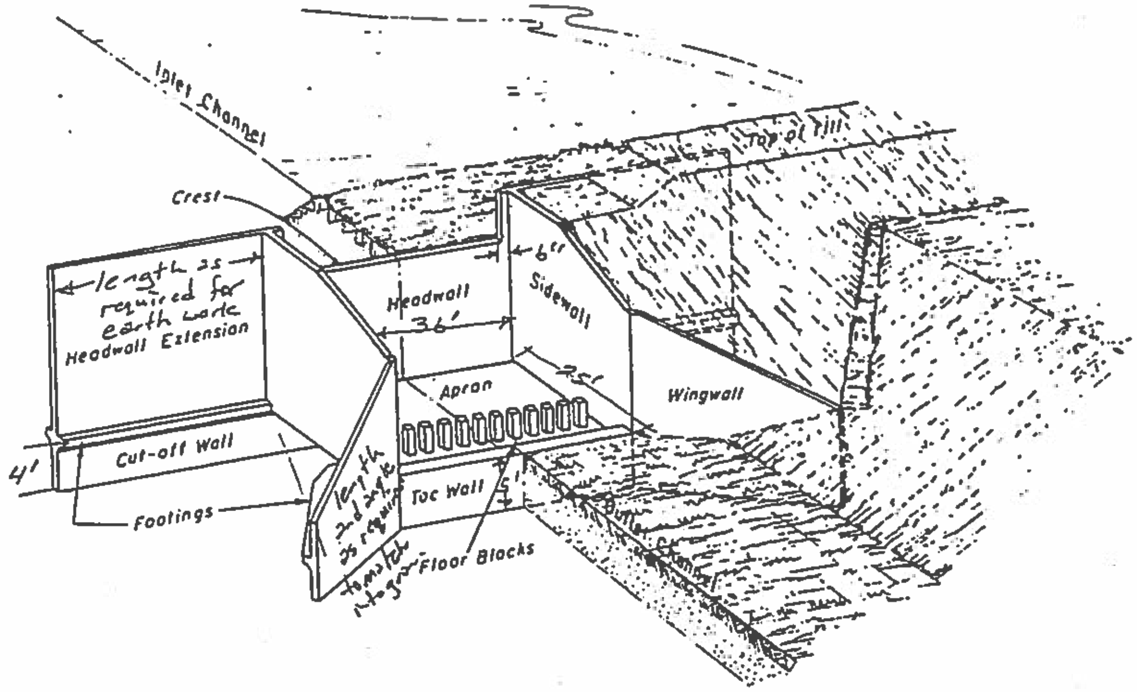
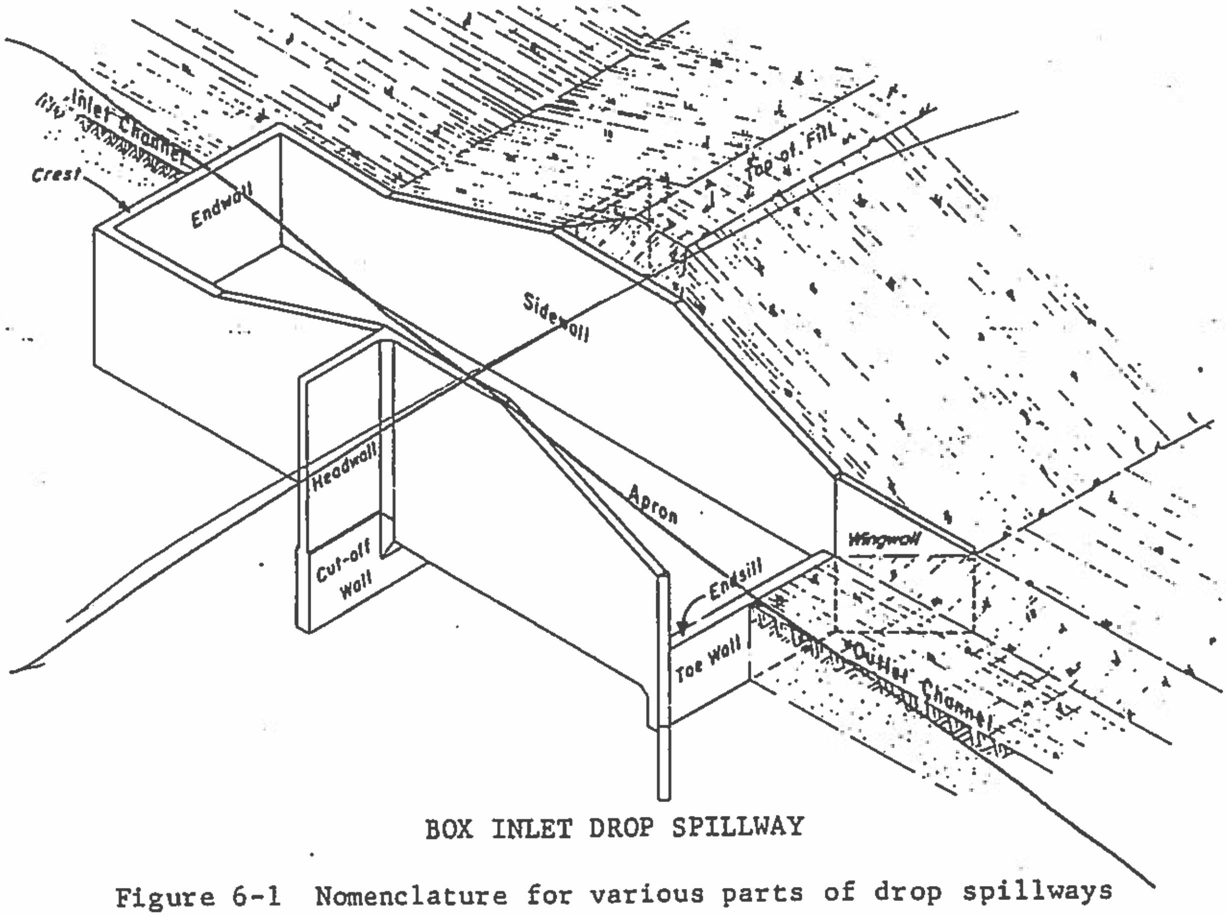


Figure 279. Hydraulic characteristics of straight drop spillways with hydraulic jump or with impact blocks. 288–D–2437.



STRAIGHT DROP SPILLWAY

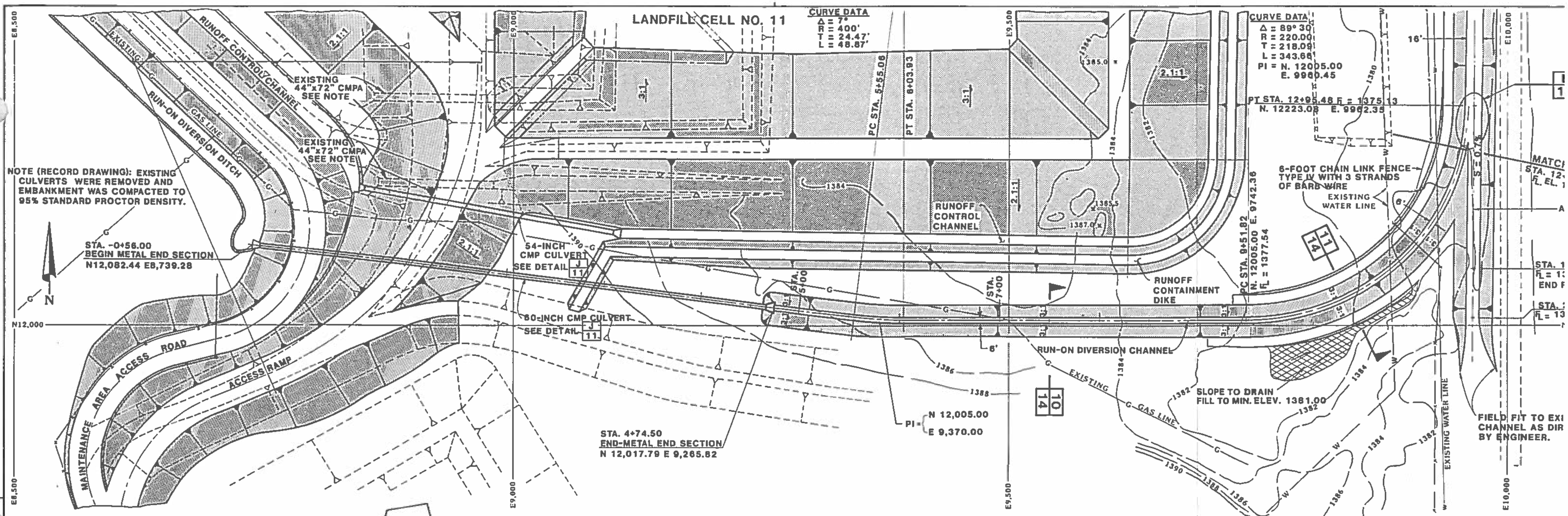


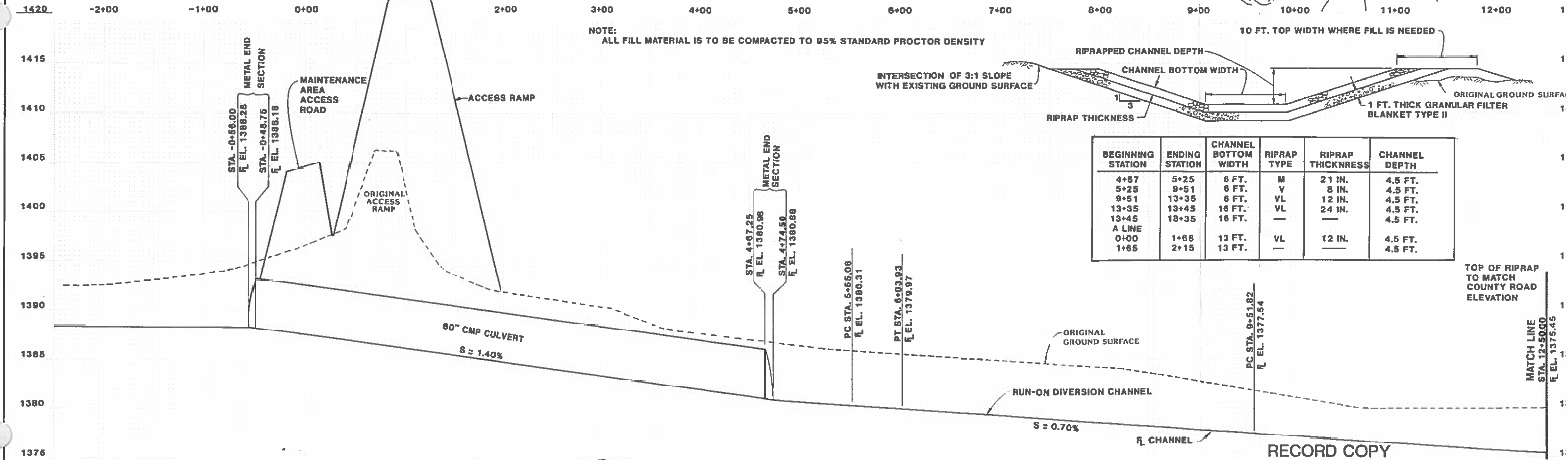
BOX INLET DROP SPILLWAY

Figure 6-1 Nomenclature for various parts of drop spillways

EXHIBIT B

RUN-ON CONTROL CHANNELS
PLAN AND PROFILE DESIGN DETAILS





BEGINNING STATION	ENDING STATION	CHANNEL BOTTOM WIDTH	RIPRAP TYPE	RIPRAP THICKNRESS	CHANNEL DEPTH
4+67	5+25	6 FT.	M	21 IN.	4.5 FT.
5+25	9+51	6 FT.	V	8 IN.	4.5 FT.
9+51	13+35	6 FT.	VL	12 IN.	4.5 FT.
13+35	13+45	16 FT.	VL	24 IN.	4.5 FT.
13+45	18+35	16 FT.	—	—	4.5 FT.
A LINE					
0+00	1+65	13 FT.	VL	12 IN.	4.5 FT.
1+65	2+15	13 FT.	—	—	4.5 FT.

RECORD COPY
FEB., 1989

NO	DATE	REVISIONS	BY	APVD		
3					DESIGNED	MPW
2	2/89	RECORD COPY	KCS	MEA	DRAFTED	JVH
1	5/4/87	REDESIGN OF RUN-ON DIVERSION CHANNEL	SDM	MEA	CHECKED	MEA
					DATE	MARCH, 1987

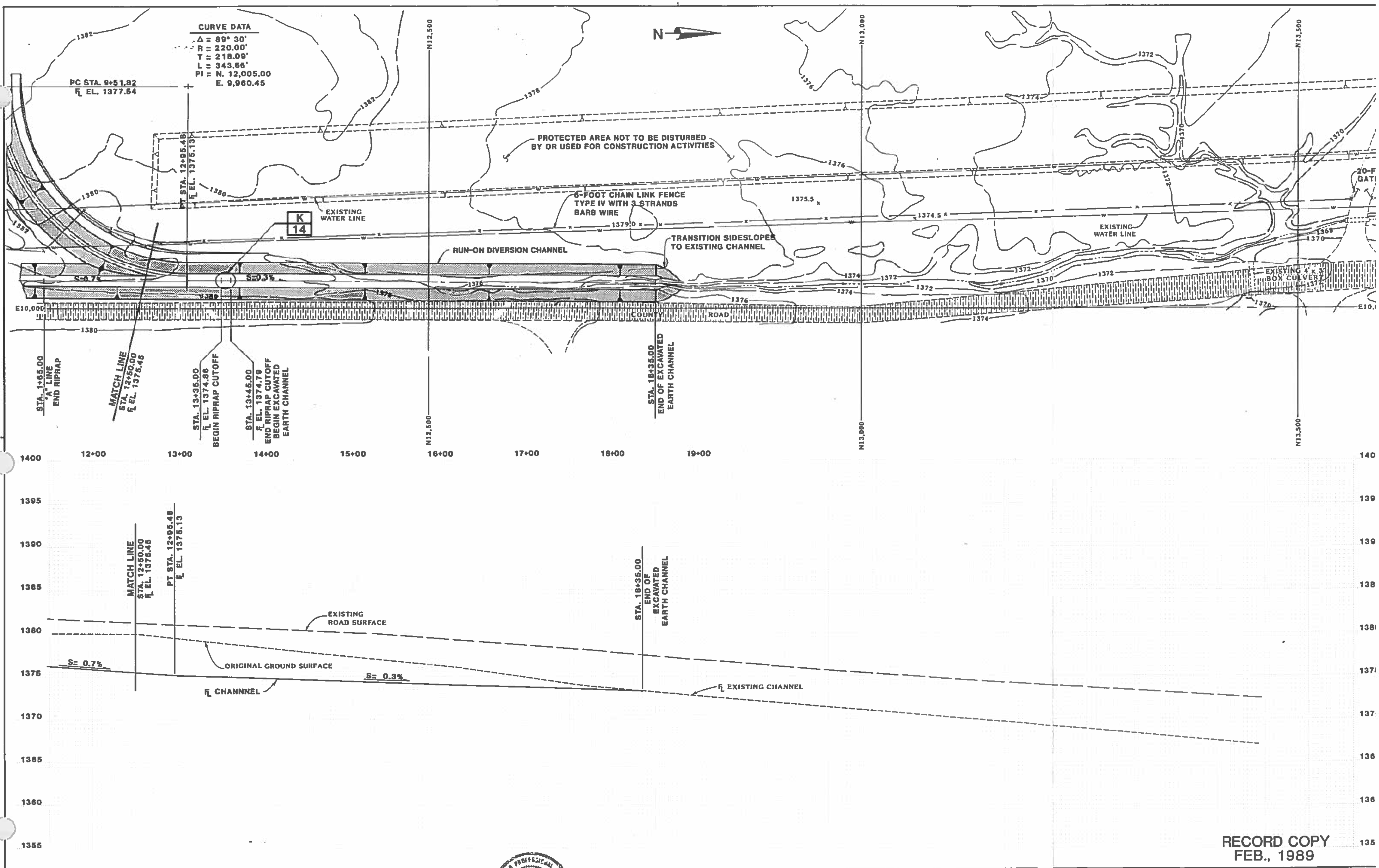
VAUGHN HANSEN ASSOCIATES

Marvin E. Allen
PROJECT ENGINEER
14802
LICENSE NO.

SCALE
HOR. 1" = 50'
VERT. 1" = 5'

VAUGHN HANSEN ASSOCIATES, INC.
CONSULTANTS / ENGINEERS
SALT LAKE CITY, UTAH

USPCI
LONE MOUNTAIN FACILITY
LANDFILL CELLS 10 AND 11
RUN-ON DIVERSION CHANNEL PLAN AND PROFILE



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FEB., 1989

3					
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1	4/15/87	REDESIGN OF RUN-ON DIVERSION CHANNEL	SDM	MEA	
NO	DATE	REVISIONS	BY	APVD.	

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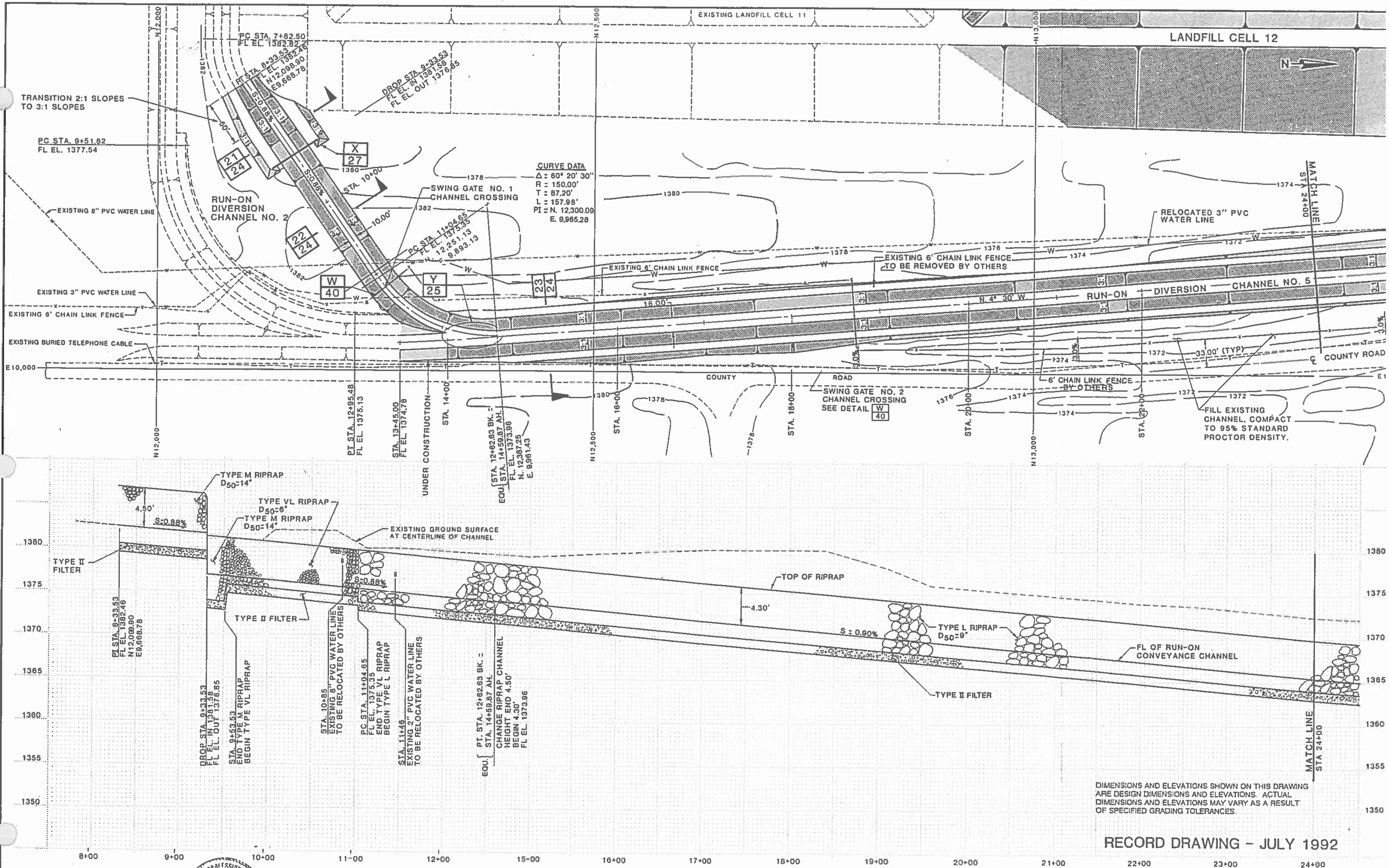
DESIGNED MPW
DRAFTED JVH
CHECKED MEA
DATE MARCH, 1987

MARVIN E. ALLEN 14802 — PROJECT ENGINEER
14802 LICENSE NO.

SCALE HOR. 1" = 50' VERT. 1" = 5'

VAUGHN HANSEN ASSOCIATES, INC.
CONSULTANTS / ENGINEERS
SALT LAKE CITY, UTAH

USPCI LONE MOUNTAIN FACILITY
LANDFILL CELLS 10 AND 11
RUN-ON DIVERSION CHANNEL PLAN AND PROFILE



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MARVIN E. ALLEN

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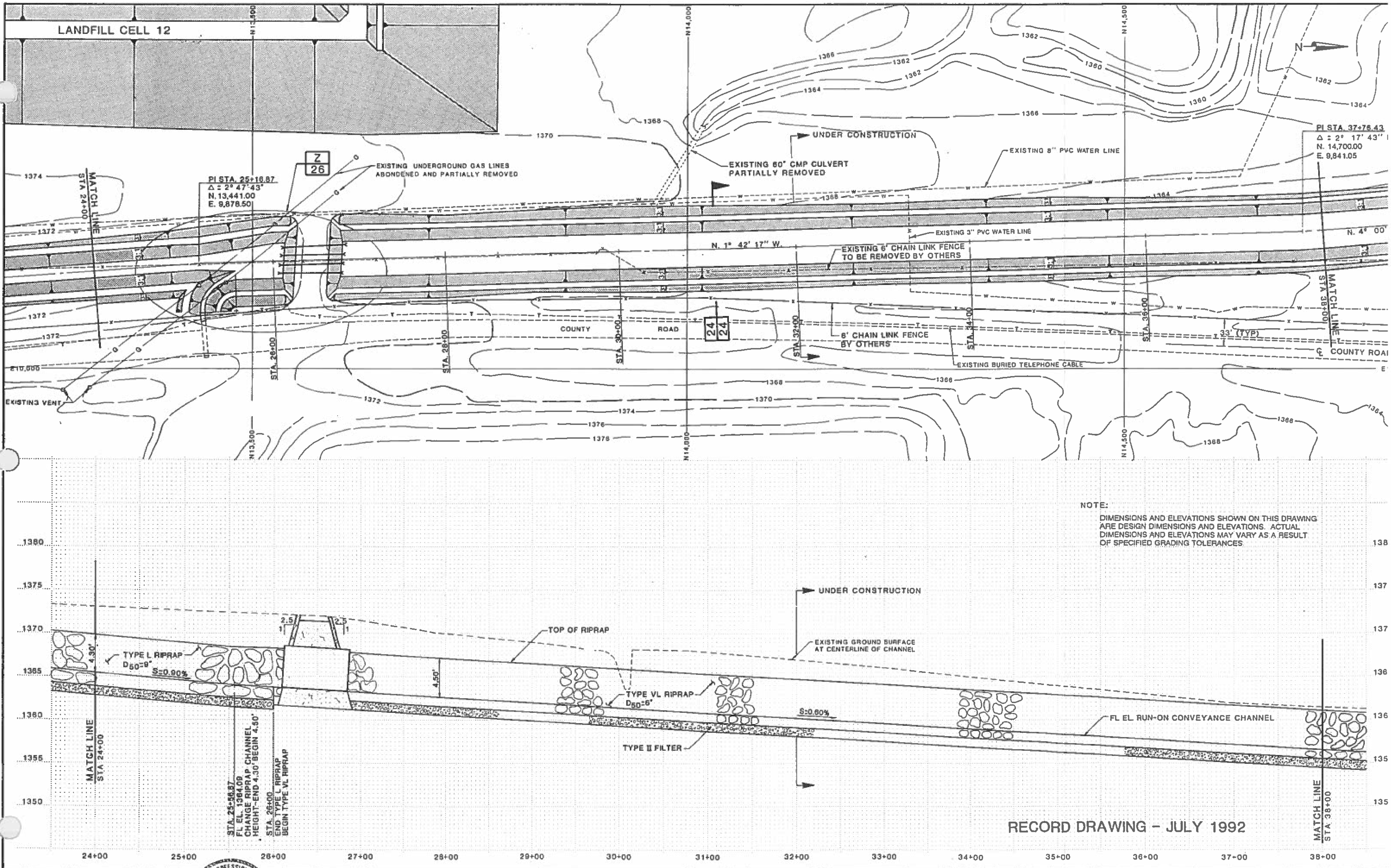
LONE MOUNTAIN FACILITY
LANDFILL CELLS 12 & 13
RUN-ON DIVERSION CHANNEL 2&5 PLAN & PROFILE

SHEET 21 OF 47



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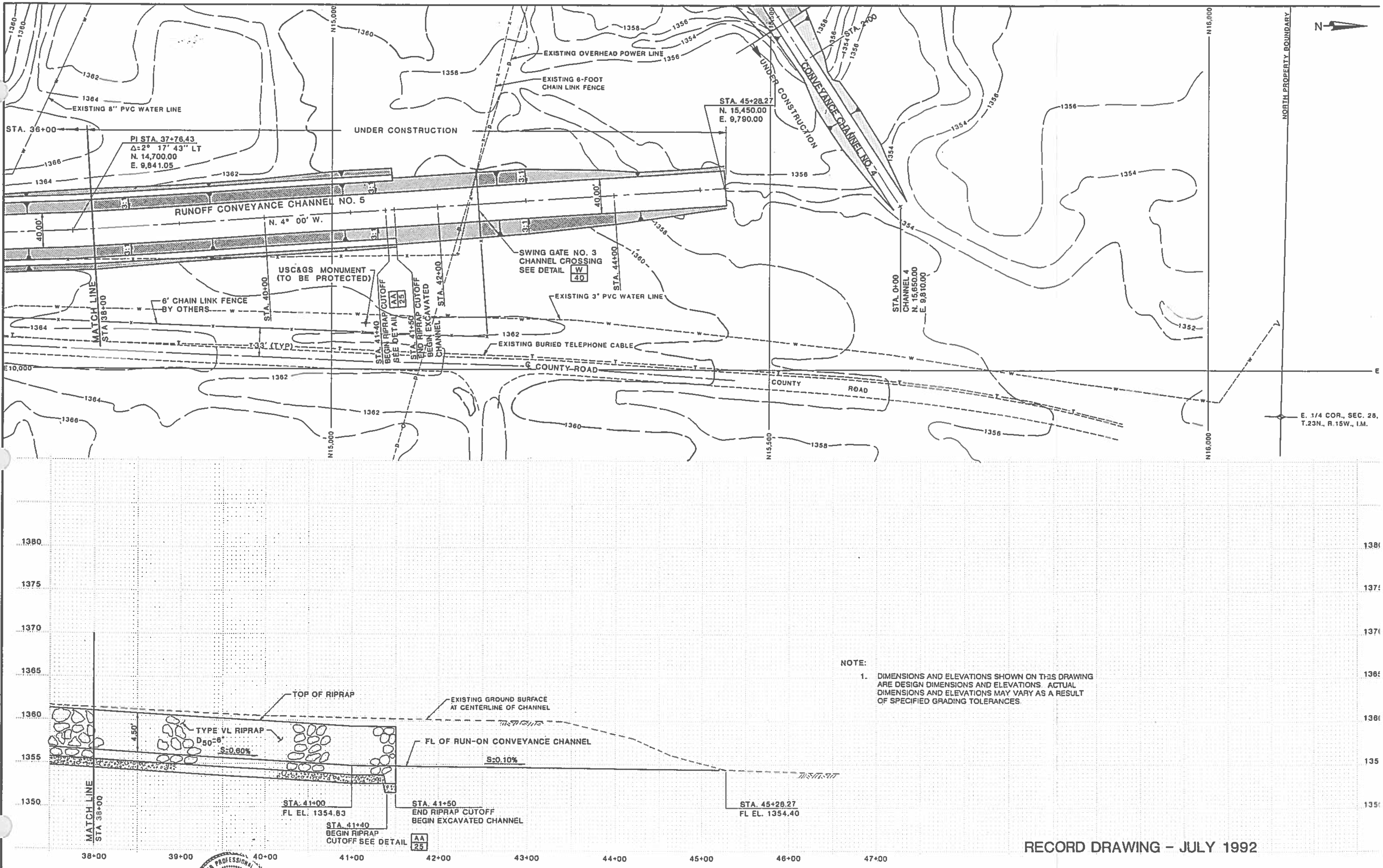
LANDFILL CELLS 12 & 13
RUN-ON DIVERSION CHANNEL 2&5 PLAN & PROFILE

SHEET 2 OF 4



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REGISTERED PROFESSIONAL ENGINEER — MARVIN E. ALLEN — 14802

DESIGNED	MPW
DRAFTED	JVH
CHECKED	MEA
DATE	SEPT., 1990

NO	DATE	REVISIONS	BY	APVD
3				
2				
1	7/92	RECORD DRAWING	PGH	MEA

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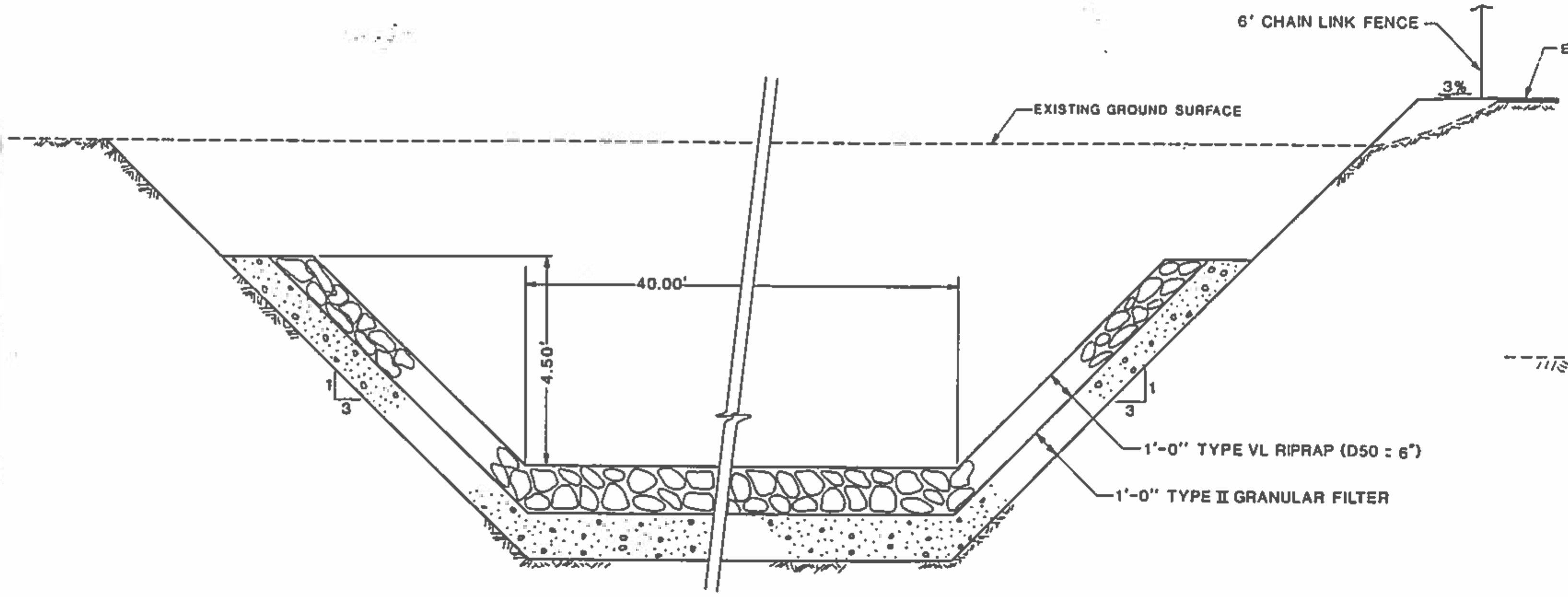
LONE MOUNTAIN FACILITY
LANDFILL CELLS 12 & 13
RUN-ON DIVERSION CHANNEL 5 PLAN & PROFILE

SHEET 23



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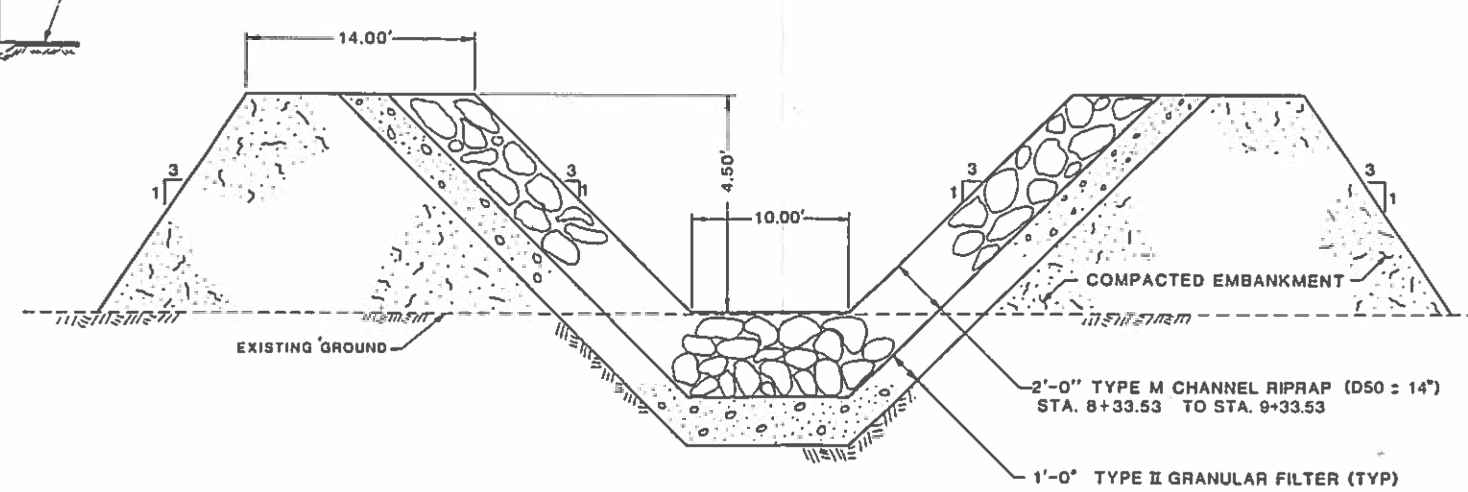
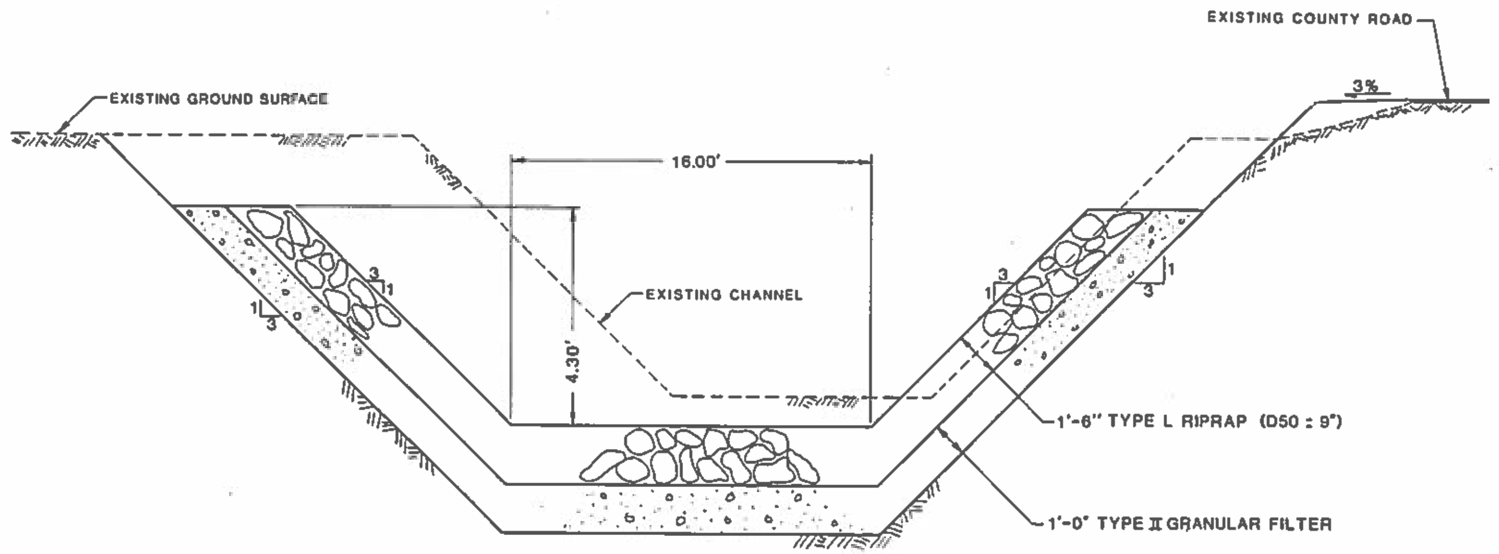


NOTE:
INSIDE CHANNEL SLOPE TRANSITIONS FROM 2H:1V OF EXISTING CHANNEL TO 3H:1V FROM STA. 8+33.53 TO STA. 8+83.53.

SECTION 21/21
N.T.S.



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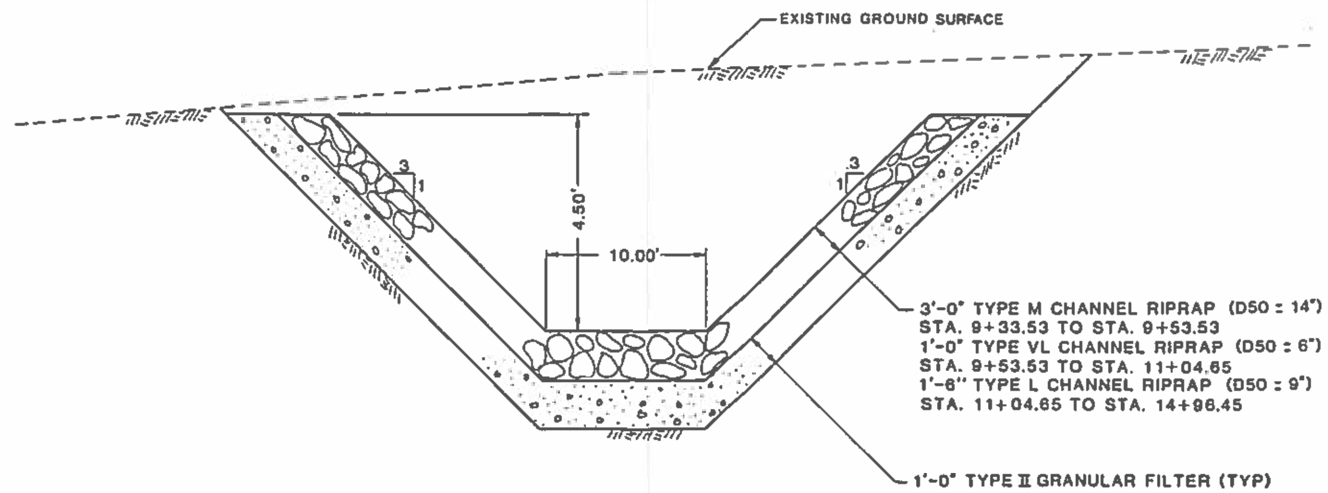

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Salt Lake City, Utah

MARVIN E. ALLEN
PROJECT ENGINEER

DESIGNED	MPW	3				
DRAFTED	RGA	2				
CHECKED	MEA	1	7/92	RECORD DRAWING	PGH	MEA
DATE	SEPT., 1990	NO.	DATE	REVISIONS	BY	APP.

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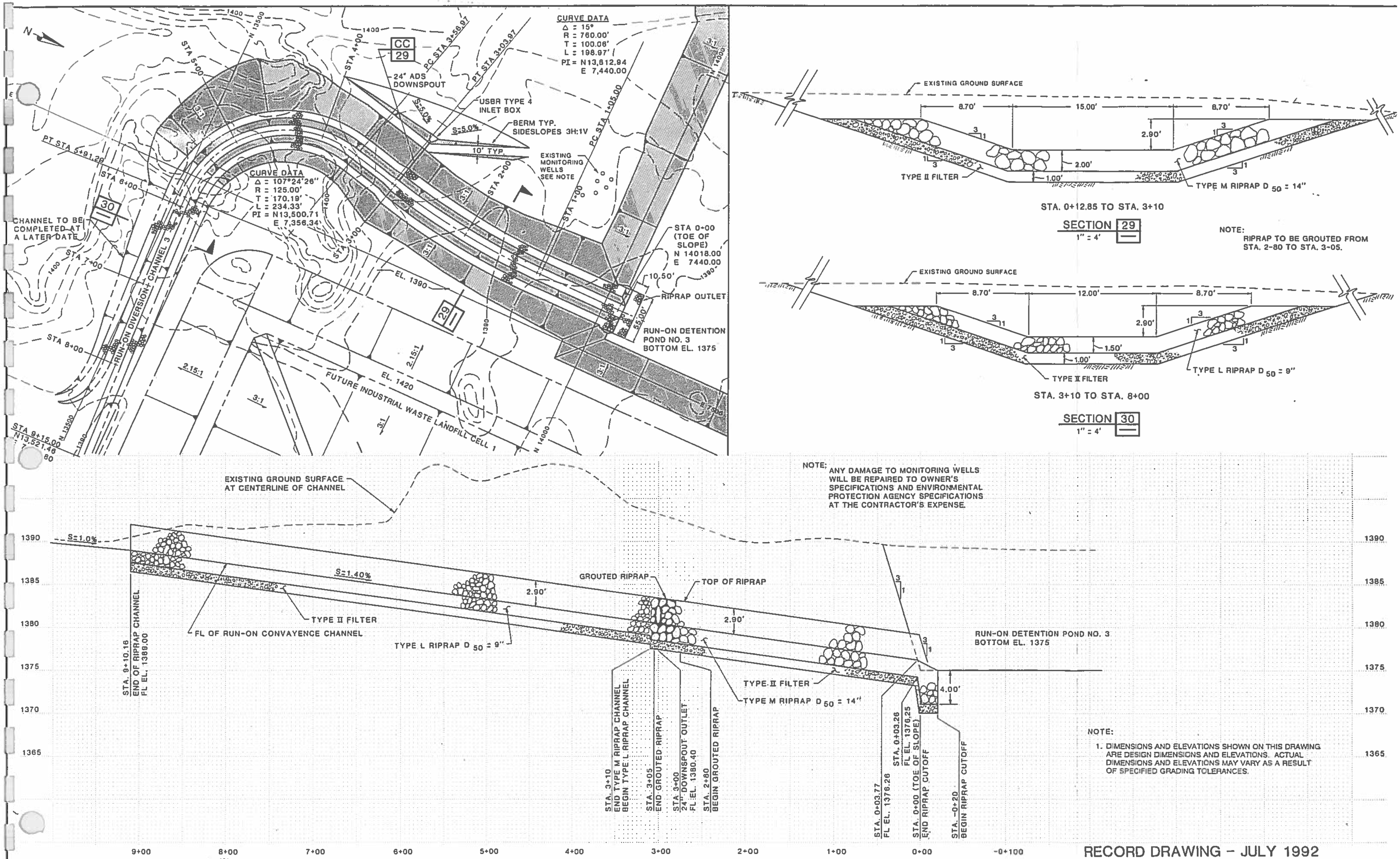
LANDFILL CELLS 12 & 13
RUNON DIVERSION CHANNEL 2 & 5 SECTIONS

SHEET 2



RECORD DRAWING - JULY 1992

HA&L ENGINEERING	CONSULTANTS ENGINEERS Salt Lake City, Utah	MARVIN E. ALLEN PROJECT ENGINEER 14802
DESIGNED MPW	DRAFTED DRB	CHECKED MEA
DATE SEPT.,1990		

NO.	DATE	REVISIONS	BY	APVD
3				
2				
1	7/92	RECORD DRAWING	PGH	MEA

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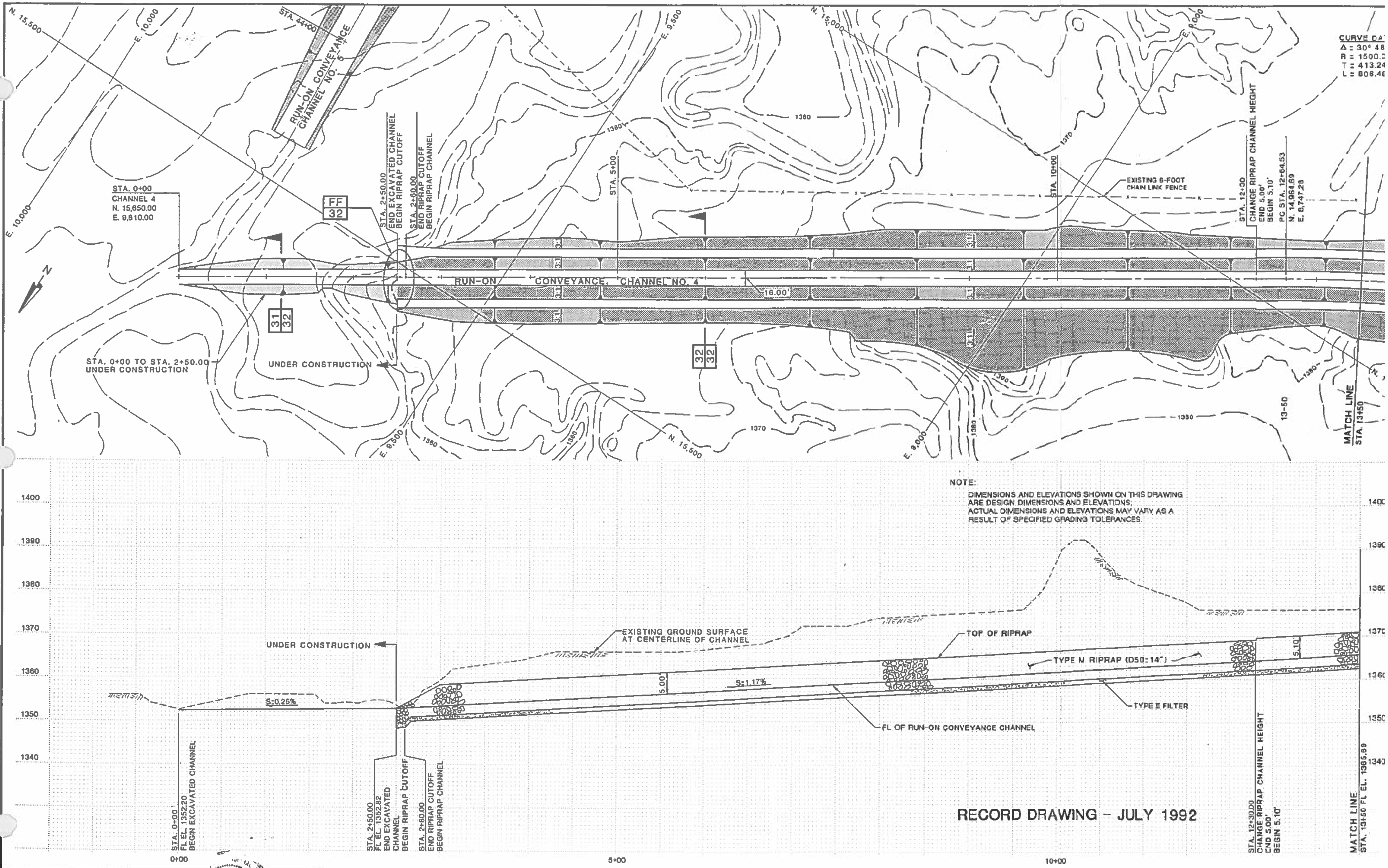
LONE MOUNTAIN FACILITY
LANDFILL CELLS 12 & 13
RUN-ON DIVERSION CHANNEL 3 PLAN & PROFILE

SHEET NO. 28 OF 47
84-25-100



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CHECKED	MEA	
DATE	SEPT.,1990	

NO.	DATE	REVISIONS	BY	APVD
3				
2				
1	7/92	RECORD DRAWING	PGH	MEA

SCALE: HOR. 1" = 50' VERT. 1" = 10'

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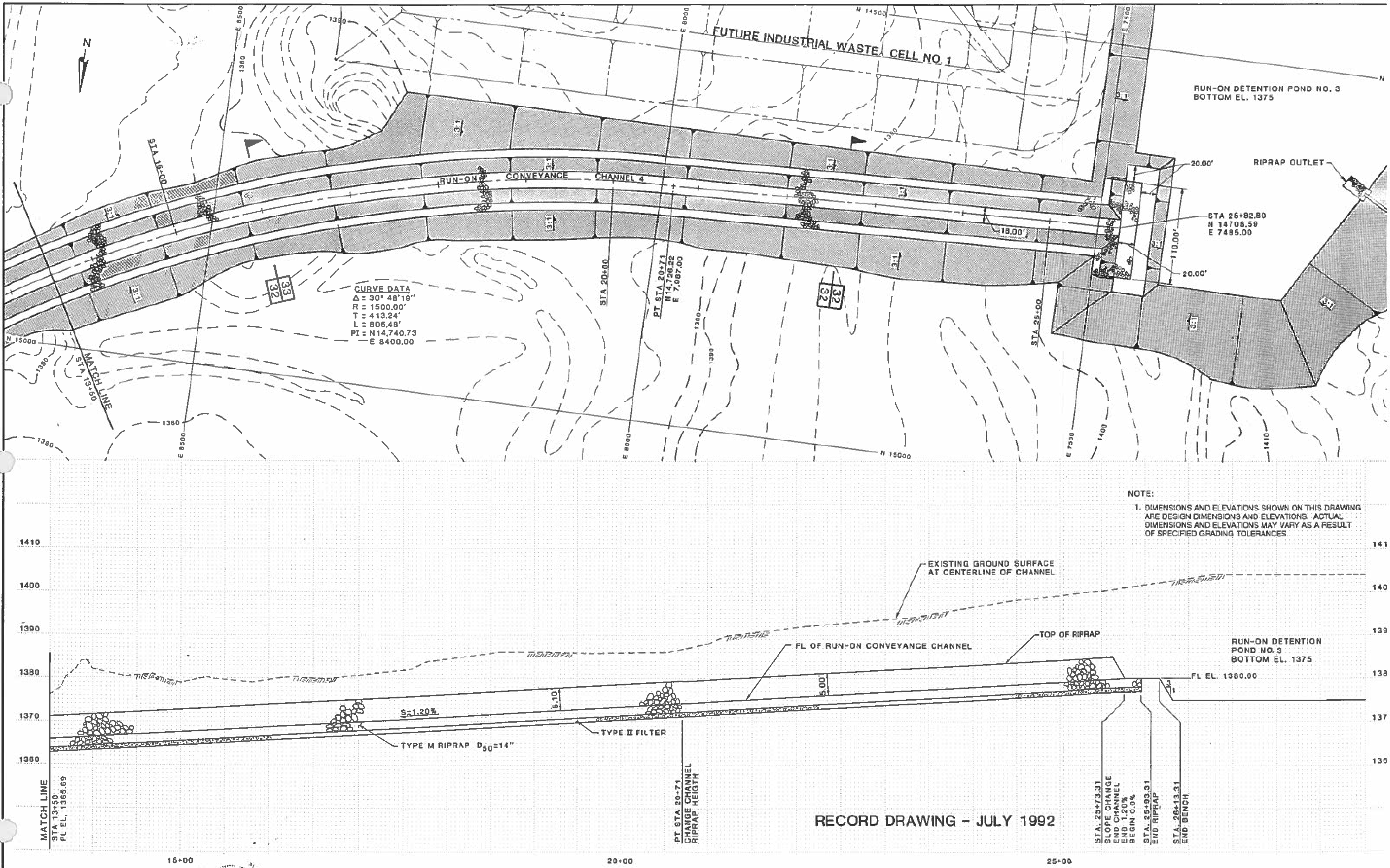
LANDFILL CELLS 12 & 13
RUN-ON CONVEYANCE CHANNEL 4 PLAN & PROFILE

SHEET 30 OF 47



HA&L ENGINEERING CONSULTANTS ENGINEERS Salt Lake City, Utah

PROJECT ENGINEER

DESIGNED MPW	3		
DRAFTED DRB	2		
CHECKED MEA	1	7/92 RECORD DRAWING	PGH MEA
DATE SEPT., 1990	NO	DATE REVISIONS	BY APVD

SCALE HOR. 1"=50' VER. 1"=10'

VERIFY SCALE — BAR IS ONE INCH ON ORIGINAL DRAWING. IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

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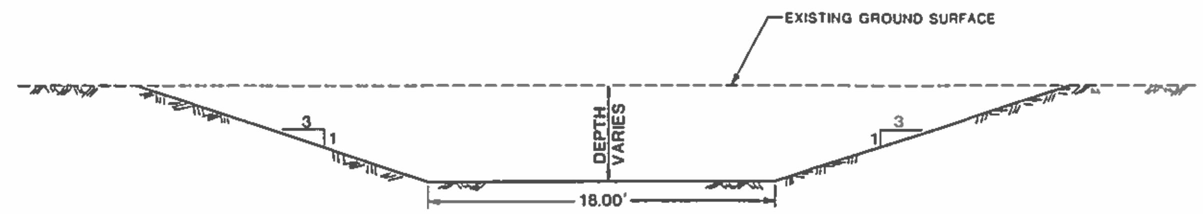
LONE MOUNTAIN FACILITY
LANDFILL CELLS 12 & 13
RUN-ON CONVEYANCE CHANNEL 4 PLAN & PROFILE

SHEET 3



STA. 0+00 TO STA. 2+50.00

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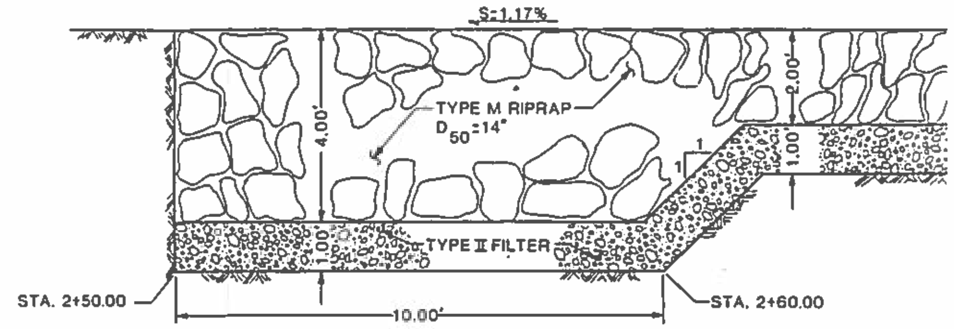
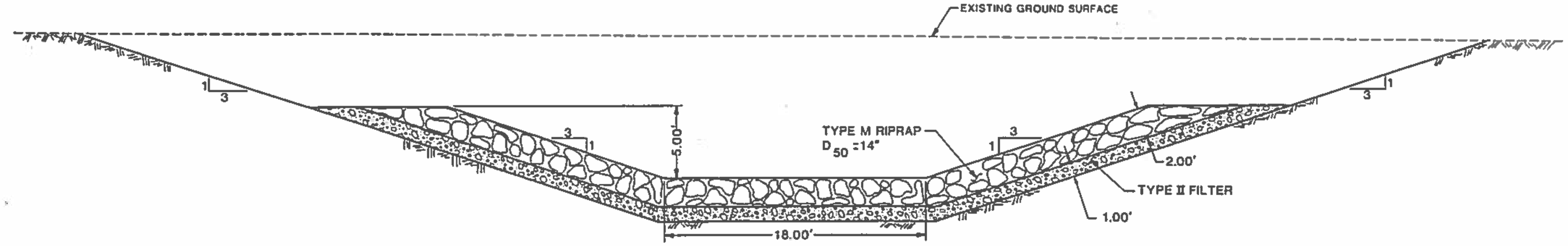
1"=5.00'

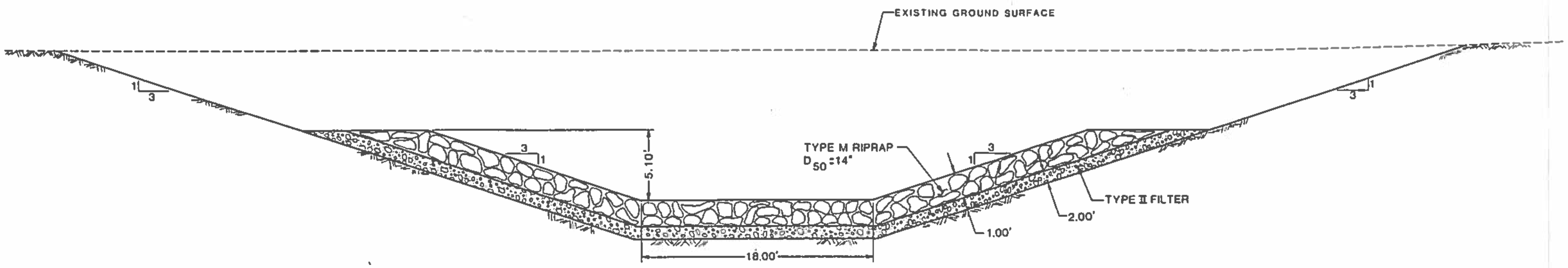


RIPRAP CUTOFF DETAIL $\boxed{FF}$ / $\boxed{30}$
1"=2.00'



STA. 2+50.00 TO STA. 12+30.00
STA. 20+71.00 TO STA. 25+77.10

SECTION $\boxed{32}$ / $\boxed{30}$ $\boxed{32}$ / $\boxed{31}$
1"=5.00'



STA. 12+30.00 TO STA. 20+71.00

SECTION $\boxed{33}$ / $\boxed{31}$
1"=5.00'

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RECORD DRAWING - JULY 1992

HA&L ENGINEERING CONSULTANTS ENGINEERS Salt Lake City, Utah

REGISTERED PROFESSIONAL ENGINEER MARVIN E. ALLEN 14802

PROJECT ENGINEER

DESIGNED	MPW	3				
DRAFTED	JVH	2				
CHECKED	MEA	1	7/92	RECORD DRAWING	PGH	MEA
DATE	SEPT.,1990	NO.	DATE	REVISIONS	BY	APVD.

SCALE AS SHOWN

VERIFY SCALE
0" 1"
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USPCI
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LONE MOUNTAIN FACILITY
LANDFILL CELLS 12 & 13
RUN-ON DIVERSION CHANNEL 4 SECTIONS

6.6

Construction Quality Assurance Plan

Table of Contents

Figures

Tables

Appendix

1.0 Introduction

Clean Harbors Lone Mountain, LLC (CHLM) has developed this Construction Quality Assurance (CQA) Plan to ensure that its Lone Mountain Facility complies with the applicable EPA and Oklahoma Department of Environmental Quality (ODEQ) regulations and demonstrates that the regulatory requirements for the construction of the landfills and closure caps, including the inspection of liners, will be met. The plan is intended as a reference for both construction and regulatory personnel. The CQA Plan has been organized following the outline recommended in the EPA Technical Guidance Document entitled "Quality Assurance and Quality Control for Waste Containment Facilities." The plan first discusses the project organization, responsibilities, and authority of the various personnel involved. It describes the qualifications of personnel involved in the administration and implementation of the CQA Plan. The inspection activities associated with the project are defined. The plan discusses meetings that should be held during the project. Finally, the plan details the documentation required to provide evidence of adherence to this plan. When the various components of this plan are combined, the resulting efforts will produce a well-constructed and operational project.

This CQA Plan is devoted to Construction Quality Assurance. In the context of this document, Construction Quality Assurance and Construction Quality Control are defined as follows:

- Construction Quality Assurance (CQA) - A planned and systematic pattern of means and actions designed to assure adequate confidence that materials and/or services meet contractual and regulatory requirements and will perform satisfactorily in service.
- Construction Quality Control (CQC) - Those actions which provide a means to measure and regulate the characteristics of an item or service in relation to contractual and regulatory requirements.

In the context of this document:

- CQA refers to means and actions employed by the CQA Consultant to assure conformity of the Project "Work" with this CQA Plan, the Construction Drawings and Project Specifications; and
- Construction Quality Control refers to those actions taken by the Contractor, Manufacturer, or Geosynthetic Installer to verify that the materials and the workmanship meet the requirements of this CQA Plan, the Construction Drawings, and the Project Specifications. In the case of soil components, CQC is combined with CQA and is provided by the CQA Consultant. In the case of the geosynthetic components and piping of the work, CQC is provided by the Manufacturer and Geosynthetic Installer and the Contractor. CQA testing of soil, pipe, concrete, and geosynthetic components is provided by the CQA Consultant.

This plan provides construction quality assurance activities for the construction of the landfill cells as well as for the construction of the closure caps for the cells. Many of the activities described in this plan are the same for both landfill cell construction and closure construction. In cases where landfill cell construction and closure construction activities differ, the applicable inspection activities will be clearly identified. Applicable inspection activities associated with both the construction of the landfill cell and the construction of the closure cap are described in the first table of the "Inspection Activities" section of this plan.

Until approved by the ODEQ, a revised CQA Plan will not be in effect, and the current ODEQ approved CQA Plan will remain in force. When approved by the ODEQ, a revised CQA Plan will be implemented for the next cell or cap to be constructed; however, if approved during the time of landfill cell or cap construction, the revised plan can be implemented immediately.

2.0 Organization, Responsibility, and Authority

Clean Harbors Lone Mountain, LLC (CHLM) is the operator of the Lone Mountain Facility. As such, it recognizes that it is ultimately responsible for the design, construction, and operation of the land disposal facilities at the site. CHLM recognizes that it is responsible for complying with the requirements of the permitting agency in these activities, including providing the proper documentation that the facility was constructed as specified in the CQA Plan. CHLM has the authority and responsibility to determine what individuals or organizations will be responsible for the design, CQA, and construction activities. CHLM also has the authority and responsibility for determining the organizational structure for these activities.

2.1 Organization and Authority

CHLM has assigned the above-indicated responsibilities of overseeing all activities associated with the design and construction of their hazardous waste landfills and closure caps, with specific emphasis to the CQA program, to the Vice President, Technology (aka Engineering). The organizational structure for the CQA program is illustrated in Figure 1. The solid lines on Figure 1 represent the lines of authority; whereas, the dashed lines indicate lines of communication. As illustrated in Figure 1, the Vice President, Technology, is ultimately responsible for all activities associated with the successful construction of the waste landfill cells and closure caps. The construction quality assurance program has been organized so that all individuals involved in construction will ultimately report to the CQA Officer, who will be an employee and report to the Vice President, Technology.

The implementation of the CQA Plan occurs through the CQA Officer. Functioning under the CQA Officer will be the Certifying Engineer. The CQA personnel will be responsible for ensuring that the work items indicated above associated with the landfill are constructed in accordance with the plans and the specifications defined herein. CQA personnel will be responsible for reviewing contractor submittals, performing field observations, conducting the various tests and making observations as specified in the CQA Plan, for documenting those tests, and for reporting and reviewing the test results.

2.2 Responsibilities

The specific responsibilities of the various individuals or entities presented in the organizational chart of Figure 1 are presented below.

Vice President, Technology. As indicated, the Vice President, Technology (aka Engineering) has the responsibility for overseeing all aspects associated with the design and construction of the landfills and closure caps at the Lone Mountain Facility. The Vice President, Technology assumes the responsibilities of the facility owner. Thus, the responsibilities include ensuring that the design and construction of the cells and closure caps comply with the requirements of the permitting agency as well as with operational needs. He has the authority to select and dismiss organizations or individuals charged with the design, CQA, and construction activities.

Construction Manager. The Construction Manager is responsible for implementing the construction and overseeing contractors. The Construction Manager may be a representative of CHLM or a sub consultant.

CQA Officer. The Vice President, Technology has assigned the CQA Officer the specific responsibility of overseeing the construction quality assurance aspects of the project. The CQA Officer coordinates aspects of the CQA Plan with the Certifying Engineer; however, the CQA Officer reports to the Vice President, Technology, and thus, functions independently from the certifying and design engineers or the construction contractors. The CQA Officer has the authority to stop any aspect of the work that is not in compliance with the CQA Plan. Work would then be resumed with the approval of the CQA Officer once corrective action has been approved and taken to correct any defective work. In the absence of the CQA Officer from the work site, the duties and responsibilities of the CQA Officer shall be delegated to one of the CQA personnel. The specific responsibilities of the CQA Officer include:

a. Review the design documents and plans to ensure that the CQA Plan can be implemented.

b. Train CQA personnel on CQA requirements and procedures.

c. Schedule and coordinate CQA inspection activities.

d. Direct and support the CQA personnel by confirming that regular calibration of testing equipment is properly conducted and recorded; confirming that testing equipment, personnel, and procedures do not change over time or by ensuring that any changes do not adversely impact the inspection process; confirming that test data is accurately recorded and maintained; and verifying that raw data is properly recorded, validated, reduced, summarized, and interpreted.

e. On at least a monthly basis, provide to the Vice President, Technology a summary report documenting the following:

- CQA activities completed during the preceding month.
- A summary of all non-conforming or suspected non-conforming work and corrective actions taken during the preceding month.
- Identification of work that the CQA Officer has accepted.
- An indication that to the best of his/her knowledge and based on the CQA activities completed to date, the construction is being accomplished in accordance with the CQA Plan.
- An evaluation of the degree of reconciliation between non-conforming work and the specifications as defined in the CQA Plan, and the ability of the CQA program to meet the quality objectives of the CQA Plan.

f. Verify that the CQA personnel are completing and properly documenting all on-site observations and tests required to ensure compliance with the CQA Plan.

g. Approve specific corrective measures to be implemented during construction where deviation occurs from the CQA Plan.

h. Review, coordinate, and approve CQA activities to ensure that testing and documentation are complete and accurate.

i. During the course of construction and following completion of the project, maintain a project CQA file for maintaining and storing the originals or copies of all data sheets and reports that are generated in carrying out the CQA Plan as identified herein. A complete copy of these reports will be maintained on-site.

j. Oversee preparation of the final construction report at the completion of the project, which will be a compilation of all of the daily reports generated during the course of construction, as well as a summary report of all CQC and CQA activities.

Design Engineer. The responsibilities of the Design Engineer include those design activities that occur during the construction of the project. The specific responsibilities include the following:

a. Review and approve design changes to the landfill (including closure cap) to meet the operational requirements of the owner and the permitting requirements of the agencies.
b. Coordinate design changes with the CQA Officer.
c. Approve corrective measures to be implemented where deviation occurs during construction from the design.

The Design Engineer has authority to work within the framework of the design and CQA Plan. The Design Engineer does not have the authority to make any decisions that would alter the design and the CQA Plan for the facility without the express approval of the CQA Officer (refer to Section VI - Change Control Procedures) and the regulatory agency (ODEQ), where applicable.

Certifying Engineer. The responsibilities of the Certifying Engineer include certifying that construction of the cell or cap was accomplished in accordance with the design documents and CQA Plan. The specific responsibilities include the following:

a. Review and approve the CQA documentation.
b. Document corrective measures to be implemented where deviation from the CQA Plan occurs during construction. Document action to the CQA file.

The Certifying Engineer has the authority to work within the framework of the design and the CQA Plan. The Certifying Engineer does not have the authority to make any decisions that would alter the design and the CQA Plan for the facility without the express approval of the CQA

Officer (refer to Section 6.6.6 - Change Control Procedures) and the regulatory agency (ODEQ), where applicable.

Construction Quality Assurance (CQA) Personnel. The Construction Quality Assurance (CQA) personnel will work under the direction of the CQA Officer and Certifying Engineer to ensure that the CQA Plan is executed properly. The authority of the CQA personnel will be limited to the performance of required testing, observation and documentation requirements of the CQA Plan. The CQA personnel will have authority to stop work as per the directive of the CQA Officer. Specific responsibilities of the CQA personnel include the following:

a. Perform on-site observation, testing, and documentation of the work in progress to monitor/document compliance with the CQA Plan.
b. Verify that the equipment used in testing has been calibrated.
c. Conduct required testing as defined in the CQA Plan.
d. Record results of all observations and tests daily. Work that fails to meet the CQA Plan after corrective action has been taken should be reported immediately to the Construction Manager so that alternate corrective action can be determined. This reporting shall be included in the daily construction reports.
e. Verify that corrective action has been taken (where required) and recorded on the daily construction reports.
f. Prepare and assemble the required documentation of the results of on-site observations, testing, and reviews conducted by CQA personnel.
g. Provide the results of on-site observations, testing, and documentation of the work in progress to the CQA Officer and Certifying Engineer.

3.0 Project Meetings

Meetings should be held during the project to enhance communications between personnel responsible for design, inspection, and construction of the project. These meetings will include a pre-construction CQA meeting and monthly CQA meetings.

3.1 Pre-Construction CQA Meetings

1. Familiarizing each organization with the CQA Plan and their role relative to the CQA Plan.
2. Reviewing the responsibilities, lines of authority, and communication of each organization.
3. Discussing the procedures for observations and testing.
4. Discussing procedures for handling construction deficiencies, repairs, and retesting.
5. Reviewing methods for reporting and documenting testing and inspection activities.
6. Reviewing methods for distributing and storing documents and reports.
7. Identifying work areas and equipment and materials storage areas.
8. Identifying required submittals for the project.

9. Discussing procedures employed by soils contractor and/or geosynthetics installer to train their operators and/or technicians to provide a quality work product.

3.2 Monthly CQA Meetings

Meetings should be held approximately once per month to discuss the progress of the project. Those to attend should include the CQA Officer, the Certifying Engineer, a representative of the CQA personnel, and a representative of the contractors (as needed). Items to be discussed in this meeting should include, but not be limited to:

1. Discussing the CQA, and construction activities and accomplishments of the previous month.
2. Exchanging, reviewing, and discussing required documentation of construction, observation, and testing activities.
3. Defining and discussing problems or deficiencies associated with the work and CQA activities. Documenting problems or deficiencies discussed in the CQA file.
4. Reviewing alternative solutions.
5. Implementing corrective actions to resolve problems or deficiencies.

CQA personnel should prepare minutes of the meeting for distribution to all attending parties.

4.0 Personnel Qualifications

In order to ensure that the various individuals associated with the CQA Plan are properly qualified, general qualifications have been developed for each position. This should ensure that participating individuals are properly qualified for the performance of their assigned tasks. The following details each position and the generally expected qualifications. Note that the qualifications listed below are not absolutes. They are presented as a general guideline for the relative education, experience, and knowledge of the personnel.

1. CQA Officer
   - Undergraduate technical degree, preferably in engineering, engineering geology, or closely associated disciplines.
   - Registered Professional Engineer.
   - Three years' experience in the waste industry.

2. Design Engineer
   - Undergraduate engineering degree.
   - Professional Engineer registered in the state of Oklahoma.
   - Three years' experience in the waste industry.

3. Certifying Engineer
   - Undergraduate engineering degree.

- Professional Engineer registered in the State of Oklahoma.
- Three years' experience in the waste industry.

4. Surveyor
   - Registered land surveyor in the State of Oklahoma.

5. CQA Personnel
   - Previous experience in executing the required inspection activities or working under the direct supervision of another CQA individual with previous experience.

5.0 Inspection Activities

This section of the CQA Plan describes the inspection-activities (observations and tests) that will be performed by the CQA personnel during the construction and installation of the work elements associated with the project.

The major work elements that comprise the project, the specifications governing each work element, and the CQA activities to be performed in a timely manner to ensure a quality outcome of each work element are identified in Table 1 for landfill cell construction and closure. Table 1 identifies the observations and tests to be conducted by the CQA personnel, the frequency of observations and tests, the acceptance/rejection criteria that will be used in the evaluation of the tests, and how the observations and tests are to be recorded and documented.

Measuring and testing equipment (M&T) used for critical items of construction must be controlled in order to ensure the quality outcome of the project. M&T equipment used for critical items of construction include the nuclear gage, scales, sealed single ring infiltrometer, two-stage boutwell test, large-scale block sampling and testing etc., used by the CQA personnel associated with the testing of the soils-related aspects of the project, surveying equipment used by the surveyor in checking and controlling construction grades, pressure gages used in the non-destructive testing of the HDPE liner welds, and tensiometers for peel and shear tests of HDPE welds. This equipment is to be calibrated in accordance with manufacturer recommendations and annually at a minimum. At the beginning of the project, Contractor will provide the CQA personnel with documentation confirming that the equipment has been calibrated. This documentation will be included in the construction documentation report at the completion of construction of the project.

6.0 Change Control Procedures

This section describes the procedure for initiating and approving minor changes in a timely manner necessary to maintain or enhance quality during construction. As the need for minor changes occurs, they must be controlled by both the permittee and by the regulatory agency. The types of changes will be divided into two categories: (1) Change Control Procedures, and (2) Class I Permit Modifications.

In either case, mutual agreement between the regulatory authority and the permittee as to the proposed change type will normally occur prior to submission of supporting documentation to the regulatory agency for processing. Verbal communication of the proposed change will aid in this determination, and the following procedures will be applicable to both types of changes:

1. Design engineering and construction changes will be initiated by, but not limited to, CQA personnel, the CQA Officer, the Vice President, Technology, or other parties which the Vice President, Technology designates.
2. All proposed design engineering and construction changes will be reviewed and approved by the Design Engineer. If approved, the Design Engineer will provide documentation to the CQA Officer indicating that the proposed change(s) will meet the minimum quality requirements of the project.
3. The CQA Officer will review and approve or disapprove the proposed change(s) based on the documentation and recommendation of the Design Engineer.
4. If the CQA Officer approves the proposed change(s), verbal notification of the proposal should be made to the Oklahoma Department of Environmental Quality (ODEQ). The scope of the proposal will be discussed to obtain a mutual understanding and agreement as to the proper type of change action. If the decision indicates a Class 1 Permit Modification, the appropriate application package format will be assembled and submitted to the ODEQ for approval. The requirements of 40 CFR 270.42 will be followed in this scenario. If the determination allows a change control procedure, then the documentation of the change should be submitted to the ODEQ within 48 hours of verbal notification.
5. All documentation submitted to the agency regarding change(s) will be included in the construction documentation report. As-built details of the project will be prepared which will reflect approved changes.

7.0 Documentation

Documentation of construction and inspection activities associated with the CQA Plan will consist of daily recordkeeping and a final report to be prepared under the direction of the CQA Officer. Daily reporting procedures associated with the CQA activities are described based on specific work elements in Table 1 of the inspection activities section and are to be performed in a timely manner.
The results of testing and observations as recorded on the daily construction reports will be reviewed and accepted by the CQA Officer or his designee. Acceptance of the daily construction reports will consist of either counter-signing the forms directly or having one of the CQA personnel sign the forms indicating that they have been reviewed and accepted on behalf of the CQA Officer. During the construction of the facility, the CQA Officer will be responsible for maintaining and storing the originals or copies of all data sheets and reports that are generated in carrying out the CQA Plan as identified herein. A complete copy of these reports will be maintained on-site during the course of construction.

The CQA Officer will direct the preparation of a final construction documentation report at the completion of the project. The CQA report will provide a summary of CQA activities and will demonstrate that the construction satisfied the CQA Plan and applicable State and Federal regulations. The CQA report will provide an evaluation of the degree of reconciliation between non-conforming work and the specifications as defined in the CQA Plan and the ability of the CQA program to meet the quality objectives of the CQA Plan.

The CQA Report will also include an overall summary of construction activities associated with the project. The Certifying Engineer will certify that construction within the inside edge of the anchor trench was accomplished in accordance with the CQA Plan and any field design, engineering, or construction changes were made in accordance with the change control procedure and/or a Class 1 Permit Modification.

The CQA Report will provide a summary of the soils observation and testing aspects of the construction or closure project. The repo1t will certify that the soils po1tions of the cell or closure cap were constructed in accordance with the CQA Plan and any field design, engineering, or construction changes made in accordance with the change control procedure and/or a Class 1 Permit Modification.

The CQA Report will include a summary of the geosynthetic liner observation and testing aspects of the project. The report will certify that the geosynthetic liner portions of the cell are constructed in accordance with the CQA Plan and any field design, engineering, or construction changes made in accordance with the change control procedure and/or a Class 1 Permit Modification.

The Final CQA Report will be certified by the Lone Mountain Facility Manager and will be submitted to the ODEQ within sixty (60) days of completion of the project. The completion of the project will be defined as the date when the CQA Officer notifies the Facility Manager in writing that the project is complete. The CQA Officer must certify that the CQA Plan has been successfully carried out, and that the unit meets the requirements of 40 CFR 264.301 (c) or (d).

TABLES

TABLE 1

LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUAILITY ASSURANCE (CQA)
CELL FOUNDATION PREPARATION		Review geotechnical investigation report to become familiar with the expected site conditions.
	CLEARING & GRUBBING: Remove vegetation, debris, organic, or deleterious material from below areas to receive embankment material. Soft and yielding spots shall be corrected by drying and recompacting the material or shall be removed and disposed of as directed by the CQA Officer. Material so removed shall be replaced with a suitable material and shall be compacted to the density requirements.	Observe the clearing and grubbing operation. Document that clearing and grubbing is complete and that vegetation, roots, and highly organic soil within appropriate areas is removed,
	SCARIFICATION & COMPACTION: Foundation area-Scarify to a depth of at least 8 inches. Moisten and compact to at least 95.0% of the Standard Proctor density as determined by ASTM D-698 with a moisture content of mins H 2.0% to plus (+) 4.0% of the optimum moisture content.	Observe and document that required activities are performed. Perform compaction testing on recompacted subgrade using applicable methods indicated in Appendix A at a minimum frequency of one per 12,000 sf. The location of the tests shall be chosen on a random basis. Report any deficiencies to the Construction Manager and confirm that deficient areas are reworked and meet the specification. Obtain signature and approval of geosynthetic subgrade acceptance from Geosynthetic Installer, as appropriate.
	Remove unsuitable material as required. Foundation approval.	Identify soft and yielding areas of subgrade and report to Construction Manager for over excavation and removal. Identify areas of unsuitable material for removal from project area. Observe and document that required activities are performed. Perform compaction testing on recompacted subgrade using application methods indicated in Appendix A at a minimum frequency presented in Table 2. Report any deficiencies to the Construction Manager and confirm that deficient areas are reworked and meet the specification. Obtain signature and approval of geosynthetic subgrade acceptance from Geosynthetic Installer, as appropriate.
BORROW PREPARATION	Remove vegetation, debris, organic, or deleterious material from borrow areas	Observe the clearing and grubbing operation. Document that clearing and grubbing is complete and that vegetation, roots, and highly organic soil within appropriate areas is removed.

CELL EMBANKMENT, ROADWAYS, AND RAMP	**BORROW:** Satisfactory embankment materials are defined as those complying with the Unified Soil Classification of CL, ML, SM, SC, or combinations of these materials.	Perform and document visual classification of borrow source materials. Notify Construction Manager of soils not meeting the specifications. Obtain laboratory moisture-density relationship (Proctor) and classification tests on every 10,000 cubic yards or change in material based on the Unified Soil Classification System (see Table 2). Applicable testing methods are referenced in Appendix A.
	EMBANKMENT AND BACKFILL: Embankment and backfill material will be placed with heavy construction equipment and will be compacted to at least 95% of the Standard Proctor density as determined by ASTM D-698 with a moisture content of minus(-) 2.0% to plus(+) 4.0% of the optimum moisture content. Material compacted with hand operated tampers will be compacted to 95% of the maximum dry density as determined by ASTh1 D698 with a moisture content of minus (-) 2.0% to plus (+) 4.0% of theoptimum moisture content.	Perform and document compaction testing on embankment and backfill using applicable methods indicated in Appendix A at a minimum frequency of one per 12,000 square feet per lift. These tests will be performed on the roadways and ramps at a frequency of one test per 300 linear feet per lift. The location of the tests shall be chosen on a random basis. Report any deficiencies to the Construction Manager and confirm that deficient areas are reworked and meet the specification.
	PLACEMENT: Backfill and fill shall be placed in uniform lifts. A lift is defined as 8 inches or less in loose depth for material compacted by heavy compaction equipment, and 4 inches or less in loose depth for material compacted by hand-operated tampers. In anchor trenches, the first lift shall be placed not more than 12 inches in loose depth with subsequent lifts placed 4 inches in loose depth. Where backfill is placed around pipes, the first lift will be placed to a depth slightly higher than the spring-line of the pipe, to prevent displacement of the pipe. When fill is to be placed and the work area is covered with snow, the snow must be removed. If the top layer of the embankment becomes frozen or if frozen material is delivered to the embankment, the frozen material must be removed.	Observe and document fill and backfill placement and compaction operations. Report any deficiencies to the Construction Manager and confirm that deficient areas are reworked and meet the specifications. Observe and document that snow is removed and that conditions meet the specifications. Report any deficiencies to the Construction Manager and confirm corrective actions are implemented in deficient areas.
	GRADING: In-place embankment materials and natural soils shall be fine graded to the design elevation and typical sections. Acceptable grading tolerance limits for finished embankment surfaces shall be as follows: Interior embankment slopes and the cell floor (subgrade for the clay liner): zero to minus (-) 0.8 of a foot. All other embankment slopes: + or – 0.2 of a foot.	Review certified as-built survey for compliance to CQA Plan and design documents. Notify Construction Manager of deficiencies. Review final survey data. Verify the frequency of survey measuring points. Verify that the surveyor certified that the construction is to the specified line and grade.

	Perform survey measurement at completion by licensed surveyor. Survey points shall be on at least a 60-ft grid and at all control points. Surveyor shall indicate where the embankment meets the design line and grade. Submit survey data to design engineer, Construction Manager and CQA Officer.	
CLAY LINER / CLAY CAP	**BORROW:** Satisfactory clay liner or clay cap material is defined as CL, CH, ML, and MH soils or combinations of these materials based on the Unified Soil Classification with at least 80 percent passing the No. 200 sieve and having a compacted permeability of less than or equal to 1 x 10^{-7} cm/sec.	Test compacted clay liner/cap material in accordance with minimum frequencies listed in Table 2. Observe and document sampling locations and confirm that samples are representative of source material. Notify Construction Manager of unacceptable material and observe and document that this material is not utilized. Obtain laboratory classification test every 1,000 cubic yards. For every 10,000 cubic yards or change in material, based on the Unified Soil Classification System, develop water content • density acceptance criteria, "Acceptable Zone", based on EPA Technical Guidance Document EPA/600/R-93/182. This procedure involves preparing and compacting each sample with standard compaction procedures (6 moisture density points each), testing each compacted specimen per ASTM D5084, and plotting the dry unit weights, molding water contents, and permeability of each moisture density point. , Finally, the "Acceptable Zone" will be determined based on hydraulic conductivity alone and will be ultimately determined by the CQA Officer.
	PROCESSING: These procedures are necessary to provide. suitable material for construction of the low permeable soil layer. 1. Mine satisfactory clay soil from the borrow area. 2. If needed to achieve a permeability of l x 10^{-7} cm/sec., uniformly apply deflocculant to the clay soils at a rate of at least 3 pounds per *50* cubic feet of loose clay soil, or at a lesser rate if approved by the Design Engineer, the Certifying Engineer and the CQA Officer. 3. Mix the deflocculant thoroughly into the clay soil using a "Bombag-type" mixer. 4. Add moisture to the clay soil to bring it near the optimum moisture content. 5. Mix and break up the material to maintain dry clod sizes smaller than l inch. Continue to mix and break un	Observe and document processing operations, including but not limited to, deflocculant application rates, equipment used, clod size, uniformity of moisture content. Confirm that all soil mixing provides a homogeneous soil. Report any deficiencies to the Construction Manager and confirm that all deficient areas/soil are reworked and meet the specification.

	the material to introduce a homogeneous material.	
TEST FILL	A test fill pad with plan dimensions of at least 60 by 75 feet is to be constructed to establish the procedure to be used during construction of the clay liner. In addition, the contractor shall construct at least one additional large test fill for Each additional process proposed for use during placement and compaction of clay liner material using large compaction equipment. A test pad with plan dimensions of at least 5 by 5 feet is to be constructed for each process proposed for use during placement and compaction of clay liner material using small self-propelled or hand operated compaction equipment. The test fills are to be constructed and tested in accordance with the following specifications: I. A minimum of three lifts of prepared clay shall be placed, The first lift is defined as 12 inches or less of loose material and subsequent lifts are defined as 6 inches or less of loose material. With the additional stipulation that the subsequent lifts cannot be greater than •2 inches thicker than the length of the feet on the sheepsfoot compactor. In the small test fill, a lift is defined as 4 inches or less of loose material. 2. The clay is to be compacted by equipment proposed for use during construction of the clay liner. In the large test fill, a minimum of one pass of the sheepsfoot compactor or soil disk will be required over the previously compacted lift of soil to tie the new lift into the preceding lift. Compaction of the test filis are to be accomplished by at least four passes of suitable compaction equipment. 3. The clay is to be compacted so that each moisture/density test falls in the "Acceptable Zone" as determined by the Project Engineer based on water content- density criteria after EPA Technical Guidance Document EPA/600/R-93/182. 4. The clay is to be compacted to provide a permeability of less than l x 10^{-7} cm/sec. 5. In the large test fill, a minimum of one pass of the smooth-drum roller will be required on the final lift to simulate finishing procedures. 6. Procedures used to construct the test fills must be reviewed and approved by the CQA Officer and Certifying Engineer prior to allowing clay to be placed inside the landfill.	Observe, document, and test the construction of the clay liner test fills. Verify that the same or similar equipment will be used in clay liner/cap construction. Perform field and laboratory testing at the minimum frequencies in Table 2 for the Test Fill. Field test locations shall be chosen on a random basis. Notify Construction Manager of unacceptable material and observe and document that this material is not utilized. Report any deficiencies to the Construction Manager and confirm that all deficient areas/soil are reworked and meet the specification. Perform in-situ hydraulic conductivity test (sealed single ring infiltrometer, or two stage borehole (Boutwell) test per ASTM D6391 or large-scale block sampling (see Appendix A2) test on each lift (one for small test pad). Test on each lift can be performed after completion of the test fill by excavating pads or utilizing deeper boreholes that encounter each lift. Approval of clay test pad shall require three passing field permeability test results. Prepare memorandum summarizing test fill construction procedures and test results.

CLAY LINER / CLAY CAP PLACEMENT	The clay liner/cap will be prepared, placed, and compacted using the same equipment, and mixing and compacting procedures that were approved in the test fill pads.	Observe, document and clay liner during placement and compaction operations. Document that procedures used follow the same procedures used to construct the test fill pads. Report any deficiencies to the Construction Manager and confirm that all deficient areas/ soil is reworked and meet the specification.
	Clay liner/ clay cap material will be constructed so that each moisture/density test falls in the "Acceptable Zone" as previously determined by water content-density criteria (EPA Technical Guidance Document EPA/600/R-93/182). The probe hole from density testing shall be filled with compacted bentonite by filling the hole in approximately 3-inch loose lifts and compacting each lift.	Observe, document and clay liner during placement and compaction operations. Perform tests at minimum frequencies presented in Table 2. Location of tests shall be chosen on a random basis. Report any deficiencies to the Construction Manager and confirm that all deficient areas/soil are reworked and meet the specification.
	The depth of the first lift of uncompacted material shall be no greater than 12 inches. The depth of subsequent lifts of uncompacted material shall be no greater than 6 inches with the additional stipulation that the subsequent lifts shall not be greater than 2 inches thicker than the length of the feet on the sheepsfoot compactor. The loose lift depth will be no greater than 4 inches for hand operated compactors. A minimum of one pass of the sheepsfoot compactor or disk will be required over the previously compacted lift of soil to tie the new lift into the preceding lift. Compaction of the clay liner is to be accomplished by at least four passes of suitable compaction equipment. To prevent the clay surface from drying, water will be applied to the clay surface as necessary or as directed by the CQC/CQA personnel. When clay liner/clay cap material is to be placed and the work area is covered with snow, the snow must be removed.	Observe and document that compaction lift thickness specifications and the requirement for passage of the sheepsfoot compactor are met during clay liner/cap placement/compaction operations. Observe clay liner surface for drying. Observe and document that corrective actions are accomplished, as necessary.
	No fill may be placed on frozen material. The frozen material may be removed so that fill may be placed. No frozen material may be incorporated in the fill. The clay liner/clay cap material shall not become contaminated with other soils or debris.	Observe and document site conditions. Confirm that all deficient areas/soil are removed and replaced or reworked to meet the specification. Observe soil conditions throughout excavation, stockpiling, unloading, placement and compaction. Notify Construction Manager of unacceptable material and observe and document that this material is removed and not utilized.
	GRADING: During cell construction final grading of the surface of the clay liner on the cell floor shall be zero (0) to plus two (2) tenths of a foot above design grade, the surface	Review and approve survey data. Notify Contractor of areas do not meet design specifications and requirements.

	of the clay liner placed on the interior slopes shall be zero (0) to plus three (3) tenths of a foot above design grade provided that no depression in the clay liner surface exceed one inch. Clay liner beneath the leachate withdrawal pipes in sump areas must be at design grade with no deviations. The grading tolerance limits for the clay liner at the inside toe of the embankment shall provide for a gradually rounded surface rather than the strict 3H:1V slope. Final grading for clay cap construction shall be greater than or equal *to* design grade provided that no depression in the clay liner exceeds one inch. Conduct survey measurement at completion by a licensed surveyor. Survey points shall be on at least a 60-foot grid and at all control points. Surveyor shall indicate where the clay liner/clay can meet design line and grade.	
CLAY LINER / CLAY CAP PLACEMENT (CONT.)	Final grading and finishing efforts on the surface of the clay liner/clay cap shall leave the surface free of sharp objects and deleterious material that might damage the overlying geosynthetics. Finishing efforts on the surface of the completed clay liner/clay cap shall be accomplished by at least one pass of the smooth--drum roller and be relatively smooth (i.e., a one-inch vertical drop). The surface shall provide a firm foundation (i.e., remolded by strong finger pressure). Rocks that can be seen are to be removed. Desiccation cracks larger than one-fourth inch wide and one inch deep shall be filled with dry powdered bentonite.	Observe, approve, and document final grading and finishing efforts for compliance with specification. Report any deficiencies to the Construction Manager and confirm that all deficient areas are reworked and meet the specification.
GEOSYNTHETIC CLAY LINE (GCL) BUFFER LAYER	**BORROW:** Prior to the placement of the Geosynthetic Clay Liner (GCL), a layer of soil at least six (6) inches thick shall be placed above the graded waste to provide a buffer layer between the GCL and the waste. This soil layer will meet the same specifications as the embankment material, except that it will also have a maximum particle size of one inch. Buffer material will be placed and compacted to 2_95.0% of the maximum dry density as determined by ASTM D-698 with a moisture content of minus (-) 4.0% to plus (+) 2.0 % of the optimum moisture content The feet on sheepsfoot compactors, if used to compact buffer material, shall be less than or equal to 4 inches in length.	Test borrow source material in accordance with requirements in Table 2. Applicable testing methods are referenced in Appendix A. Review test results for compliance with specifications and approve material for use, as appropriate. Observe and document placement operations for compliance with specifications. Perform and document in place density tests in accordance with the requirements in Table 2. The location of the tests shall choose on a random basis. Report any deficiencies to the Construction Manager and confirm that all deficient areas are reworked and meet the

		specification.
	GRADING: In-place buffer material shall be graded to the designed elevation and typical sections. Acceptable grading tolerance limits for finished surfaces shall be plus two (2) tenths (+0.2') to minus zero (0) tenths of a foot (-0.0'). Survey measurements shall be performed at completion by licensed surveyor. Survey points shall be on at least a 60-foot grid and at all control points. Surveyor shall indicate where the buffer surface meets the design line and grade.	Review survey data and verify that the survey documents for the buffer layer meet the grading tolerances of the CQA Plan, Notify the Construction Manager of any deficiencies and confirm that all deficient areas are reworked and meet the specification.
	PLACEMENT: A minimum of six (6) inches of compacted buffer material is required. Placement of the buffer material is to be done in such a- manner as *to* not incorporate the underlying waste into the buffer material. The buffer material is to be free of deleterious materials. The buffer soil will be graded to conform to the planned final drainage patterns. The surface will be shaped to avoid forming any depressions that might pond water. The thickness of the buffer layer should be verified through direct measurement on a grid no greater than 100 feet square, The buffer material shall be proof rolled to a smooth condition, with no protrusions, ridge marks, or abrupt grade changes. Any minor depressions, holes, etc., may be filled with soil or bentonite. Buffer material shall not be saturated immediately prior to the placement of the overlying GCL.	Observe and document placement of buffer zone. Review measurement of buffer layer thickness notify Construction Manager of deficiencies and confirm that all deficient areas are reworked and meet the specification. Observe and document proof rolling of buffer layer.
GEOSYNTHETIC CLAY LINER (GCL)	**REQUIREMENTS PRIOR TO GCL PLACEMENT:** Prior to GCL installation, the liner contractor shall provide to the CQC and CQA personnel: 1. Quality Control Certificates: submit conformance testing results in accordance with requirements of Table 3. Materials shall meet minimum requirements in Table 3. GCL whose certificates indicate material which does not meet the specifications are to be marked conspicuously and removed from construction area. 2. GCL Panel Placement Plan: The installer is to provide a GCL panel placement plan to the CQA Officer prior to the placement of the GCL. 3. GCL rolls shall be identified, handled, and stored in accordance with ASTM D5888. Each roll shall be identified and labeled with a unique identification number.	Review required submittals for compliance with specifications. Reject rolls not meeting the minimum specifications. Confirm that rejected rolls are removed from the project area and are unused. Observe and document material handling procedures and equipment. Review, comment and approve GCL panel layout as appropriate. Observe panel installation for conformance with panel layout plan.
	GCL SUBGRADE SURFACE PREPARATION: The surface onto	Observe and document subgrade conditions prior to

	which the GCL is to be placed shall be free of sharp objects and visible rocks in the surface. The surface shall be regular with no abrupt changes in grade greater than a one (l) inch vertical drop. Final rolling of the soil surface shall be by pneumatic tired equipment, vibratory roller, or steel wheel roller. The soil surface onto which the GCL is to be placed shall not have standing water.	placement of GCL panels for compliance with specification. Notify Construction Manager of deficiencies and confirm that all deficient areas are reworked and meet the specification.
	GCL PLACEMENT: The GCL panels are to be placed as closely as practical to the GCL panel placement plan approved by the CQA Officer. No GCL seams should be placed parallel to the direction of toe on slopes greater than 5%. No equipment shall be allowed on the surface of the GCL that will cause damage. GCL shall be placed in general accordance with ASTM D6102. The installation of GCL must start at the ridge line and proceed down the slope with the upper end extending at least three feet beyond the ridge line. The GCL shall be covered by HOPE liner the same working day that the GCL is placed. HOPE liner shall extend at least one foot beyond the edge of the GCL. Rolls of GCL are to be inspected for defects as they are unwound. Defects may include, but are not limited to: equipment damage, holes, thin spots, areas where the bentonite does not adhere to the support fabric, or the support fabric has become separated, signs of contamination by foreign material, or areas where the GCL has become completely hydrated. Defective areas in the GCL shall be repaired with an additional piece of GCL placed over the area with a minimum overlap of twelve (12) inches beyond the defective area.	Observe and document that panels are placed in general accordance with the approved GCL placement plan and specifications. Approve any minor alterations to the placement plan prior to the change being made. Maintain an as built drawing showing the general placement of the panels, Notify Construction Manager of deficiencies and confine that all deficient areas are reworked and meet the specification. Document a!! corrective actions. Observe condition of GCL rolls during deployment and identify areas of damage to Construction Manager. Observe and document the repair of defective areas and verify that the repair is in conformance with the specification item.
	GCL shall be installed in a dry condition and shall be protected from becoming wet. GCL that is allowed to become wet shall be removed and replaced with GCL that is dry. GCL seams shall maintain a minimum of six (6) inches of overlap along the edges and twelve (12) inches at end joints at all times regardless of shrinkage. Seams shall be free of foreign material. Seams shall run parallel with the greatest slope. For seams across the slope, the uphill panel should overlap the downhill panel. The GCL shall be installed so as to provide a surface with minimal creases or irregularities.	Observe and document subgrade conditions meet the specifications prior to GCL deployment. Identify any GCL panels that have become wet for removal. Verify and document that adequate overlap has been provided and maintained. Verify that corrective actions have been taken where required. Observe condition of GCL rolls during deployment. Identify areas of damage, creasing, or irregularities to Construction Manager. Verify that corrective actions have been taken where required.
FLEXIBLE MEMBRANE LINERS	**REQUIREMENTS PRIOR TO LINER PLACEMENT:**	Review submittals for conformance with specification. Reject any submittals that do not comply with specifications.

		Review manufacturer conformance testing frequencies and results in accordance with Table 4. Reject rolls not meeting the minimum specifications. Confirm that rejected rolls are removed from the project area and are unused.
	The HDPE liner contractor shall provide a summary of previous installations and previous warranty work, or if the liner contractor has previously provided their services at the facility, the submittal of the above items is not required since these will have been submitted for previous projects. Prior to HDPE liner installation, the liner contractor shall provide the CQA and CQC personnel: I) Conformance testing results in accordance with requirements of Table 4. Materials shall meet minimum requirements in Table 3. Rolls that do not meet project requirements shall be marked conspicuously and removed from the construction area. Manufacturer shall submit a statement that the following is true for the geomembrane to be used for this project: No post-consumer resin is used. The addition of reworked polymer (from the manufacturing process) to resin shall be permitted if it does not exceed 2% by weight, contains no encapsulated scrim, and is performed with appropriate cleanliness. Rolls shall not be deployed until approval from the CQA Consultant has been received. 2) Polymer Raw Material Certificates: The liner manufacturer is to supply certification that the resin meets the density specification defined in Table 4. 3) Welding Rod Certification: The welding rod manufacturer is to provide certification that the rod is of the same polymer as the sheet. 4) Resume of Installation Superintendent: Installation superintendent is to have prior experience supervising installation of a minimum of one (1) million square feet of liner. 5) Resumes of Welding Technicians: There will be	

	one welding supervisor designated per welding crew. The welding supervisor is to have experience welding a minimum of one (1) million square feet of liner. Welding technicians shall not be allowed to weld until approval has been received from the CQA personnel indicating that the welding technicians have been approved based on the required submittals.	
FLEX MEMBRANE LINERS (CONT.)	**LINER SURFACE PREPARATION:** The surface clay line/clay cap or soil protective cover beneath the HDPE liner is to be free of sharp objects and deleterious material that might damage the overlying geosynthetics. Rocks that can be seen in the liner are to be removed. The surface of the completed clay line/clay cap or soil protective cover shall be generally smooth (i.e., greater than or equal to a 1-in vertical drop). The surface shall provide a firm foundation. Desiccation cracks larger than one-fourth inch wide and one inch deep shall be filled with dry powdered bentonite. No standing water shall be allowed. Prior to the installation of HDPE liner, two conditions must be met, unless an alternative is specifically authorized by the ODEQ: 1. A minimum of one-eight (1/8) of a cell/cap (or less if the ODEQ on-site inspector agrees) must be available for approval. 2. The ODEQ on-site inspector must be provided with the required elevation data for the top of the clay liner. Note: the material properties sheet and quality control certificates shall be signed by a responsible HDPE liner manufacturer employee and shall be notarized.	Observe the subgrade for the HDPE liner for conformance with specifications. Notify Construction Manager of any deficiencies and document corrective actions have been taken. Record findings of observations, review and actions taken.
	HANDLING OF HDPE LINER: Geomembrane rolls shall be identified, handled, and stored in accordance with ASTM D4873. Each roll shall be identified and labeled with a unique identification number. HDPE liner shall be labeled with manufacturer, thickness, and roll number prior to shipment to the site. When transported to the site, the HOPE liner shall be handled by appropriate means so that no damage is caused to the liner. Transportation to the site shall be the responsibility of the installer.	Observe and document material handling procedures and equipment. Notify Construction Manager of any deficiencies. Confirm and document that any damaged or improperly labeled rolls are removed from the construction area.

	On-site unloading, storage, and- handling is the responsibility of the installer. Liner materials shall be stored in a location away from possible sources of deterioration. Appropriate handling equipment shall be used to move HDPE liner. The liner shall not be dragged on the ground.	
	LINER PLACEMENT: Prior to installation, the liner contractor shall present to the CQA Officer a liner placement plan. The plan shall indicate the panel configuration and location of seams. Seams shall be oriented parallel to the line of the maximum slope. Seams placed in high stress areas will be minimized (i.e., cell comers, parallel with the top of the embankment, or at the t0e of the side slopes). No seams shall be placed parallel to and within 3 feet of the toe of the slope. To minimize the risk of damage by wind during placement, adequate loading on the HDPE liner to prevent uplift by wind shall be provided by sandbags or other means which will not damage the liner. Liner placement shall not proceed at an ambient temperature below 1° C (34° F) or above 35°C (95° F), unless approved by the CQA Officer, The liner is to be placed as closely as practical to the liner placement plan. The as- built drawing will reflect modifications to the liner placement plan. Care shall be exercised to not damage the HDPE liner during installation.	Review and approve the panel placement plan. Notify the Construction Manager of any deficiencies. Observe and document that the liner is placed in accordance with the approved liner placement plan. Review and approve any modifications to the proposed placement plan during construction. If rejected, an alternative plan must be proposed and accepted, or the previously approved plan must be followed.
	Rolls are to be inspected as they are unwound for equipment damage, holes, blisters, thin sports, undispersed raw materials, or any signs of contamination by foreign material. Note: In several instances, visual defects (such as blisters) are small enough that repair of a visual defect may consist of placing a bead of extrudate from the extrusion welding gun over the visual defect. Welding beads placed to repair such visual defects are not considered extrusion welding and therefore do not require vacuum testing. Any form of hole or penetration through the liner must be patched with a liner cap which must be vacuum tested.	Observe the rolls during handling and placement for conformance to specifications. Notify Construction Manager of any damage or deficiencies. Confirm and document that corrective actions are performed, as required.
	WELDING: Field welding is to be accomplished by either the fusion method or the extrusion welding method. Prior to any welding (using either welding method) in both the morning and afternoon, a pre-weld test will be run for each technician/equipment combination. After cooling, coupons will be taken and will be tested for peel and shear. If any pre- weld test fails, then an additional pre-weld sample will be made and tested. After any second pre-weld test	Observe and document welding procedures, including the type of weld, welded date, and the welding technician for each seam. Observe, document, and review test welds. Approve test weld results and report deficiencies to Construction Manager and observe and document corrective actions.

	failure, two consecutive pre-weld samples must be made, tested, and have passing results before that particular technician/equipment combination is put into production welding. Shear testing stresses the top sheet in relation to the bottom sheet in a direction away from the weld. A passing result will occur when the upper or lower sheet fails. A failing result will occur when the weld fails. Peel testing stresses the top sheet in relation to the overlapped edge of the lower sheet in an effort to peel away the weld. A passing result will occur when the liner fails. A failing result will occur when the weld peels.	
FLEXIBLE MEMBRANE LINERS (CONT.)	Seams shall be clean, dry, and have adequate overlap (minimum 3 inches) prior to welding. Overlap placement in high stress locations, such as cell comers, parallel with the top of the embankment, or at the toe of the side slopes, shall be minimized. No overlaps shall be placed parallel to and within 3 feet of the toe of the embankment. Seams must be aligned with the fewest number of wrinkles or "fishmouths".	Observe the condition of the seam for conformance with specifications and report deficiencies to Construction Manager and observe and document corrective actions.
	NON-DESTRUCTIVE SEAM TESTING: Geosynthetic Installer shall perform non-destructive testing on all production fusion welds in accordance with ASTM 05820 and on all extrusion welds in accordance with ASTM 05641.	Observe and document all non-destructive testing. Where defective results are obtained, require, and verify that the seams are repaired in accordance with specifications for repair and/or patching.
	DESTRUCTIVE SEAM TESTING: Geosynthetic Installer shall perform destructive testing at a minimum frequency of every 400 lf (with a minimum of one sample per equipment/welder combination each shift). Locations shall be selected by CQA Consultant and shall be at non-critical locations such as anchor trench locations or leachate collection sumps whenever possible. Sample shall be a minimum of 38 inches by 12 inches. Samples shall be numbered consecutively. Remove two coupons of one-inch in width from the sample for field testing in the peel and shear modes. Field test strips for peel and shear with digital field tensiometer capable of quantitatively measuring shear and peel strengths. If one or more field test fail in either peel or shear, implement procedures provided below. If the samples pass the field test, divide the sample into three approximately 12 inch x 12 inch samples (one portion to Geosynthetic Installer's independent laboratory for testing; one portion for the Owner's independent laboratory for testing; and one portion to the Owner for archiving). One sample shall be sent to an approved laboratory for peel and	Identify destructive sampling locations. Record locations on liner placement plan. Collect two 12xl2 inch samples from Geosynthetic Installer. Test one sample (minimum 5 replicate specimens) for seam strength and peel adhesion. Archive remaining samples as directed by Owner. Review, document, and approve seams. Notify Construction Manager of any deficiencies and review and document corrective actions. Observe, review, and document all seam failures and corrective actions. Review laboratory test results for compliance with specifications and notify Construction Manager of passing tests and failures.

	shear testing (ASTM D6392) by the Geosynthetic Installer. At least five replicates shall pass seam strength and peel adhesion criteria (Table 3). If destructive test seam failure is identified, the following procedures shall apply: a. Reconstruct the seam between any two passes test locations, or: b. Retrace the welding path to intermediate location, at 10 ft minimum from location of failed test in each direction and take samples for additional field tests. If the second test passes, then seam shall be either reconstructed or cap stripped between the two passes locations. If any sample fails, the process shall be repeated. c. The boundary samples shall be tested in the same manner as the original sample. In any case, acceptable seams shall be bounded by two pass test locations (i.e., above procedures shall be followed in both directions from original failed location). d. In the event that seam sample fails laboratory destructive test, then above procedures shall be followed considering laboratory tests exclusively. Because final seam must be bounded by two passing test locations, it may be necessary to take one or more samples for laboratory testing. e. Each sample hole and coupon hole shall be patched, along with the entire length of the defective seam.	
	Any sample holes in a fusion-welded seam shall be repaired by sealing the air space between the wedge tracks at both ends of the sample hole using a leister instrument and vice grips. A patch will be welded over any sample holes using the extrusion welding technique. Patches shall be circular or oval in shape, be of the same HDPE material as the liner, and extend a minimum of six (6) inches over the edge of the sample hole. The comers of the patches will have a radius of not less than three inches. Caps over seams shall also be extrusion welded. The welds on the patches and caps shall be non-destructive tested.	Confirm that seams for all patches and caps are clean, dry and have adequate overlaps in accordance with specifications prior to welding. Observe and document all non- destructive testing on seams of all patches and caps. Where defective results are obtained, require, verify, and document that seams are repaired. Record all repair locations on the liner placement plan.
DRAINAGE NET	**REQUIREMENTS PRIOR TO DRAINAGE NET INSTALLATION:** Prior to installation, the manufacturer shall provide the CQA personnel quality control certificates pertaining to the drainage net. The material properties of testing performed to demonstrate compliance with	Review and approval required submittals for compliance with specifications. Approve and document materials meeting project specifications. Notify Construction Manager of any deficiencies and confirm that all failing rolls are moved from the construction area.

	specifications are presented in Table 5. A QC certificate must be provided in accordance with the minimum MCQ frequencies presented in Table 5. A certificate must be provided for each roll that is not produced consecutively. Each roll must have a unique manufacturing identification number.	
	DEPLOYMENT: Prior to deployment of the drainage net, the underlying HDPE liner is to be cleared of soil or debris. The drainage net shall then be covered and maintained free from blowing sand or soil material. Sand or soil material in the drainage net, whether placed by machine or weather related, shall be removed from the drainage net.	Observe and document drainage net placement. Observe HDPE liner prior to drainage net placement for dust and debris. Observe drainage net prior to placement of overlying HDPE liner or filter fabric for compliance with the requirement that the drainage net be maintained free of blowing sand and other soil material. Report deficiencies to Construction Manager and confirm and document any corrective actions.
	The drainage net shall be installed by hand to prevent damage to the underlying surface(s). Adjacent rolls shall be joined by overlapping the edges by a minimum of four inches. The upslope net is to overlap the downslope net, where possible. Adjacent rolls shall be connected by spot welding or tying adjacent net rolls together. If tying material is used, the tying material shall be a polymer cable ties of a different colored material than the drainage net. The edges of the net shall be tied or secured at no greater than five-foot intervals along the sides of the nets and two-foot intervals along the ends of the rolls.	Observe placement for compliance with specifications and damage to drainage net or other geosynthetic materials. Observe and document that overlapping and tying or welding meets the project specifications. Report deficiencies to Construction Manager and confirm and document any corrective actions.
FILTER FABRIC	**REQUIREMENTS PRIOR TO FILTER FABRIC INSTALLATION:** Prior to installation, the manufacturer shall provide the CQA Consultant quality control certificates pertaining to the filter fabric and receive approval from the CQA Consultant. The material properties of testing performed to demonstrate compliance with specifications are presented in Table 6. A CQ certificate must be at the minimum frequencies presented in Table 6. A certificate must be provided for each roll that is not produced consecutively. Geotextile rolls shall be identified, handled, and stored in accordance with ASTM D4873. Each roll be identified and labeled with a unique identification number.	Review required submittals for compliance with specification. Observe and document the condition, handling, and storage of filter fabric materials. Notify Construction Manager of any materials that do not meet the project specification. Confirm and document that rejected rolls/material is removed from the construction area.
	DEPLOYMENT: The filter fabric shall be installed by hand to prevent damage to the underlying surface. The rolls of geotextile filter fabric shall be placed to provide a minimum width of 12 inches of overlap for each joint, or the overlap shall not be less than 3 inches for joining the adjacent sheets by either the sewing or the fusion weld methods. The	Observe and document filter fabric placement, overlapping, and joining for conformance with specifications. Report deficiencies to Construction Manager and confirm and document any corrective actions.

	overlap shall be glued together or otherwise fastened or secured. The fabric shall be placed such that the upslope fabric will overlap the downslope fabric, if possible.	
SOIL PROTECTIVE COVER	Satisfactory soil protective cover materials for the cell liners (floor) are defined as those complying with the Unified Soil Classification of SM, SP, or SW materials, or combination thereof. Satisfactory soil protective cover materials for the closure cap linear are defined as those complying with the Unified Soil Classification of SM, SC, SP, or SW materials, or combination thereof.	Collect and sample soil sample in accordance with requirements of Table 2. Notify Contractor of acceptable materials. Applicable testing methods are referenced in Appendix B.
	PLACEMENT: The size of equipment shall be limited to ensure that the bearing pressure of the equipment does not exceed the bearing capacity of the underlying system. Equipment used during the placement of the soil protective cover shall be restricted to: 1. Rubber tire dozer tractors pressures not to exceed 40 psi. 2. Track-type tractor/dozer with ground pressures not exceeding 8 psi. 3. Three & one-quarter yard bucket (or smaller) 4. Wheel loaders with tire pressures not to exceed 40 psi. 5. Three and one-quarter yard bucket (or smaller) track-type loaders with ground pressures not to exceed 10 psi. 6. Motor graders with tire pressures not to exceed 40 psi. 7. Track-type excavators/backhoes with tire pressures not to exceed 10 psi. 8. Wheel-type excavators/backhoes with tire pressures not to exceed 40 psi. 9. Trucks that do not exceed maximum highway wheel loads specified by AASHTO for an HS20 truck. 10. Smooth-drum rollers with a ground pressure not to exceed 8 psi.	Observe and document equipment used to place protective cover soil. Report deficiencies to Contractor and confirm and document any corrective actions.

TABLE 2

EARTHWORK CONFORMANCE TESTING

Material Type	Test Method		MIN CQA Frequency
Foundation/Subgrade Recompaction	Nuclear Density/Moisture Content	ASTM D6938	1 per 12,000 square feet (sf)
	Standard Proctor	ASTM 698	1 per material type
Compacted Soil/Engineered Fill	Nuclear Density/Moisture Content	ASTM D6938	1 per 1,000 cy (min 1 per lift)
	Standard Proctor	ASTM D698	1 per 12,000 sf per lift, or 1 per 300 linear feet (lf) per lift on roadways and ramps
	Visual Classification	ASTM D2488	1 per 10,000 cy (min 1 per material type)
Clay Liner/Cap Borrow Source	Standard Proctor	ASTM D698	1 per 5,000 cy (min 1 per material type)
	Atterberg Limits	ASTM D4318	1 per 5,000 cy (min 1 per material type)
	Sieve Analysis	ASTM D422	1 per 5,000 cy (min 1 per material type)
	Visual Classification	ASTM D2488	1 per 1,000 cy (min 1 per material type)
	Laboratory Hydraulic Conductivity[1]	ASTM D5084	6 per 5,000 cy
Clay Liner/Cap Test Fill	Nuclear Density/Moisture Content	ASTM D6938	1 per 1,500 sf per lift (or min 1 per lift for a small test pad
	Field Hydraulic Conductivity	ASTM D5126	Min 1 per lift (min 1 for a small test pad)
	Laboratory Hydraulic Conductivity[1]	ASTM D5084	Min 1 per lift (min 1 for a small test pad)

TABLE 2 Continued

EARTHWORK CONFORMANCE TESTING

Material Type	Test Method		MIN CQA Frequency
Compacted Clay Liner/Cap	Nuclear Density/Moisture Content	ASTM D6938	1 per 8,000 sf
	Grain Size Analyses	ASTM D422	1 per 10,000 cy (min 1 per material type)
GCL Buffer Layer	Nuclear Density/Moisture Content	ASTM D6938	1 per 12,000 sf per lift
	Standard Proctor	ASTM D698	1 per 10,000 cy (min 1 per material type)
	Visual Classification	ASTM D2488	1 per 10,000 cy (min 1 per material type)
Soil Protective Cover	Visual Classification	ASTM D2488	1 per 10,000 cy (min 1 per material type)
	Standard Proctor[3]	ASTM D698	1 per 10,000 cy (min 1 per material type)
	Nuclear Density/Moisture Content	ASTM D6938	See Note 2
Rip-Rap	Visual Classification	See Appendix A.1	Minimum 3 tests per construction project
Type I and Type II Granular Filter	Visual Classification	See Appendix A.1	1 per 1,000 cy for material on steep slopes and 1 per 500 cy for material on slopes 10% or flatter.

Notes:

1) Laboratory hydraulic conductivity testing (ASTM D5084) shall be performed at confining stress as directed by the Design Engineer at variable moisture content and density conditions to be determined by CQA Consultant to determine acceptable range of compaction criteria to obtain an as-compacted hydraulic conductivity of no greater than $1\text{x}10^{-7}$ cm/s.
2) Soil protective cover testing for field compaction is only required for cap shoulder construction (one per 300 linear feet) and for cell ramps (minimum 2 tests per lift) and leachate riser trenches (minimum one test per 30-ft of pipe).

TABLE 3

MATERIAL PROPERTIES AND CONFORMANCE TESTING FOR GEOSYNTHETIC CLAY LINER

PROPERTIES	QUALIFIERS	UNITS	SPECIFIED VALUES	TEST METHOD [(4)]	MQC FREQUENCY	CQA FREQUENCY
Bentonite Content[3]	Minimum	lb/ft^3	0.75	ASTM D5993	5,000-yd3	100,000-ft2
Hydraulic Index Flux[2]	Maximum	Cm^3/cm^2-s	$1x10^{-6}$	ASTM D5887	30,000-yd3	400,000-ft2
Bentonite Swell Index	Minimum	mL/2g	24	ASTM D5890	50 metric ton	-
Bentonite Fluid Loss	Maximum	mL	18	ASTM D5891	50 metric ton	-

Notes:

1) All values represent minimum average roll values (i.e., any roll in a lot should meet or exceed the values in this table).
2) Hydraulic flux testing shall be performed under an effective confining stress of 5lbs per square inch.
3) Measured at a moisture content of 0 percent; also known as mass per unit area.
4) Material requirements and manufacturer conformance testing frequency are based on the most recent version of GRI Specification GCL-3.

TABLE 4

MATERIAL PROPERTIES AND CONFORMANCE TESTING FOR HDPE LINER

Properties	Qualifiers	Units	60 Mil	60 Mil Textured	80 Mil	80 Mil Textured	ASTM Test Method	MQC Frequency	CQA Frequency
Physical Properties									
Thickness	Average Minimum	Mils	54	54	72	72	ASTM D5199	Per Roll	100,000-ft^2
Carbon Black Content	Range	%	2-3	2-3	2-3	2-3	ASTM D1603	20,000-lb	100,000-ft^2
Carbon Black Dispersion	N/A	None	Note 2	Note 2	Note 2	Note 2	ASTM D5596	45,000-lb	100,000-ft^2
Density	Minimum	g/cc	0.94	0.94	0.94	0.94	ASTM D792 Method A or ASTM D1505	200,000-lb	100,000-ft^2
Mechanical Properties									
Tensile Properties (each direction) 1. Tensile Break Strength 2. Elongation at Break 3. Tensile (Yield) Strength 4. Elongation at Yield	Minimum	lb/in % lb/in %	228 700 126 12	90 100 126 12	304 700 168 12	120 100 168 12	ASTM D638	20,000-lbs	100,000-ft^2
Tear Resistance (min ave.)	Minimum	lb	42	42	56	56	ASTM D1004	45,000-lbs	100,000-ft^2
Puncture Resistance	Minimum	lb	108	90	144	120	ASTM D4833	45,000-lbs	100,000-ft^2
Stress Crack Resistance	Minimum	hr	300	300	300	300	ASTM D5397	Per GRI-GM10	--
Oxidative Induction Time Standard OIT, -or- High Pressure OIT	Minimum Average	Minutes	100 400	100 400	100 400	100 400	ASTM D3895 ASTM D5885	200,000-lb	--
Oven Aging at 85° C Standard OIT - % retained after 90 days, -or- High Pressure OIT - % retained after 90 days	Minimum Average	%	55 80	55 80	55 80	55 80	ASTM D5721 ASTM D5885	Per Each Formulation	--

TABLE 4 Continued

MATERIAL PROPERTIES AND CONFORMANCE TESTING FOR HDPE LINER

REQUIRED GEOMEMBRANE SEAM PROPERTIES[5]									
Properties	**Qualifiers**	**Units**	**60 Mil**	**60 Mil Textured**	**80 Mil**	**80 Mil Textured**	**ASTM Test Method**	**MQC Frequency**	**CQA Frequency**
Shear Strength [3]									
Fusion	Minimum	lb/in	120	120	160	160	ASTM D6392	N/A	500 linear feet
Extrusion	Minimum	lb/in	120	120	160	160	ASTM D6392	N/A	500 linear feet
Peel Adhesion									
FBM [4]							Visual Observation		500 linear feet
Fusion	Minimum	lb/in	91	91	121	121	ASTM D6392	N/A	500 linear feet
Extrusion	Minimum	lb/in	78	78	104	104	ASTM D6392	N/A	500 linear feet

Notes:

1. Material requirements, manufacturer conformance testing frequency and minimum seam properties are based on the most recent version of Geosynthetic Research Institute (GRI) Specifications GM13 and GM19.
2. Minimum 9 of 10 in Categories 1 or 2; 10 in Categories 1, 2, or 3.
3. Also called "Bonded Seam Strength".
4. FTB = Film Tear Bond means that failure is in the parent material, not the seam. The maximum seam separation is 25 percent of the seam area.
5. Four of five specimens per destructive sample must pass both the shear and peel strength tests.

TABLE 5

MATERIAL PROPERTIES AND CONFORMANCE TESTING FOR DRAINAGE NET

PROPERTIES	QUALIFIERS	UNITS	SPECIFIED (1) VALUES	TEST METHOD	MQC FREQUENCY	CQA FREQUENCY
Resin Density	Minimum	g/cc	0.94	ASTM D792 or D1505	100,000-ft^2	200,000-ft^2
Carbon Black Content	Range	%	2.0 - 3.0	ASTM D1603 or D4218	100,000-ft^2	200,000-ft^2
Thickness	Minimum	mils	205	ASTN D5199	100,000-ft^2	200,000-ft^2
Transmissivity (2)	Minimum	m^2/sec	5 x 10^{-4}	ASTM D4716	100,000-ft^2	200,000-ft^2

Notes:

1) All values (except transmissivity) represent average roll values.
2) Transmissivity shall be measured using water at 68˚F with a gradient of 0.1 under a confining pressure as directed by the Design Engineer. The geonet shall be placed in the testing device between 60 mil HDPE smooth geomembrane. Measurements are taken one hour after application of confining pressure.

TABLE 6

MATERIAL PROPERTIES AND CONFORMANCE TESTING FOR FILTER FABRIC

PROPERTIES	QUALIFIERS	UNITS	SPECIFIED (1) VALUES	TEST METHOD	MQC FREQUENCY	CQA FREQUENCY
Mass Per Unit Area	Minimum	oz/yd^2	8	ASTM D5261	130,000-ft^2	Not Required
Grab Tensile Strength	Minimum	lbs	200	ASTM D4632	130,000-ft^2	1 test per 200,000-ft^2
Puncture Resistance	Minimum	lbs	120	ASTM D4833	130,000-ft^2	1 test per 200,000-ft^2
Permittivity	Maximum	s^{-1}	1.3	ASTM D4491	540,000-ft^2	1 test per 200,000-ft^2
Apparent Opening Size	Maximum U.S. Standard Sieve	--	70	ASTM D4751	540,000-ft^2	1 test per 200,000-ft^2

TABLE 7

RIP-RAP GRADATION SPECIFICATIONS

<table>
<tr><th rowspan="2">Rip-Rap Thickness (Inches) Typical</th><th rowspan="2">Rip-Rap Type Designation</th><th rowspan="2">% Smaller Than Given Size By Weight</th><th colspan="3">Intermediate Rock Weight Dimension*</th><th rowspan="2">D_{50}** (Inches)</th></tr>
<tr><th>(Lbs)</th><th colspan="2">(Inches)</th></tr>
<tr><td>6</td><td>Type V</td><td>70-100
50-70
35-50
2-10
0-1</td><td>43
18
5.3
0.7</td><td colspan="2">8
6
4
2
¾</td><td>4</td></tr>
<tr><td>12</td><td>Type VL</td><td>100
50
20
0-1</td><td>150
30-50
20</td><td colspan="2">11.6
6.8-8.1
5.9
3/4</td><td>6</td></tr>
<tr><td>18</td><td>Type L</td><td>100
50
20
0-1</td><td>350
70-125
30</td><td><u>Embankments</u>
16.2
9.4-11.5
7.1
3/4</td><td><u>Channels</u>
15.4
9.0-10.9
6.8
3/4</td><td>9</td></tr>
</table>

* Dimension based on volume of cube and SG=2.30 for Type V and Type L rip-rap used on cell caps and outer embankments, and SG=2.65 for Type VL and Type L rip-rap used in channels.

** D50 = Nominal particle size.

TABLE 8

TYPE I GRANULAR FILTER GRADIATION SPECIFICATION

U.S. Standard Sieve	Percent Passing by Weight
3/8 inches	100
No. 4	95-100
No. 16	45-85
No. 50	5-30
No. 100	0-10
No. 200	0-3

TABLE 9
TYPE II GRANULAR FILTER GRADATION SPECIFICATIONS

U.S. Standard Sieve Size	Percent Passing by Weight, as Specified for Steep Closure Cap Slopes (2.5H: 1V – 3H: 1V)	Percent Passing by Weight, as Specified for 10 Percent or Less Closure Cap Slopes	Percent Passing by Weight, as Specified for Steep Exterior Embankment Slopes (2.1H: 1V)
3 Inches	90-100	90-100	90-100
¾ Inches	35-70	35-80	35-90
No. 4	0-20	0-35	0-30
No. 16	0-3	0-15	0-15
No. 200	0-1	0-5	0-3

APPENDIX A

SOIL TESTING METHODS

A.1 Soil Testing Methods

Soil testing methods are outlined in the following table.

Description	Test Method*
Nuclear Density/Moisture Content (Rapid Method)	ASTM D6938
Moisture Content of Soil by Microwave Oven Method	ASTM D4643
Soil Classification	ASTM D2488
Particle – Size Analysis of Soils	ASTM D422
Test Method for Material Finer than the No. 200 Sieve	ASTM D1140
Test Method for Atterberg Limits	ASTM D4318
Moisture – Density Relationship (Standard Proctor)	ASTM D698
Moisture – Density Relationship (Modified Proctor)	ASTM D1557
Thin-Walled Tube Sampling of Soils	ASTM D1587
Laboratory Permeability Testing of Soils	ASTM D5084
Field Permeability Testing of Soils by Sealed Single Ring Infiltrometer	See Appendix A.2
Two-Stage Borehole (TSB, i.e.; "Boutwell") Tests	ASTM D6391
Large Scale Block Sampling and Testing	See Appendix A.2
Particle – Size Analysis of Natural and Man-Made Rip-Rap Materials	Independent Visual Evaluation by CQA**

Note: Calibration of testing equipment must meet the requirements of the applicable standards.

* Most Current Published ASTM Method

** Independent visual evaluations must yield acceptable (i.e., material meets specifications) results prior to placement of rip-rap. If either independent evaluation determines rip-rap does not meet the specification on Table 7, material must be rejected and not used on the cells. To adequately evaluate the fine material fractions of the rip-rap, sample(s) if rip-rap must be spread out in a layer having an average approximate thickness of the applicable D50 size material (see Table 7). Minimum sample size required for visual rip-rap gradation evaluation is as follows:

Type L: 7,000 pd.

Type VL: 3,000 pd.

Type V: 860 pd.

A.2 Sealed Single Ring Infiltrometer Field Permeability Test

Note: *This procedure describes the methodology for utilizing a sealed single ring apparatus provided by Trautwein Soil Testing Equipment. Other SSRI equipment may have different set-ups and procedures.*

1. Equipment

(a) **Infiltrometer.** Metal square (24-in. x 24-in.) frame with Plexiglas top and no bottom.
(b) **Small Garden Shovel or Tool.** An approximate 2-in.-wide trench will need to be excavated in a square such that the Infiltrometer fits into the trench approximately 4 to 5-in. deep with 1-in. of open space on each side of the Infiltrometer sides.
(c) **Nuts, Washers, and Bolts.** These attach the Infiltrometer to the Plexiglas.
(d) **Seals (2).** The seals prevent leaking and are placed on the bottom and top of the Plexiglas.
(e) **Granular Bentonite.** Used to seal the Infiltrometer to the ground surface.
(f) **Marriotte Bottle.** Bottle used to measure the amount of water that moves into the Infiltrometer, therefore measuring the amount of water the infiltrates through the soil.
(g) **Stand.** Holds the Marriotte Bottle above the Infiltrometer to provide head.
(h) **Tubing.** Approximately 2-ft of Tygon® plastic tubing to connect the Marriotte Bottle to the Infiltrometer. Approximately 6-in. of tubing that provides a release for water at the high end of the Infiltrometer. Approximately 6-in. of tubing to provide an air release for the Marriotte Bottle.
(i) **Tubing Clamps (4).** Placed on the tubing to restrict flow into or out if the Marriotte Bottle and the Infiltrometer.
(j) **Shovel or Plate.** Allows water to fill the Infiltrometer without disturbing the ground surface.
(k) **Level.** Measures the low corner of the Infiltrometer identifying which corner of the Marriotte Bottle should be located.
(l) **Plastic or Visquin.** This material should be placed around the Infiltrometer to keep the ground surrounding the test area from desiccating.
(m) **Cinder Blocks.** These keep the Infiltrometer from raising out of the ground.

1. Equipment Setup and Procedure

(a) Place the Infiltrometer on the ground surface where the test will be conducted. Trace the outer perimeter of the Infiltrometer on the ground. Excavate a 2-in. wide, 5 to 6-in. deep trench around the perimeter tracing.

(b) Place the Infiltrometer into the trench. Ensure a void space exists on both sides of the Infiltrometer. Establish a low corner using the level. Remove the Infiltrometer from the trench.

(c) Place a thick 1-in. lift, or layer, of granular bentonite in the bottom of the trench. Tamp the bentonite to prevent air voids. Add water. Place the Infiltrometer into the trench and continue to add bentonite in 1-in. lifts with water on the outside of the Infiltrometer until the bentonite is even with the ground surface.

(d) Add bentonite and water in 1-in. layers to the area on the inside of the Infiltrometer until even with the ground surface. Be sure that no bentonite is on the ground surface inside the Infiltrometer as it will affect the permeability of the soil.

(e) Place a shovel or plate inside the Infiltrometer and add water by pouring onto the flat part of the plate or shovel until the water level reaches the top of the Infiltrometer.

(f) Place a seal, then the Plexiglas, another seal, and finally the metal square on top of the Infiltrometer. The Plexiglas needs to be orientated such that the connections for the tubing are on the low and high corners. Attach the seals and the Plexiglas to the Infiltrometer using the nuts, bolts, and washers.

(g) Attach the Marriotte Bottle to the Stand. It should be between the Marriotte Bottle and the Infiltrometer; attach 6-in. of tubing to provide a release for water at the high corner of the Infiltrometer; and finally, attach 6-in. of tubing to provide an air release for the Marriotte Bottle.

(h) Allow the Infiltrometer to sit overnight so that the bentonite establishes a seal.

(i) Fill the Marriotte Bottle until the water level reaches approximately 30-cm. When finished, be sure that all the clamps are closed except for the one between the Marriotte Bottle and the Infiltrometer. This clamp should be left open to allow the volume in the Marriotte Bottle to adjust with the rate of infiltration. Place concrete cinder blocks on top of the Infiltrometer to prevent uplift movement.

(j) Measure the distance from the bottom of the tube inside the Marriotte Bottle to the ground test pad surface (this measure is the head of water placed on the test section.) Take your first reading from the Marriotte Bottle (read the water level in the bottle.) Be sure to check the tubing connecting the Marriotte Bottle to the Infiltrometer for bubbles. Tap on the tubing to move the bubble through the Marriotte Bottle.

(k) Saturate the ground around the Infiltrometer and cover with plastic or Visquin.

(l) Continue taking readings approximately every hour for the rest of the workday. For the next workday, take readings approximately every two hours. For the third workday, take approximately three to four readings throughout the course of the day. Continue this until the permeability stabilizes. Refill the Marriotte Bottle, as required.

(m) Once the Infiltrometer is removed, measure the wetting front. This is done with a spade and a visual inspection. Utilize a tape for the actual measurement.

Documentation and Data Recording

- **(a)** Test Number (e.g., SSRI-1)
- **(b)** Description (location, lift, etc.)
- **(c)** Area of the Infiltrometer (cm^2) – measured once during the test.
- **(d)** Marriotte Bottle Calibration (ml/cm) – measured once.
- **(e)** Head (cm) – measured once at the beginning when starting to take readings.
- **(f)** Wetting Front – measured at the end of the test.
- **(g)** Date and Time – taken at each reading.
- **(h)** Infiltrometer Reading – taken at each reading.
- **(i)** From (g) and (h) above, the test time (days), the interval time (seconds), the volume (ml), the cumulative volume (ml), the infiltration (cm/s), and the permeability (cm/s) can be calculated.

Volume (ml) = [Infiltrometer Reading (cm)] * [Marriotte Bottle Calibration (ml/cm)]

Infiltration (cm/s) = [Δ (Volume (ml))] / {[Interval Time (s)] * [Area of the Infiltrometer (cm^2)]}

Permeability (cm/s) = [Infiltration (cm/s] / {[Head (cm) + Wetting Front (cm)] / [Wetting Front (cm)]}

A.3 Procedure for Obtaining Large Scale Block Samples

This procedure is intended for guidance only. Actual procedures may be modified by the Project Manager and CQA Engineer. This procedure is based on an approximately 12 to 14-in. diameter block sample.

Step 1. Put the sample ring on the ground where block sample will be carved. (Fig. 1)

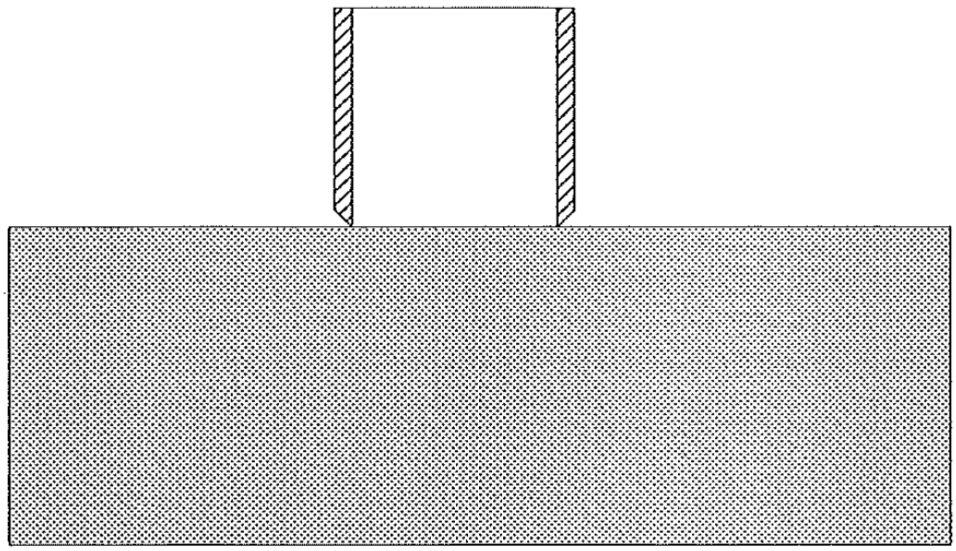


Figure 1.

Step 2. Carefully dig soil around the sample ring to a depth of 10 to 16-in., leave about 14 to 15-in. soil core. (Fig. 2)

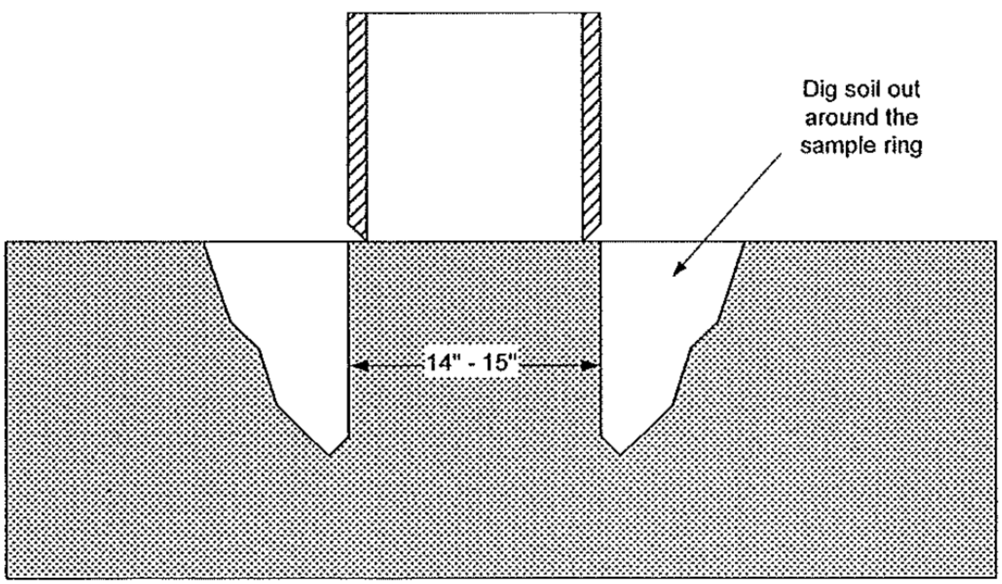


Figure 2.

Step 3. Use a small knife or spatula to carefully trim soil about 1-in down around the bottom edge of the sample ring and then push the ring down. (Fig. 3)

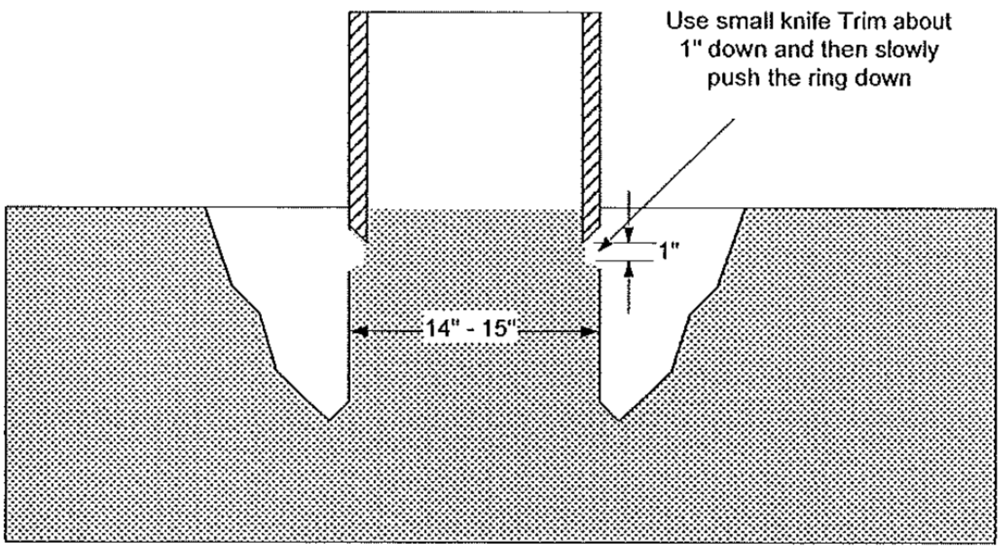


Figure 3.

Step 4. Continue step 3, until soil fits inside the sample ring. (Fig. 4, 5)

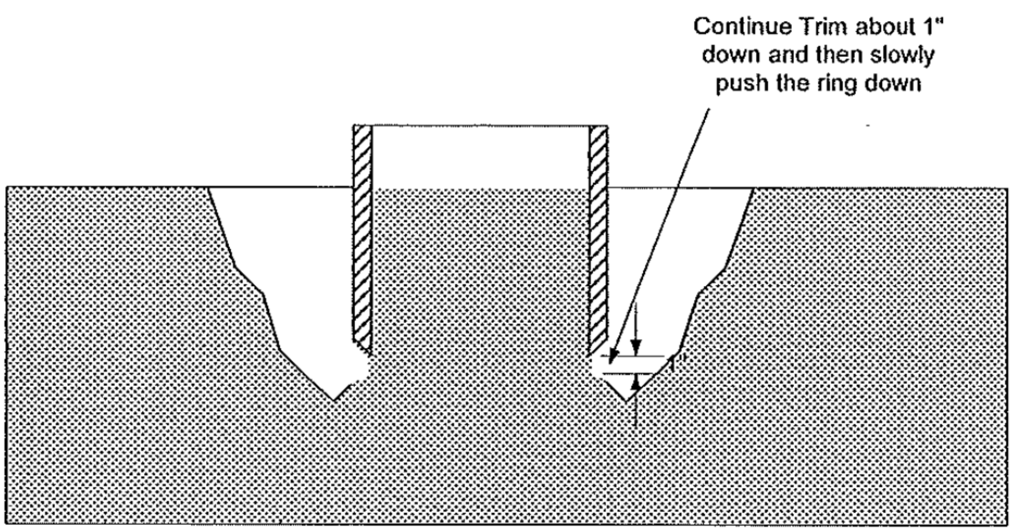


Figure 4.

Note: Steps 3 and 4 may be combined into a single alternate step whereby the trimming process may be eliminated and instead the ring may be carefully pushed to its full depth in one step to yield the configuration shown below. (Fig. 5)

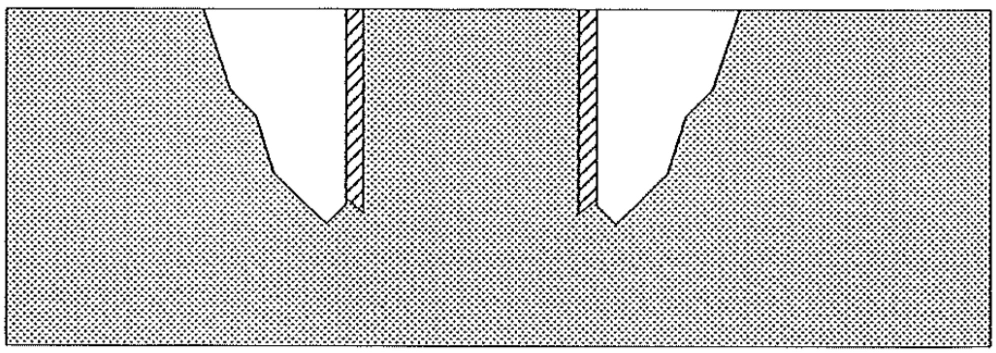


Figure 5.

Step 5. Put 2 layers of plastic sheet on top of the sample ring, and then use duct tape to wrap it around the ring. (Fig. 6)

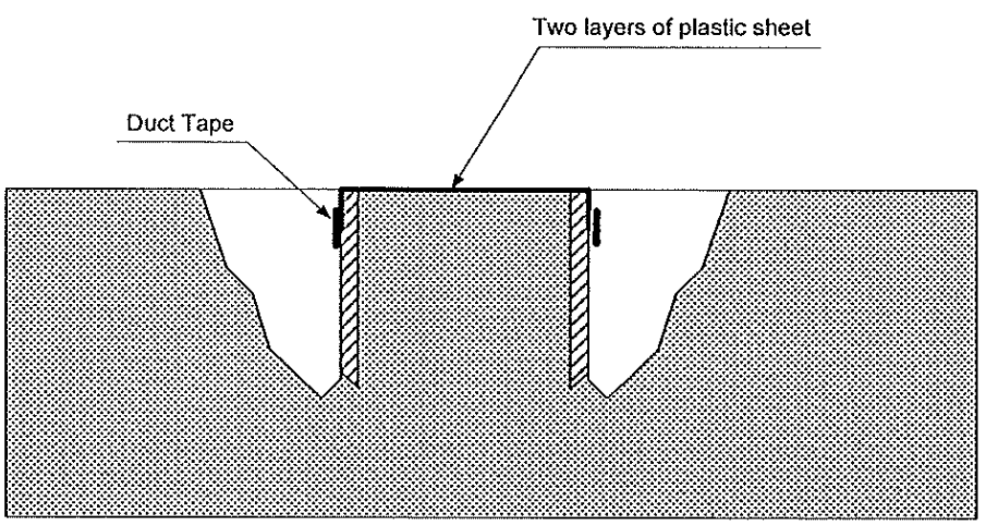


Figure 6.

Step 6. Use a shovel dig soil at the bottom of the ring for whole around sample ring.

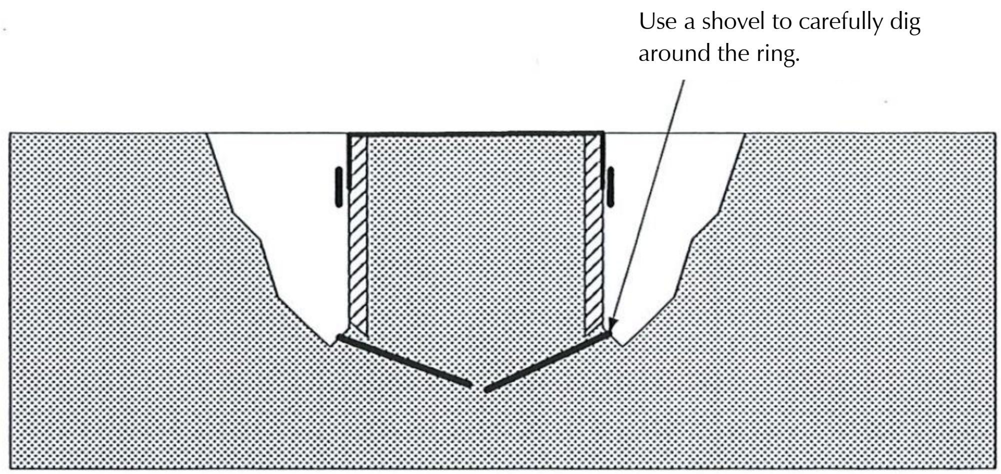


Figure 7.

Step 7. Carefully move the sample ring with soil out of the pit, flip over and carefully trim soil at the bottom end.

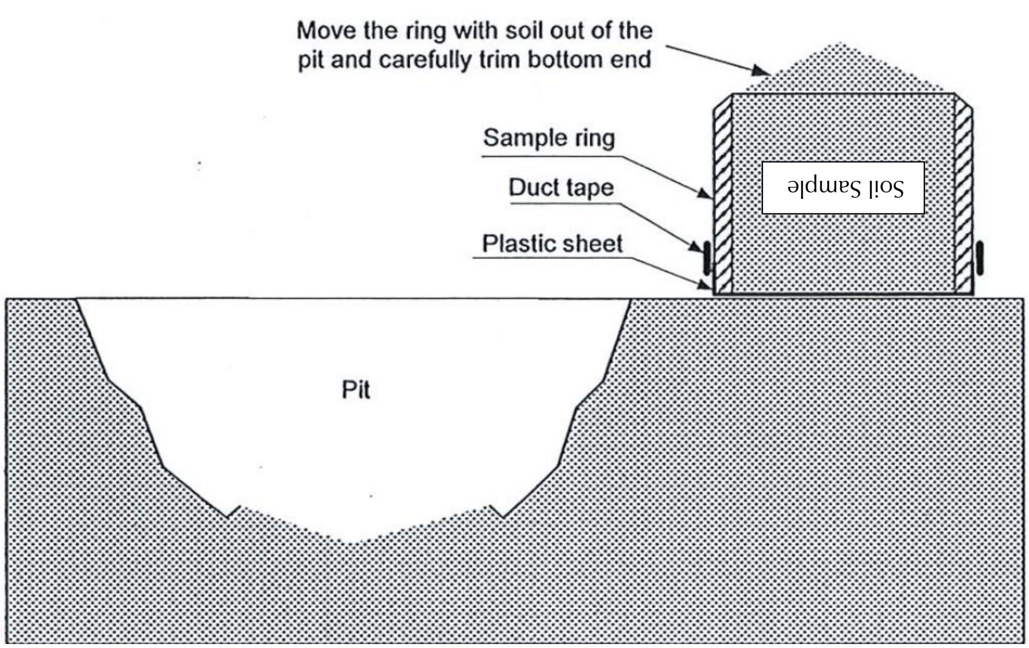


Figure 8.

Step 8. Put 2 layers of plastic sheet on to the sample ring, and then use duct tape and wrap it around the ring. (Fig. 9)

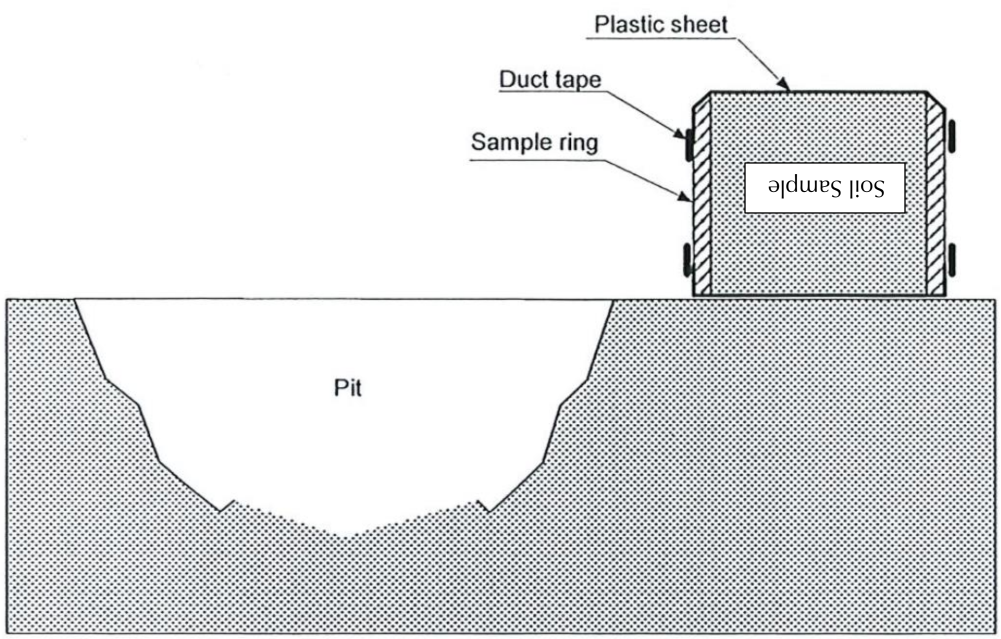
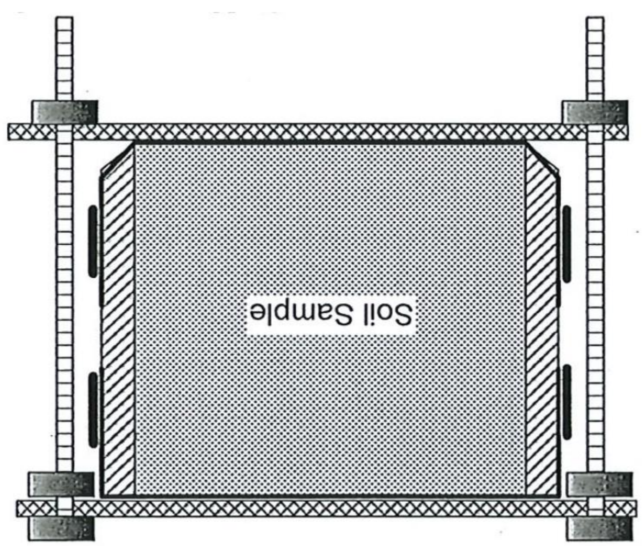


Figure 9.

Step 9. Finally pack and bolt the sample ring between two boards (see below), or using other packing methods, to keep the sample secure and protected for shipping.



APPENDIX B

HDPE TESTING METHODS

B. HDPE TESTING METHODS

HDPE testing methods are outlined in the following table.

PROPERTIES	TEST METHOD
Thickness	ASTM D5199
Carbon Black Present	ASTM D1630
Carbon Black Dispersion	ASTM D5596
Density	ASTM D792 Method A or ASTM D1505
Tensile Properties	ASTM D6693
Tear Resistance	ASTM D1004
Puncture Resistance	ASTM D4833
Stress Crack Resistance	ASTM D5397
Oxidative Induction Time	ASTM D3895
Oven Aging at 85°C	ASTM D5885
Standard OIT - % retained after 90 days, -or- High Pressure OIT - % retained after 90 days	ASTM D5721 ASTM D5885
GEOMEMBRANE SEAM PROPERTIES	
Shear and Peel Strength Properties	ASTM D6392
Pressure Air Channel Evaluation	ASTM D5820
Vacuum Testing	ASTM D5641

APPENDIX C

GEOSYNTHETIC CLAY LINER TESTING METHODS

C. GEOSYNTHETIC CLAY LINER TESTING METHODS

Geosynthetic Clay Liner testing methods are outlined in the following table.

Description	Method
Bentonite Mass Per Unit Area	ASTM D5993
GCL Index Flux	ASTM D5887
Bentonite Swell Index	ASTM D5890
Bentonite Fluid Loss	ASTM D5891

APPENDIX D

GEOTEXTILE FILTER FABRIC TESTING METHODS

D. GEOTEXTILE FILTER FABRIC TESTING METHODS

Geotextile filter fabric testing methods are outlined in the following table.

Description	Method
Mass Per Unit Area	ASTM D5261
Grab Tensile Strength	ASTM D4632
Puncture Resistance	ASTM D4833
Permittivity	ASTM D4491
Apparent Opening Size	ASTM D4751

6.7

Leachate Recycling Standard Operating Procedures

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Tables

1.0 Introduction

In 1993, the Safety-Kleen (Lone and Grassy Mountain), Inc. (SKI) Lone Mountain Facility began discussions with the EPA and ODEQ concerning the recycling of leachate as dust suppression water within the active landfills. In an interoffice memorandum dated May 23, 1996, EPA concluded that the leachate recycling activity was allowed under the RCRA statutes and regulations. Currently, the Lone Mountain Facility is permitted under and operated by Clean Harbors Environmental Services Inc. On April 16, 1999, the Lone Mountain Facility proposed numerical constituent concentration limits to the ODEQ above which the recycling efforts would cease. On May 20, 1999, the ODEQ approved the proposed limits, which have been incorporated into this SOP in Section 2.0.

This SOP outlines the operational requirements to be followed when using leachate for dust suppression water in the open landfill from which the leachate was originally generated.

2.0 Recycling Constituent Concentration Standards

To provide timely detection of a constituent increase and to observe trends, the Lone Mountain Facility will analyze weighted composite leachate samples monthly for the constituents in the following table. As an alternative to composite samples, individual quadrant or subcell samples may be analyzed.

The numerical standards in the table represent the maximum concentrations of constituents in leachate which can be recycled. Once the concentration of a constituent in leachate exceeds any one of the numerical standards, the leachate from that cell, or subcell, or quadrant could no longer be recycled and would be managed as hazardous waste (i.e., F039) at either an on-site or off-site treatment, storage, and/or disposal facility until such time as all the constituents are equal to or below the numerical limits.

Table 1
Leachate Constituent Recycling Limits

Constituent	Recycling Limits
TOC	15,500 mg/L
TOX	25 mg/L
Arsenic	5.0 mg/L (TCLP)
Barium	1.0 mg/L (TCLP)
Cadmium	1.0 mg/L (TCLP)
Chromium	1.5 mg/L (TCLP)
Lead	1.0 mg/L (TCLP)
Nickle	30 mg/L (TCLP)
Selenium	5.0 mg/L (TCLP)
Silver	1.0 mg/L (TCLP)

TOC = Total Organic Carbon
TOX = Total Organic Halogens

3.0 Leachate Management Plan

The Lone Mountain Facility will utilize the recyclable leachate requirements in this section to ensure the proper management of leachate when used as dust suppression water in the open landfill from which the leachate originated.

3.1 Storage and Accumulation

To ensure conformance with ODEQ interpretations, recyclable leachate will remain in the cell and be used soon after its collection as dust suppression water within the landfill from which it originated. Therefore, no land disposal restriction (LDR) placement, storage, or accumulation requirements are applicable.

3.2 Methods of Collection and Application

Leachate is typically collected in a tanker-type highway truck. For recycling purposes, an off-road, non-highway type water wagon may also be employed. The truck will be located within the open landfill before pumping begins. After collection of the leachate, the truck will move around the landfill for application of the leachate water to the surface of the waste in the landfill. Alternately, the truck may transfer the leachate (within the cell) to another truck more appropriate for landfill travel.

To ensure appropriate application of the leachate, the Lone Mountain Facility will not apply leachate during high wind conditions (e.g., >25 mph) or when the surface of the landfill is already adequately wetted. The recycling activity can only be performed when there is a bona fide need to control the potential for dust emissions.

The application of leachate will likely be in a manner identical or very similar to that currently employed for clean dust control suppression water, which can best be described as sprayed or sprinkled. Slight modifications to the orientation, aperture size, pressure, etc. of the spray system may occur to further minimize the effect of wind. In these regards, the application equipment would be located closer to the landfill surface, produce larger size droplets of leachate, and be operated at a lower pressure. Using these factors will all serve the purpose to reduce the potential effects of wind dispersal of leachate from the landfill.

Leachate will not be applied in close proximity to the cell edge, especially in the downwind direction when the cell is level-full or in the mound-building phase. Prior to being level-full, the effect of the wind is of much less concern. Even after the cell is level-full or in the mound building phase, the run-off control ditches around the perimeter of the cell will prevent the water trucks from operating too close to the cell edge.

To ensure that leachate is not accidentally applied to the facility roadways, wither a truck will be dedicated to leachate collection and recycling or the RCRA-empty tank truck will be decontaminated with one load of clean water. This load of clean water will also be applied to the surface of the open landfill. Once the tank truck has been decontaminated in this manner, it may be filled with clean water for dust suppression on the facility roadways.

Another alternative application method is to pump leachate directly into a sprinkler type system within the cell. The system would be equipped to produce relatively large size droplets and be located close to the landfill surface to reduce potential wind dispersal. This system would also be placed a safe distance from the cell edge.

7.1

Organic Air Emissions Standards

Table of Contents

1.0 Subpart AA

Process Vents. As noted in the Waste Analysis Plan, the 40 CFR Part 264, Subpart AA regulations appear to apply to the Wastewater Treatment System because: 1) it manages waste containing greater than 10 ppmw total volatile organic compounds (VOCs) as determined by SW-846 Methods 8260 and 8270, 2) the U.S. EPA Region 6 believes that an evaporator meets the definition of a distillation unit, and 3) the evaporators have associated process vents.

As noted in the Waste Analysis Plan, the Lone Mountain Facility will ensure that the volatile organic compound emissions from the evaporator vents associated with the Wastewater Treatment System do not exceed 3.0 pounds/hour and 3.1 tons/year.

As noted in the Waste Analysis Plan, records are kept which identify the process vents, the annual throughput and operating hours of the affected units, and the calculated emission rates for the process vents. The calculated emission rates are performed in accordance with the Waste Analysis Plan and the conditions established by the DEQ.

2.0 Subpart BB

Equipment Leaks. As noted in the Waste Analysis Plan, the 40 CFR Part 264, Subpart BB requirements could potentially apply to the Wastewater Treatment System and to the management of hazardous waste fuels. Each of these is described further below.

Wastewater Treatment System. Influent hazardous wastes to the Wastewater Treatment System are limited to less than ten percent (<10%) total organic carbon (TOC), and up-to-date analyses and/or the supporting information to ensure that the Wastewater Treatment System is not subject to the 40 CFR Part 264, Subpart BB requirements is recorded in the facility operating record.

Hazardous Waste Fuels. Hazardous Waste fuels may be managed in two (2) tanks – Tanks D1 and D2 if constructed. Should other permitted storage tanks for the management of hazardous waste fuels be constructed, the requirements of the Waste Analysis Plan and this section will also apply to the tanks,

Because these tanks store hazardous waste fuels, the waste is automatically assumed to contain >10% TOC and be in light liquid service. The equipment associated with Tanks D1 and D2 and any future tanks will be marked in such a manner that it can be readily distinguished from other pieces of equipment. The recordkeeping requirements of 40 CFR 264.1064 will be maintained in the facility operating record as noted.

3.0 Subpart CC

Tanks and Containers. As noted in the Waste Analysis Plan and in accordance with 40 CFR 264.1084, at this time the VOC concentration of hazardous waste is accepted at the Lone Mountain Facility for storage in tanks will be less than five hundred parts per million by weight (<500ppmw), unless the tank is fully-equipped with emissions controls or is subject to an exemption as stated in the regulation (e.g., meets organic LDR standards, etc.). Up-to-date analyses and/or the supporting information will be recorded in the facility operating record to document that the hazardous waste which enters tanks contains <500 ppmw VOCs or is exempt.

The same limitations and exemptions apply to management of waste in containers, with some additional exemptions (e.g., container has capacity <0.1 m^3, etc.). As noted in the Waste Analysis Plan and in accordance with 40 CFR 264.1086, hazardous waste which contains > 500 ppmw VOCs may also be accepted at the Lone Mountain Facility for storage in containers. These hazardous wastes will be managed by direct landfill or shipment off-site, if the waste does not qualify for an exemption. Up-to-date analyses and/or supporting information will be recorded to document the VOC concentration of waste received in containers.