APPENDIX A
DESIGN EXAMPLE

A-1. Introduction

The following fictional case study example illustrates the planning and design procedures presented in this manual. This example involves Fort Swampy, a U.S. Army Forces Command (FORSCOM) installation which also trains National Guard units. The installation is located in a region with annual precipitation level of 63 inches (1.6 meters), and a 1-hr., 10-yr design storm of 2 inches (5.1 centimeters) intensity. The evaporation rate at the installation is 68 inches (1.7 meters) per year. The soil in the training areas contains some expansive, cohesive clays that will be a problem to remove from vehicles during the rainy periods throughout the year. Freezing temperatures are not expected at the installation. The prevailing winds are from the west-northwest.

A-2. Master planning consderations

a. Training schedule. Two major training activities were scheduled at Fort Swampy last year, with the same number of major exercises expected to continue in the future. The installation requires vehicle washing all year. Table A-I lists all of the troop units on-post by motor pool assignment. During a major exercise, the installation sends all working vehicles to the field. Range Control reports that it takes from 2 to 4 days to recall all of the vehicles from the field. Daily training activities consist of three or four company teams going to and returning from the field. Each company team consists of approximately 8 tracked vehicles and 30 wheeled vehicles. The National Guard units perform both monthly and annual training activities at the installation. The installation has provided the planner with a summary of the estimated number and types of N. 0. vehicles returning from the training field on a monthly basis. This information is listed in table A-2 and graphically in figure A-l to show the distribution of vehicles used throughout the training year.

b. Number and types of vehicles.

(1) *Regular Army.* Table A-1 shows the vehicle types by motor pool. Several units are in each motor pool. A major training exercise assumes that every unit in every motor pool goes out to the field. Skirted vehicles, such as the M-l tank, are more difficult to clean since dirt can collect under the skirt. Fort Swampy currently has 85 M-l tanks, and more are expected to be acquired in the future. Seventy-nine percent of the vehicles are wheeled.

(2) *National Guard units.*

(a) The following vehicles will return after the monthly National Guard training events:

31 light track	146 light wheel
26 heavy track (no M-ls)	58 heavy wheel
57 total tracked vehicles	204 total wheeled vehicles

(b) Seventy-eight percent of the total number of vehicles to be washed at the CVWF are wheeled.

(c) Washing requirements. The Regular Army at Fort Swampy requires that all vehicles be washed as they return from field exercises. The installation requires that vehicles returning from major field exercises be washed within a period of 54 hours. Vehicles returning from routine, daily training activities must be washed within a period of 3 hours. The National Guard requires its vehicles to be washed within 8 hours of completing field exercises. Both the installation and the National Guard have indicated some flexibility with these washing times. Night time washing operations must be provided to meet the installation's requirements; therefore, lighting will be provided in the preparation, bath, wash station, and vehicle assembly areas. Vehicle interior washing capabilities are also required by the installation. Since the vehicles are returned to the motor pools for maintenance inspections, they must receive a detailed washing.

d. Vehicle soiling. Soil samples taken from the training areas, as well as off dirty vehicles, have been tested in a soils laboratory. A grain size analysis (dispersed) was made as described in chapter 3. Results indicated a composition of 14 percent sand, 54 percent silt, and 32 percent clay. From the soil classification diagram (fig 3-3), the soil is a silty clay with a soil type number (S_i) of 4. Based on the amount of rain received annually at the installation and the fact that the rainy season is also a training season, the climatic factor was chosen as 2.0. From equation 3-1, the soiling index (S_i) is calculated to be 8, which indicates heavy soiling conditions and thus potentially longer washing times using standard means. A nondispersed particle size analysis was also made by the laboratory which indicated that 50 percent of the

Table A—1. Number of vehicle types by motor pool assignment

Unit names by motorpool	Heavy track	Light track	Heavy wheel	Light wheel	Nonstandard and trailers
HHC Infantry	2	6	5	11	4
Infantry	85	11	49	18	2
Armor	74	7	53	12	7
HHB Divarty		1	11	17	
Field Artillery	14	26	41	27	2
Field Artillery, FC	16	19	57	31	2
Field Artillery	10	24	41	29	2
HHC Division Support Cmd		7	11	5	
Maintenance BN			118	50	9
Supply and Transport EN			101	25	17
NBC BN (Provisional)			27	39	1
Infantry	3	1	5	24	2
Medical BN			62	47	1
Engineer BN	6		39	36	5
Engineer BN	10		42	11	20
Maintenance Company	1		29	2	5
Maintenance Company	1		37	9	5
Ordnance Company			25	6	4
supply & Support Co			25	7	6
Supply Company			21	6	6
HHD, TVans BN			1	6	3
Military Police EN			5	72	2
Air Defense Artillery	18	2	39	101	3
Cavalry	94	5	32	25	2

Table A-1. Number of vehicle types, by motor pool assignment—continued

Engineer BK	82	5	53	64	9
Engineer BK			49	2	8
Signal BK			38	131	
MIEN	14	1	25	47	4
Air BK			42	28	
TOTAL					
Total Tracked	538				
Total Wheeled	1973				

Table A-2. Number of vehicles returning from the field each month.

Month	Total tracked	Total wheeled
Jan	253	233
Feb	354	467
Mar	456	343
Apr	753	958
May	872	1089
Jun	768	1125
Jul	1198	1299
Aug	1227	1698
Sep	865	944
Oct	723	834
Nov	321	232
Dec	194	176
Avg per		
month	665	783

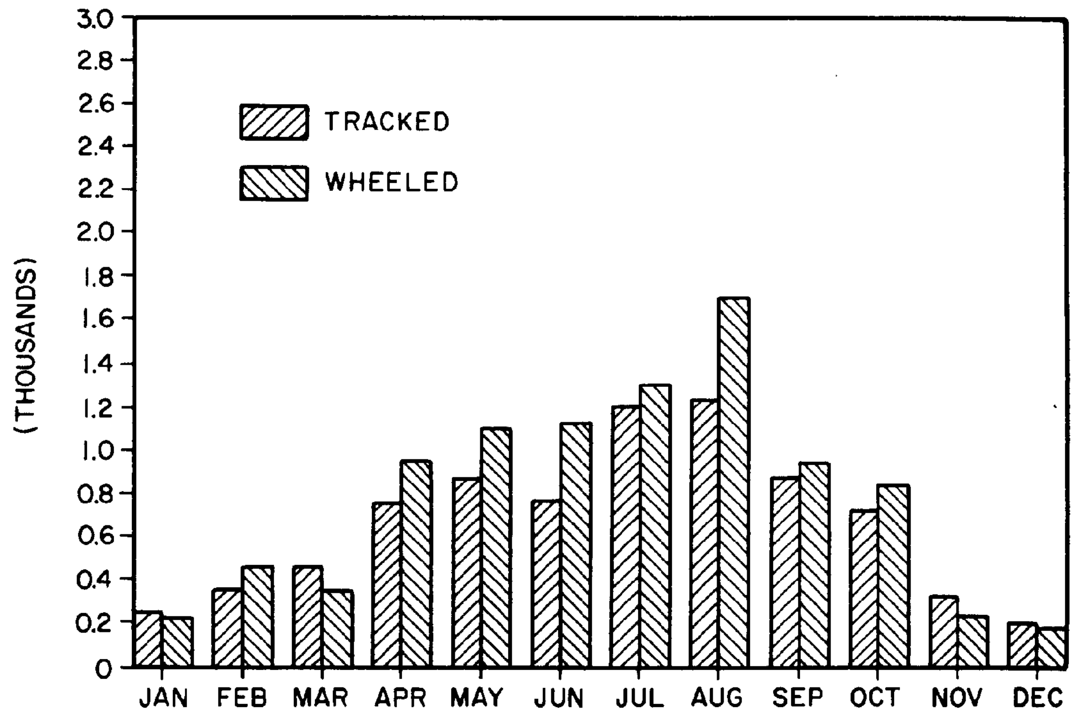


Figure A–1 Vehicles returning from the training areas each month.

particles were larger than 0.05 mm, 80 percent of the particles were larger than 0.02 mm, 90 percent of the particles were larger than 0.01 mm, and 97 percent of the particles were larger than 0.005 mm.

e. Installation requirements.

(1) *Prewash.* A bath prewash is indicated at Fort Swampy because cohesive soil found in the training areas, combined with the limited washing period, require the type of prewashing best served by a bath facility. To achieve the desired soaking action on the skirted M- 1 tanks for gross soil removal, the depth of water in the bath should be adjustable up to 3.5 feet (1.1 meters).

(2) *Wash stations.* The wash stations will be the standard design described in chapter 4. Interior wash equipment will be included. Since tracked vehicles will also be using the wash stations, each island must be protected by concrete barriers and all pavement in the CVWF must be constructed of concrete.

(3) *Preparation area.* Since the CVWF will have a bath, two preparation areas are required. The first area will be located before the bath to allow troops to prepare the vehicles for washing and to queue-up behind the bath lane. The second preparation area will be between the bath exit and the entrance to the wash stations, this is a queuing area for vehicles that have left the bath or have bypassed the bath.

(4) *Waste washwater treatment.* Fort Swampy purchases potable water from a local water district at a current price of$ 1 per 1000 gallons (3785 liters). The existing wastewater treatment system at the installation does not have the capacity to treat the large hydraulic and solids loadings expected from the CVWF. In addition, the State will not allow discharge to the environment. Therefore, a total recycle system is required. Due to the high clay content of soils in the training area, laboratory settling tests have indicated extremely long detention times should be required for a lagoon treatment, therefore a sand filter system was chosen as the form of secondary treatment

(5) *Makeup water.* Sources have been investigated and the only reliable, environmentally acceptable source of makeup water is the potable water system. The potable water supply

is limited to 3 million gallons (11.36 million liters) per day. Daily water usage at the installation is 2 million gallons (7.57 million liters) per day, with 1 million gallons (3.79 million liters) reserved for firefighting. No water is available for expansion of facilities. However, it is estimated that the motor pools now use 0.13 to 0.20 million gallons (0.49 to 0.76 million liters) of water per day to wash vehicles. Part of this volume of conserved water can be used as makeup water for the new CVWF.

f. Sizing.

(1) *Bathprewash.* The designer estimates that the processing rate through the bath will be 6 vehicles per hour per tracked vehicle lane and 11 vehicles per hour per dual-purpose lane. This decision was based on the soiling index computed for the site and the processing rates given in chapter 3 and illustrated on figure 3-4.

(a) Regular Army. The designer uses equations 3-2 and 3-3 from chapter 3 to determine how many tracked and dual-purpose lanes are needed for prewashing Regular Army vehicles. The tracked lanes will be used for most of the large tactical vehicles; therefore, dual-purpose lanes are estimated without including the tracked vehicles, as discussed in chapter 3. The installation has estimated that 80 percent of the tracked vehicles and 65 percent of the wheeled vehicles returning from the field will require immediate washing in the bath with the rest bypassing to the wash stations. It has been assumed that trailers and nonstandard vehicles, such as bulldozers and goers, will proceed directly to the wash stations. Other vehicles, such as ambulances and support vehicles, may not require immediate washing and will use the facility at a later time. Malfunctioning vehicles may be returned to the motor pool directly or may be left in the field until all other vehicles return. The designer has also considered vehicles in-tow such as tanks and trailers. Using the vehicle counts from table A-2, the number of tracked and dual-purpose lanes required for washing after a major training exercise are computed:

A. Number of tracked lanes: $\frac{0.80 \text{ x } (538 \text{ veh})}{6 \text{ veh/hr/lane x } (54 \text{ hr})}$ = = 1.33 lanes

B. Number of dual-purpose lanes: $\frac{0.65 \text{ x } (1973 \text{ veh})}{11 \text{ veh/hr/lane x } (54 \text{ hr})}$ = 2.16 lanes

Since the installation is flexible with respect to washing times, the designer rounds the number of lanes as described in chapter 3. One tracked lane and two dual-purpose lanes were recommended to accommodate the Regular Army's needs. Using the above information, the numbers of tracked and dual-purpose lanes required for washing after routine daily training exercises are computed:

C. Number of tracked lanes $\frac{0.80 \text{ x 8 veh/team x 4 teams}}{6 \text{ veh/hr/lane x 3 hr}}$ = 1.42 lanes

D. No. dual-purpose lanes $\frac{0.65 \text{ x 30 veh/team x 4 teams}}{11 \text{ veh/hr/lane x 3 hr}}$ = 2.36 lanes

It is apparent that the one tracked vehicle lane and the two dual-purpose lanes estimated above will meet the requirements for both major training exercises and routine daily training activities.

(b) National Guard. The same computation is used to compare the bath requirements for the National Guard units except that a high percentage of vehicles will use the bath because there are few support vehicles and all units are to be returned to the motor pool extremely clean. It is estimated that 90 percent of tracked vehicles and 75 percent of wheeled vehicles will use the bath prewash. Using information from above, the number of bath lanes required is computed:

E. No. tracked lanes $\frac{0.90 \text{ x 57 veh}}{6 \text{ veh/hr/lane x83 hr}}$ = 1.07 lanes
F. F.

F. No. dual-purpose lanes $\frac{0.75 \text{ x 204 veh}}{11 \text{ veh/hr/lane x 8 hr}}$ = 1.74 lanes

A comparison of the results shows that the one tracked lane and two dual-purpose lanes will satisfy both Regular Army and National Guard needs at the prewash facility. Designer realizes that light-tracked vehicles may be washed in the dual-purpose lanes.

(2) *Wash stations.* The clay content in the soils at the installation and the requirement that vehicles return to the motor pools well cleaned for inspection and maintenance after washing suggest that the processing time required for troops to do a detailed washing at the wash stations will be at the high end of the range. From the processing rates given in chapter 3 (fig 3-4) and the soiling index (S_i) previously computed, the designer has determined that 3.75 vehicles can be processed per hour in each wash station following the prewash. For the tracked vehicles not using the prewash, a processing rate of 1.75 vehicles per hour is selected; and for wheeled vehicles not using the prewash, a processing rate of 5 vehicles per hour is selected. Compute the number of wash

lanes required after a major training exercise:

G. Tracks from bath:	$\frac{0.80 \times 538 \text{ veh}}{3.75 \text{ veh/hr/lane} \times 54 \text{ hr}}$	= 2.12
Tracks bypassing bath:	$\frac{0.20 \times 538 \text{ veh}}{1.75 \text{ veh/hr/lane} \times 54 \text{ hr}}$	= 1.14
Wheeled from bath:	$\frac{0.65 \times 1973 \text{ veh}}{3.75 \text{ veh/hr/lane} \times 54 \text{ hr}}$	= 6.33
Wheeled bypassing bath:	$\frac{0.35 \times 1973 \text{ veh}}{5 \text{ veh/hr/lane} \times 54 \text{ hr}}$	= 2.56
	Total Wash Lanes	= 12.15 lanes

The number of lanes required to meet the daily training exercise is computed:

H. Tracks from bath:	$\frac{0.80 \times 32 \text{ veh}}{3.75 \text{ veh/hr/lane} \times 3 \text{ hr}}$	= 2.28
Tracks bypassing bath:	$\frac{0.20 \times 32 \text{ veh}}{1.75 \text{ veh/hr/lane} \times 3 \text{ hr}}$	= 1.22
Wheeled from bath:	$\frac{0.65 \times 120 \text{ veh}}{3.75 \text{ veh/hr/lane} \times 3 \text{ hr}}$	= 6.93
Wheeled bypassing bath:	$\frac{0.35 \times 120 \text{ veh}}{5 \text{ veh/hr/lane} \times 3 \text{ hr}}$	= 2.80
	Total Wash Lanes	= 13.23 lanes

Requirements for the Regular Army exceed those for the National Guard and because the installation is flexible in regard to wash times, the designer selects 12 wash stations.

g. Site selection.

(1) *Geography.* The site selected over several possibilities is adjacent to the only main route, Range Road, that the vehicles will travel as they return to the cantonment area from the training fields.

(2) *Geology.* The site has 45 feet (13.7 meters) of relief over a 25-acre (0.10-square kilometer) area. The site is on the top of a ridge that is approximately 200 feet (61 .0 meters) wide and 700 feet (213.4 meters) long. Site borings have shown that the water table will not interfere with construction or operation of the CVWF. The site has never been used for any purpose. Engineers have determined that if work to lengthen or widen the ridge is to be done at the site, it will raise construction costs considerably due to the location of the bedrock. Figure A-2 shows a topographic map of the site.

(3) *Utilities.* All required utilities are within a reasonable distance to the proposed site. A 10 inch (25.4-centimeter) potable water line runs parallel to Range Road. Electrical and telephone lines also run parallel to this road. The latrines can be tied into the sanitary sewer lines which are within 0.75 miles (1.2 kilometers) of the site. As long as wastewater from the facility is recycled, the added load from the CVWF is not expected to burden any of the existing sewer lines.

A-3. Engineering and design

a. Bath design. Figure A-3 shows the bath arrangement for the new Fort Swampy CVWF consisting of one tracked lane and two dual purpose lanes. Dimensions are taken from the definitive drawings and entrance and exit slopes are selected as shown. Overall length is computed using these slopes.

(1) *Water cannons.* The flow rate from the water cannons in all lanes is selected as 80 gallons per minute (gpm) (303 liters per minute). The delivered pressure selected is 100 pounds per square inch (psi) (6.8 atmospheres). These are the maximum flow rate and pressure values recommended and are chosen because the soil consists of clays which are not easily removed.

(2) *Flexors.* Flexors in the dual-purpose lane should be exposed 4 inches (10.1 centimeters) with a center-to-center spacing of 17 inches (43.2 centimeters), since about the same number of light- and heavy-wheeled vehicles are expected to use the bath. The tracked lane should have flexors exposed 10 inches (25.4 centimeters) and spaced 5.5 feet (1.7 meters) o.c. because the primary user will be heavy tracked vehicles.

(3) *Entrance ramp.* Because Fort Swampy does not have freezing weather, the maximum slope on the entrance ramp, 1 in 7, can be used. This design will give a projected ramp length of 24.5 feet (7.5 meters).

(4) *Exit ramp.* The maximum slope of 1 in 11 can be used for the exit ramp. With this slope, the projected ramp length is 38.5 feet (11.7 meters).

b. Wash station design. The flow rate selected per hose is 30 gpm (114 liters per minute) at 90 psi (6.1 atmospheres) pressure. These are the maximum flow rate and pressure values recommended and were chosen because the soil consists of clays which are not easily removed. Interior washing points, which are low-pressure, low-flow outlets consisting of yard hydrant and utility hose will be placed at each island. The limited area for construction on the natural ridge will dictate the configuration of the wash station area. Two configurations, A and B, are evaluated.

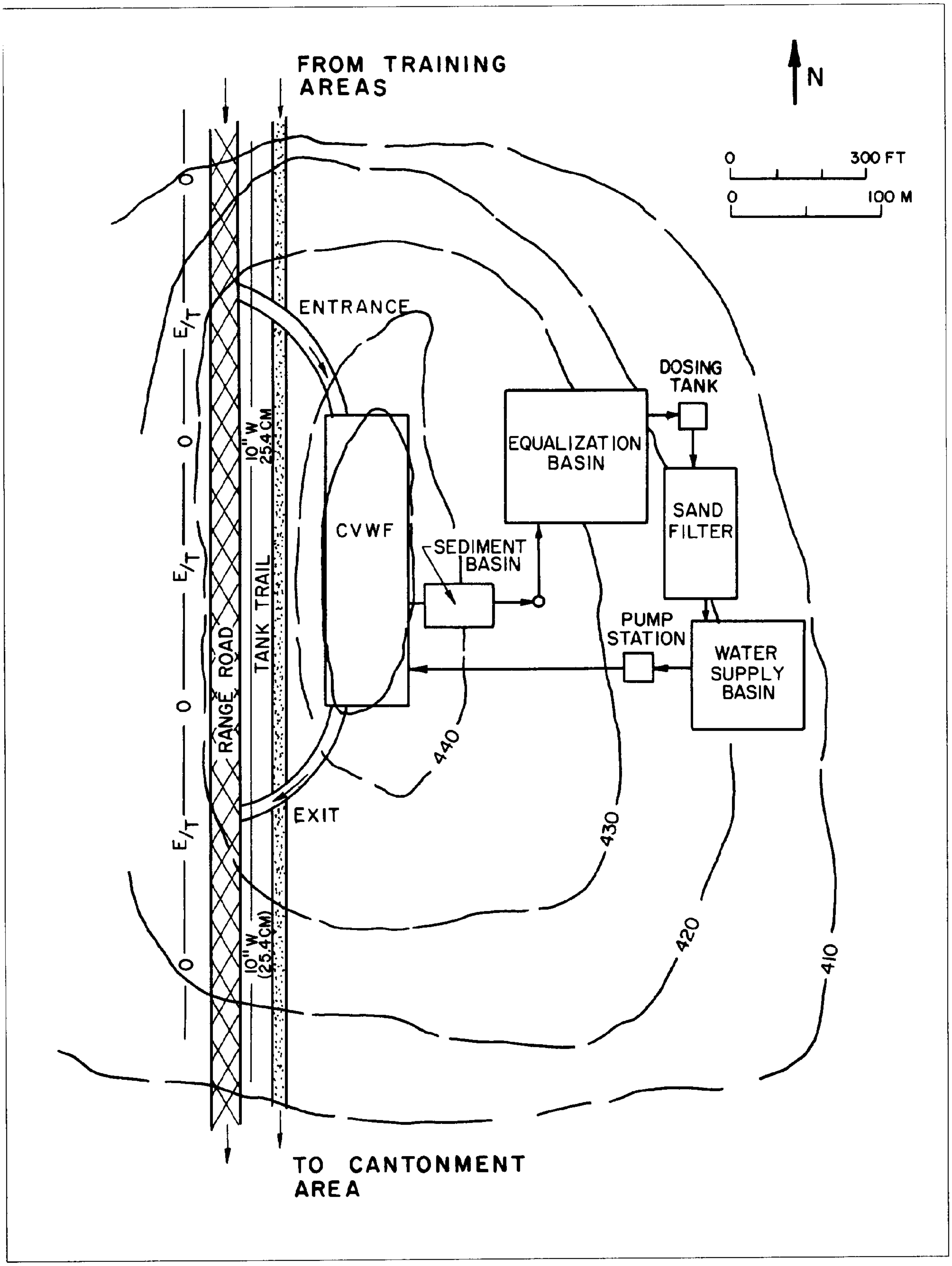


Figure A–2. Site map with a proposed layout—Fort Swampy.

(1) *Configuration A.* With the 12 stations placed in a linear fashion perpendicular to traffic flow and a standard center-to-center spacing of 25 feet (7.6 meters), the total width of the wash station would be 300 feet (91.2 meters) (fig A-4). Adding the width of the bypass lane, 22 feet (6.7 meters), yields a facility width of 322 feet (97.9 meters), which is too wide to be constructed on this narrow ridge.

(2) *Configuration B.* This configuration would place the islands in two parallel rows, with a queuing area down the center of the rows and two bypass lanes on the outside of the stations (fig A-5). Half-islands are placed at the ends of each row. The islands would be placed at a 60 degree skew to the normal flow of traffic. This layout would require more area to be cleared and paved, but the facility width would be no more than 180 feet (54.9 meters), which is less than the constraint imposed by the ridge. The designer chooses configuration B as the best alternative after performing a cost comparison.

c. *Vehicle preparation areas.* The installation has stated that three vehicles queuing to enter each bath lane should be sufficient. Other vehicles waiting to use the facility can queu-up along Range Road adjacent to the wash facility. If traffic problems occur, Range Control will coordinate the number of vehicles leaving the training areas with the wash facility activities.

(1) The entrance vehicle preparation area should provide enough room for three vehicles per lane to wait to be washed in the bath. The longest tracked vehicle to use the facility is the M-l tank, which is some 32 feet (9.8 meters) long. The longest wheeled vehicle is the M-978 Tanker Truck at 33 feet (10 meters). At least 52 feet (12.8 meters) per vehicle should be allowed (10 feet (3.lm) clear on each end). Therefore, the preparation area should be at least 156 feet (47.5 meters) long. An additional 20 percent or 30 feet (9.0 meters) of entrance staging is added yielding a total length of 165 feet (50.3 meters).

(2) The preparation area between the bath and the wash stations should be at least two vehicle lengths, rounded to 60 feet (18.2 meters) with all other factors considered. The assembly area after the wash stations should also allow for two vehicles, again rounded to 60 feet (18.2 meters).

(3) The aisle space between the two rows of islands should be at least 75 feet (22.9 meters) wide to allow the vehicles to maneuver and queue and the Exit lanes should be a minimum of 22 feet (6. 7m) wide. The exit vehicle assembly area will be the full width of the facility, 159 feet (48.5 meters). Figure A-S shows these dimensions.

d. *Sizing the treatment system.*

(1) *Water usage factor.* A bath system is to be installed. The soils on the vehicles will be partially cohesive, and not easily removed; therefore, a reasonably steady rate of vehicles is expected through the bath and the wash stations. The designer selects the following estimates for the various water usage factors, based on experience: U_1 = 1.0; U_2 = (bath full)

U_2 = 0.90; U_3 = 0.80; U_4 = 0.20; U_3 = 0.20; U_6 = 0.20; U_7 = 0.80; U_8 = 0.20

(2) *Cleanup time.* The cleanup time (K) is estimated to be 1 hour based on the 30 minutes it will take the operator to drain the bath (T_D) and an additional 30 minutes for troops to hose down the bath and staging areas. It is assumed that bath flushing and area clean-up will occur once per wash period.

(3) *Flow rate.* Using the parameters defined in chapter 6, the designer computes the various flow conditions.

(a) *Bath drain flow rate, Q_1:*

Refer to figure A–6.

Q_1 = (width x cross section) x 7.48 gpcf/drain time

Q_1 = (90 ft x 285sf) x 7.48/30 min

Q_1 = 6395 gpm (24207 Lpm)

(b) *Bath overflow, Q_2:*

Q_2 = Number of cannons x cannon discharge

Q_2 = N_{wc} x F_{wc}

Q_2 = 12 x 80 gpm

Q_2 = 960 gpm (3634 Lpm)

(c) *Wash station flow, Q_3:*

Q_3 = Number of wash station hoses x hose discharge

Q_3 = N_{st} x F_{st}

Q_3 = 24 x 30 gpm

Q_3 = 720 gpm (2725 Lpm)

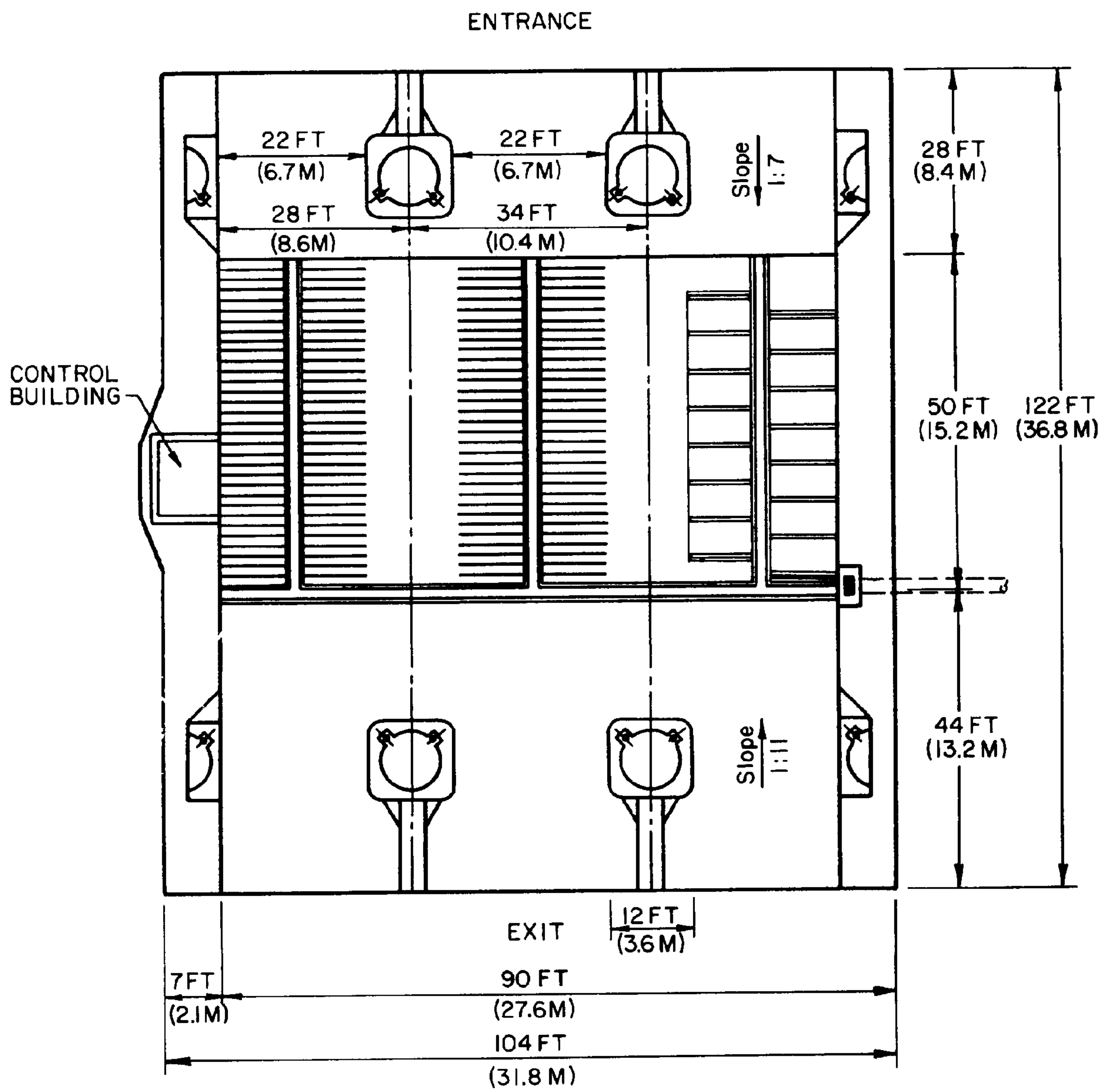


Figure A–3. Bath design.

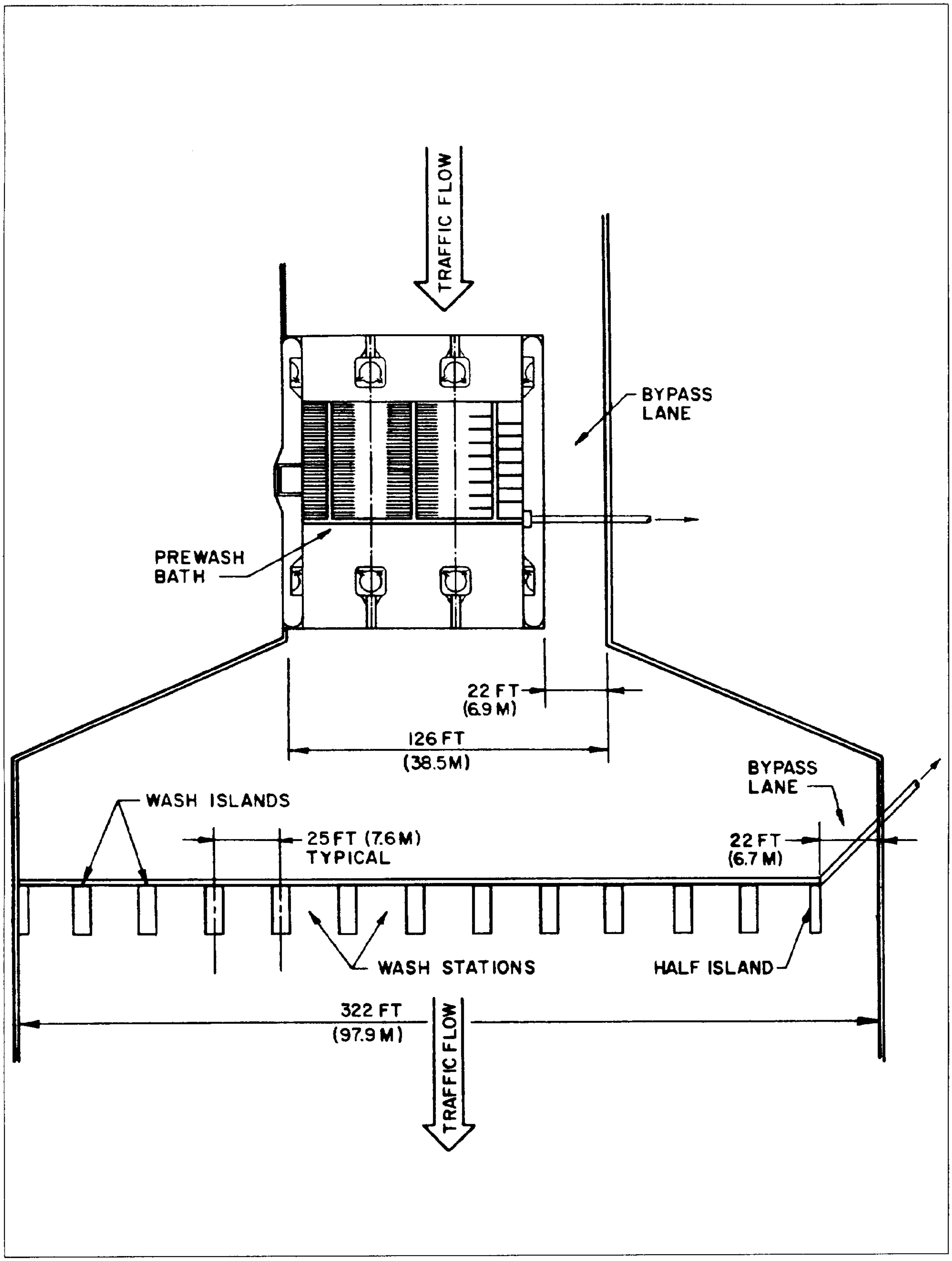


Figure A–4. Configuration A.

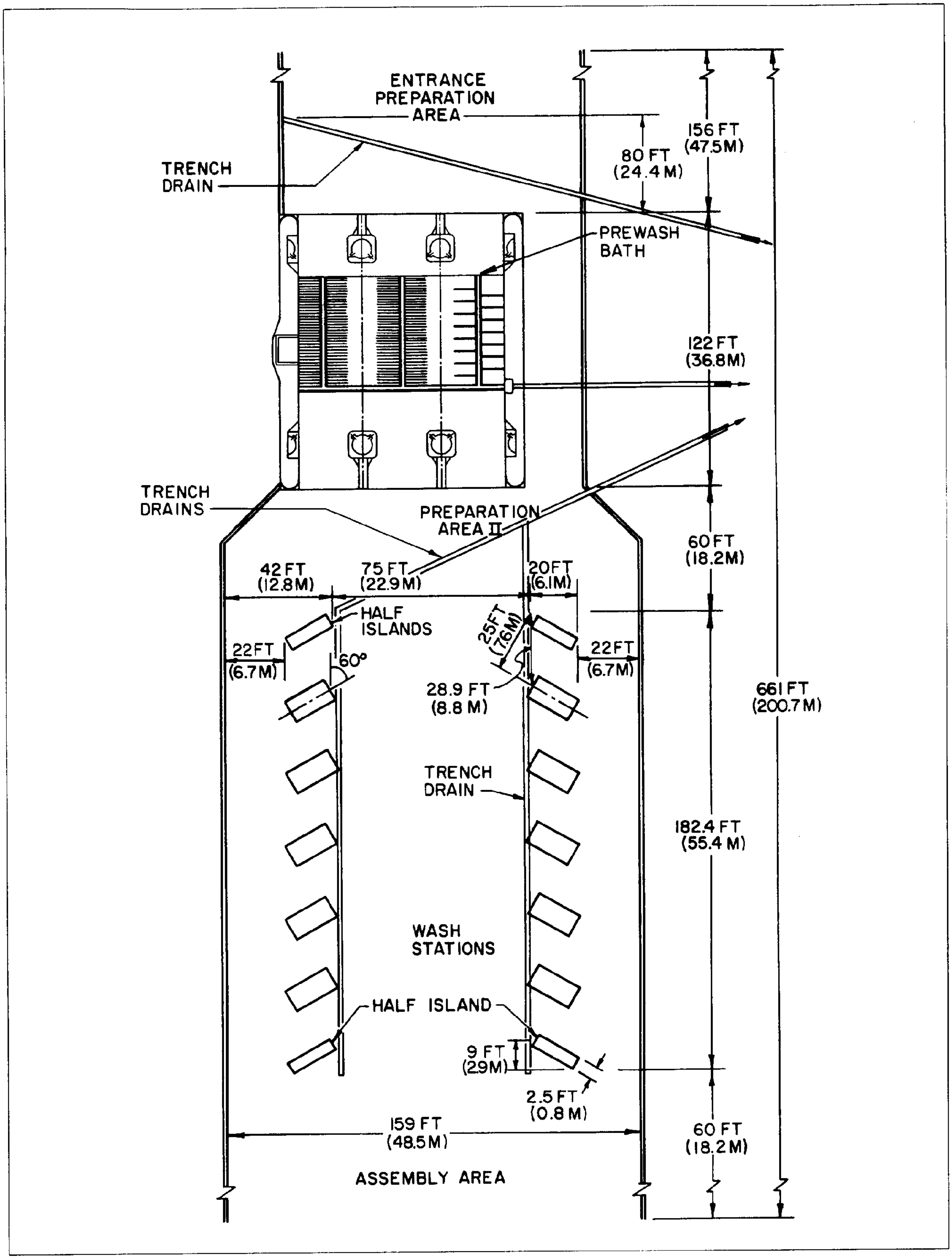


Figure A–5. Configuration B.

(d) Entrance area trench flush flow, Q_4

Q_4 = Number of flusher points x flusher discharge

$Q_4 = N_{tl} \times F_{tl}$

Q_4 = 1 x 75 gpm

Q_4 = 75 gpm (284 Lpm)

(e) Bath flush flow, Q_5:

Q_5 = Number of flush points x flusher discharge

$Q_5 = N_{ud} \times F_{ud}$

Q_5 = 4 x 750 gpm

Q_5 = 3000 gpm (11355 Lpm)

(f) Wash station trench flushes flow, Q_6

Q_6 = Number of flush points x flusher discharge

$Q_6 = N_{tz} \times F_{tz}$

Q_6 = 3 x 75 gpm

Q_6 = 225 gpm (852 Lpm)

(g) Interior hydrant flow at wash stations, Q_7

A total of six duplex hose bibs are placed on alternating full islands to serve the 12 wash stations.

Q_7 = Number of interior washpoints x hose discharge

$Q_7 = N_{int} \times F_{int}$

Q_7 = 12 x 10 gpm

Q_7 = 120 gpm (454 Lpm)

(h) Clean-up yard hydrant flow, Q_8:

A total of six hydrants, strategically placed, are required to hose down the paved areas.

Q_8 = Number of hydrant hose connections x hydrant discharge

$Q_8 = N_y \times F_y$

Q_8 = 6 x 30 gpm

Q_8 = 180 gpm (681 Lpm)

(i) Storm runoff from paved wash facility, Q_9:

Use Rational Formula with runoff coefficient, C, of *0.95* and a rainfall intensity fora 1-hr., l.-yr storm of 2.0 inches. Then,

Q_9 = C x I x Length x width / 43560 gfpa

Q_9 = 0.95 x 2.0 x 580 ft. x 160 ft. 43560 gfpa

Q_9 = 4.05 cfs or 1818 gpm (6881 Lpm)

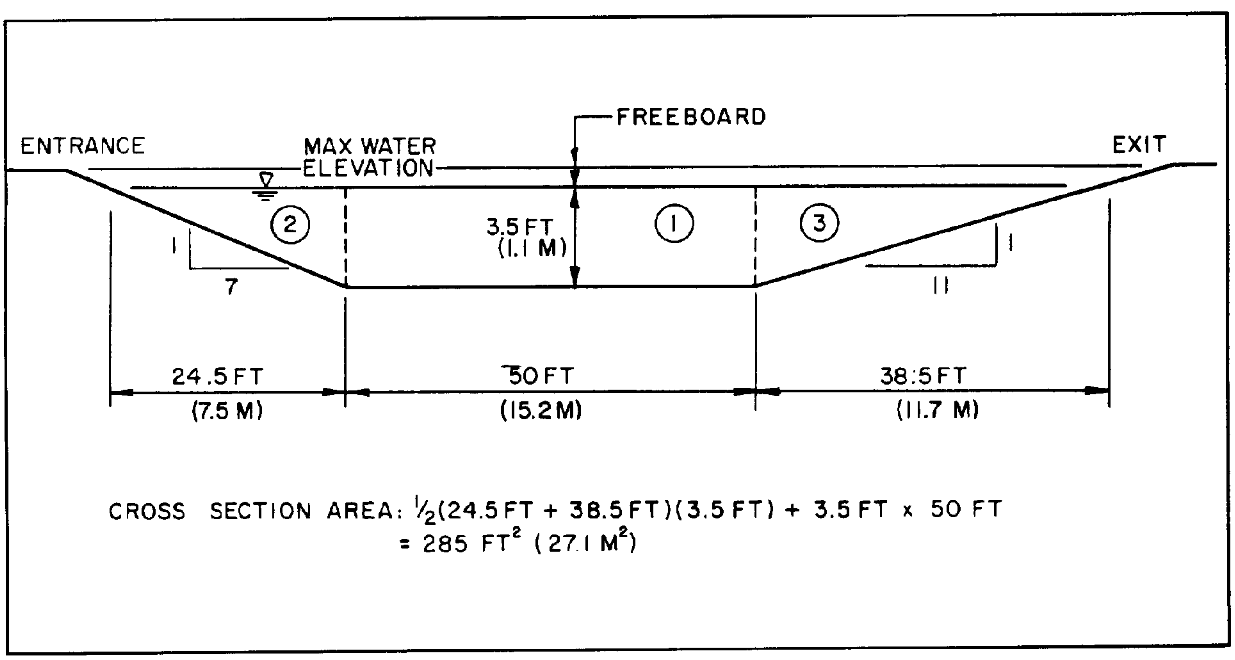


Figure A-6 Cross section of the bath.

(j) *Rainfall falling on open basins, Q_{10}*

1) Estimate surface area of dual-cell sediment basin

L x W x 2 = 150 ft x 50 ft x 2 = 15,000 sf

2) Estimate surface area of equalization basin

L x W = 300 ft x 300 ft - 90,000 sf

3) Estimate surface area of sand filters

L x W=300 ft x 150 ft = 45,000 sf

4) Estimate surface area of washwater supply basin

L x W = 300 ft x 300 ft = 90,000 sf

Then: Q_{10} = C x I x A_B/143560 sfpA

Q_{10} = 1.0 x 2.0 x 240,000 sf/ 43560 sfpA

Q^{10} = 11 cfs or 4937 gpm (18686 Lpm)

(k) *A summary of computed flows is presented in Table A-3.*

Overflow rate, Q_{over}:

Using equation 6-5, calculate the sediment basin overflow rate during the washing period. The designer assumes that the entrance preparation area trench flusher, represented by Q_4, and the bath flushers, represented by Q_5, are not in operation after the bath is filled and, therefore these values are not used in the calculation. Apply the appropriate usage factor at each flow source. Then,

Q_{over} = $U_2Q_2 + U_3Q_3 + U_6Q_6 + U_7Q_7$

Q_{over} = 0.90 (960 gpm) + 0.80 (720 gpm) + 0.20 (225 gpm) + 0.30)(120 gpm)

Q_{over} = 1581 gpm (5984 Lpm)

(4) *Volumes.* Using equations defined in chapter 6, the designer computes the various component volumes for the following selected average daily conditions:

Clean-up period, K	60 min
Daily wash period, T_w	180 min
Total Wash and clean -up T^2	240 min
Storm Duration, T_s	60 min

(a) *Earth volume drained, V_1:* Assume only one bath fill/flush per wash period.

Then, V_1 = Bath volume x Number of fills

V_1 = 90 ft x 285 sf x 7.48 gpcf x l fill

V_1 = 191862 gal (726198L)

(b) *Bath overflow volume, V_2:*

V_2 = Bath weir overflow rate x (wash period + clean up)

V_2 = Q_2 x T_w = 960 gpm x 240 min

V_2 = 230400 gal (872064L)

(c) *Wash station volume, V_3:*

V_3 = Wash station flow rate x wash period

V_3 = Q_3 x T_w = 720 gpm x 180 min

V_3 = 129600 gal (490536L)

(d) *Entrance trench flusher volume, V_4:*

V_4 = trench flush flow rate x cleanup period

V_4 = Q_4 x K = 75 gpm x 60 min

V_4 = 4500 gal (17032L)

(e) *Bath flusher volume,*

V_5 = bath flusher flow rate x cleanup period

V_5 Q_5 x k = 3000 gpm x 60 min

V_5 = l80000 gal (681300L)

(f) *Wash station trench flusher volume, V_6:*

V_6 = trench flusher flow rate x (wash period + clean-up)

V_6 = Q_6 x T_t = 225 gpm x 240 min

V_6 = 54000 gal (204390 L)

(g) *Interior wash water volume, V_7:*

V_7 = Interior wash flow rate x wash period

V_7 = Q_7 x T = l2 gpm x l80 min

V_7 = 21600 ga1 (81756L)

(h) *Clean-up yard hydrant volume, V_8:*

V_8 = yard hydrant flow rate x cleanup period

$V_8 = Q_8 \times K = 180$ gpm x 60 min

$V_8 = 10800$ gal (40878L)

(i) *Pavement runoff volume, V_9:*

V_9 = pavement runoff rate x storm duration

$V_9 = Q_9 \times T^5 = 1818$ gpm x 60 min

$V_9 = 109080$ gal (412868 L)

(J) *Rainfall volume added to basins, V_{10}:*

V_{10}= Rainfall rate x storm duration

$V_{10} = Q_{10} \times T_S = 4937$ gpm x 60 min

$V_{10} = 296220$ gal (1121193 L)

(k) *Summary of average daily volume.* Table A-4 summarizes the computed average daily volumes for the stated design conditions at Fort Swampy.

Total average daily volume for facility V_{avg}: The designer uses equation 6-2, however, designer chooses not to include pavement runoff volume, V_9 or rainfall volume on basins, V_{10} Designer also assumes that flush water will be withdrawn from the washwater supply basin and therefore, V_1, V_5, and V_6 are included in the computation. Then,

$$V_{avg} = U_1V_1+U_2V_2+U_3V_3+U_4V_4+U_5V_5+U_6V_6+U_7V_7+U_8V_8$$

$$V_{avg} = 1.0(191862) + 0.9(230400) + 0.8(129600) + 0.2(4500) + 0.2(180000) + 0.2(54000) + 0.8(21600) + 0.2(10800)$$

$$V_{avg} = 570042 \text{ gal } (2157609 \text{ L})$$

(5) *Calculate maximum volume for the peak use period, V_{max}:* The designer computes the various component maximum volumes for the following selected peak use conditions:

Clean-up period, K	60 min (1 hr)
Peak use period. T_w	3240 min (55 hr)
Total wash and clean-up, T_t	3300 min (56 hr)
Storm duration, T_s	60 min (1 hr)

The designer assumes that one bath fill, B, will be withdrawn from the equalization basin.

(a) *Maximum bath volume drained, V_l:*

V_1 = V_B x Number of fills

V^1 = 191862 gal x 1

V_1 = 191862 gal (726198 L)

(b) *Maximum bath overflow volume, V_2:*

V_2 = bath overflow rate x (total wash period plus clean-up)

$V_2 = Q_2 \times T_2 = 960$ gpm x 3300 min

V_2 = 3168000 gal (11990880 L)

(c) *Maximum volume from washstations, V_3:*

V_3 = washstation flow rate x peak wash period

$V_3 = Q_3 \times T_w = 720$ gpm x 3240 min

V_3 = 2332800 gal (8829648 L)

(d) *Maximum volume from entrance trench flusher, V_4:*

V_4 = entrance trench flusher flow rate x clean-up period

$V_4 = Q_4 \times K = 75$ gpm x 60 min x 3 cleanups

V_4 = 13500 gal (51,098 L)

(e) *Maximum volume from bath flushing, V_5:*

V_3 = bath flusher flow rate x cleanup period

$V_5 = Q_5 \times K = 3000$ gpm x 60 min

V_5 = 180000 gal (681300 L)

(f) *Maximum volume from wash station flushing. V6:*

V_6 = flusher flow rate x (wash plus cleanup + two additional clean-up periods)

$V_6 = Q_6 \times (T_1 + 2K)$

V_6 = 225 gpm (3300 min + 2 x 60 min)

V_6 = 769500 gal (2912558 L)

(g) *Maximum interior wash water volume, V_7:*

V_7 = Interior wash flow rate x wash period

$V_7 = Q_7 \times T w = 120$ gpm x 3240 min

V_7 = 388880 gal (1471608 L)

(h) *Maximum volume from yard hydrants, V_8:*

Table A—3. Summary of CVWF flow rates.

Parameter	Discharge Points		Unit Flow Rate gpm	Unit Flow Rate Lpm	Total Flow (Q) gpm	Total Flow (Q) Lpm
Q_1 Bath		outflow	6395	24207	6395	24207
Q_2 Water cannons	12	cannons	80	303	960	3634
Q_3 Wash stations	24	home.	30	114	720	2725
Q_4 Prep flushers	1	flusher	75	284	75	284
Q_5 Bath flushers	4	flushers	75	2840	3000	11355
Q_6 Trench flushers	3	flushers	75	284	225	852
Q_7 Interior wash	12	hoses	10	38	120	454
Q_8 Yard hydrants	6	nozzle.	30	114	180	681
Q_9 Rainfall pavement	2.13	acres	1818	6881	1818	6881
Q_{10} Rainfall basins	5.51	acres	4937	18686	4937	18686

Table A—4. Summary of average daily volume.

Parameter	Discharge Points	Total Flow Rate gpm	Total Flow Rate 1pm	Operating time, min	Volume (V) gal	Volume (V) L
V_1 Bath	outflow	6395	24207	30	191862	726198
V_2 Water cannons	12 cannons	960	3634	240	230400	872064
V_3 Wash stations	24 hoses	30	2725	180	129600	490536
V_4 Prep flushers	1 flusher	75	284	60	4500	17032
V_5 Bath flushers	4 flushers	3000	11355	60	180000	681300
V_6 Trench flushers	3 flushers	225	852	240	54000	204390
V_7 Interior wash	12 hoses	120	454	180	21600	81756
V_8 Yard hydrants	6 nozzles	180	681	60	10800	40878
V_9 Rainfall pavement	2.13 acres	1818	6881	60	109080	412868
V_{10} Rainfall basins	5.51 acres	4937	18686	60	296220	1121193

V_8 = yard hydrant flow rate x clean-up period x number clean-ups

V^8 = Q_6 x K x 3=10800 gal x 60 min x 3

V_8 = 32400 gal (122634 L)

(i) *Maximum pavement runoff volume,* V_9:

V_9 = pavement runoff rate x storm duration

V_9 = Q_9 x T_S = 1818 gpm x 60 min

V_9 = 109080 gal (412868 L)

(j) *Maximum rainfall volume on basins, V_{10}:*

V_{10} = rainfall rate x storm duration

V_{10} = Q_{10} x T_S = 4937 gpm x 60 min

V_{10} = 296220 gal (1121193 L)

(k) *Summary of maximum volumes.* Table A-5 summarizes the computed maximum volumes for the stated conditions at Fort Swampy.

Calculate maximum wash volume for facility, V:

V_{max} = U_1V_1+U_2V_2+U_3V_3+U_4V_4+ U_5V_5 +U_6V_6 +U_7V_7 +U_8V_8

V_{max} = 1.0(19186 2 ga1) + 0.9 (3168000gal) + 0.8(2332800 gal) + 0.2(13500 gal) + 0.2(180000 gal) +0.2(769500 gal) +0.8(388800 gal) + 0.2(32400 gal)

V_{max} = 54319422 gal (20512512L) or

V_{max} = 724,522 cf (20287 CM)

(6) *Sediment basin design.* The effective water depth of the basin will be 8 feet (2.4 meters) and free board is 2 feet (0.6 meters). The sediment depth will be determined by calculations. Settling tests performed on soils found in the training areas showed that 82 percent of the suspended solids will settle in less than 2 hours (120 minutes). This can be checked theoretically by using Stoke's Law and the nondispersed soil particle gradation test results, after the basin size has been determined.

(a) *Operation.* A dual-celled sediment basin is required. One cell will be used to settle solids during continuous washing and the adjacent basin will detain the surge volume created when the bath is flushed. A dual-cell arrangement will also allow one cell to be closed for cleaning while the other is treating wastewater; the wastewater will not have the designed detention time, but the wash facility will be operable. The installation has indicated that the basins will be cleaned every 6 months and it will take approximately 5 days to drain and clean each cell.

(b) *Water volume.* In addition to a sediment volume, each cell in the basin must be able to hold the greater of the overflow and bath volume or the stormwater volume; therefore, the bath and the overflow volumes are compared with the stormwater volume to determine which value will control the basin site. The total volume of water required in each cell is computed:

V_w = Bath overflow volume + bath volume = Q_{over} detention time + V_B

V_w = 1581 gpmx 120 min + 202633 gal

V_w = 392353 gallons (1485056 L)

V_w = 52453 cf (1469 CM)

Calculate storm water volume:

V_{st} = paved area storm runoff

V_{st} = V_o/7.48 gpcf

V_{st} = 109080/7.48 = 14582 cf (408 CM)

Since the overflow plus the bath volume is larger than the stormwater runoff volume, the ovefflow plus bath volume is the controlling factor and each cell is sized to detain at least 52453 cf (1504 CM) of water. The designer chooses an effective water depth of 8 ft. (2.4 M), an access ramp slope of 1 on 6, a ramp width of 18 ft. and a basin length-to-width ratio of 3 to 1. Figure A-7 shows the general geometry of each cell. The dimensions of the basin are then calculated using the information given and noting that the volume occupied by the ramp must be considered:

V_{sw}= L_S x W_S x D_W - l/2 x L_r x D_w x W_r = 52453

$3W^s$ x W_s x 8 - l/2 x 48 x 8 x 18 = 52453

W_S = 2042

W_S = 45 ft. (13. 7M)

and L^s = 135 ft. (41.2M)

(c) Sediment volume. The designer estimates that the installation has average-to-heavy soiling conditions. By applying Stoke's Law, using Q_{over} with the basin size previously calculated, and checking the soil particle size information, removal of 82 percent of the soil, as determined by settling tests, is verified. Using equa-

Table A—5 Summary of Maximum Volumes

Parameter	Discharge Points	Flow Rate gpm	Flow Rate 1pm	Operating time, min	Volume (V) gal	Volume (V) L
V_1 Bath	outflow	6395	24207	30	191862	726198
V_2 Water cannons	12 cannons	80	303	3300	3168000	11990880
V_3 Wash stations	24 hoses	30	114	3240	2332800	8829648
V_4 Prep flushers	1 flusher	75	284	180	13500	51098
V_5 Bath flushers	4 flushers	750	2840	60	180000	681300
V_6 Trench flushers	3 flushers	75	284	3420	769500	2912558
V_7 Interior wash	12 hoses	10	38	3240	388000	1471608
V_8 Yard hydrants	6 nozzles	30	114	180	32400	122634
V_9 Rainfall pavement	2.15 acres	1818	6881	60	109080	412868
V_{10} Rainfall basins	5.51 acres	4937	18686	60	296220	1121193

tions 6-3 and 6-4 with data from table A-2: Sediment Volume = (Tracked vol. + Wheeled vol.) x duration of wash season x sediment basin trap efficiency.

Sediment volume = (2.0 cu ft/wash x 665 washed/month + 0.6 cu ft/wash x 783 washes/month) x 6 months x 0.82 percent cleaning
=8855 cf (248 CM)

The same equations that were used to size the cell based on water volume are used to size the cell for the sediment volume, except that the volume of the ramp is assumed negligible. The width and length of the cell are known, and the depth is calculated. Thus—

$(L_s - L_r)$ xW_x x D_s = Sediment volume
(145 ft - 48 ft) x 48 ft x D_s = 8855 cf
D_s = 1.9 ft. (0.58M)
say D_s = 2.0 ft. (0. 61M)

(d) *Total cell size*. The calculated sediment basin dimensions are summarized in figure A-8.

(7) Equalization basin. The volume of water in the equalization basins is based on the greater of V_{avg} for any assumed *5* day wash period or V_{max}:

V_{EB} = 5xV_{avg}=5x570042 gal= 2850210 gal (10788045 L)
V_{EB} =381044 cf (10699 CM) or;
V_{EB} =V_{max} = 724522 cf (20287 CM)

The designer uses a safety factor of 1.25 times the value of Vmax or 905653 cf (25358CM to size the basin. The designer selects an effective water depth of 8 ft (2.4 M), 2.0 ft (0.6 M) of sediment storage, 2.0 ft (0.6 M) of dead storage or a total depth of 15 ft (3.7 M). The average area at the mid point of the equalization basin water zone is:

905653 cf/8 ft = 113207 sf (10528 SM)

The designer selects to use a square basin (fig A-9) with side slopes of 1 to 3.5. The basin is sized by taking the square root of the average area required to determine the average length and width of the basin. This method gives the average basin size—336 feet by 336 feet (102 meters by 102 meters). With the slope of the walls at 1 to 3.5,7.0 ft (2.2 M) are added to the average side for each foot (meter) of depth above or subtracted below the average depth. The length of the basin at the water surface would be 364 feet by 364 feet (110 meters by 110 meters). With 3 feet (0.9 meters) of freeboard added, the overall top dimension of the basin will be 385 feet by 385 feet (117 meters by 117 meters). Subtracting 3.5 feet (1.1 meters) off of each side for each foot (meter) below the average depth, the dimensions of the bottom of the basin, with 2 feet (0.6 meters) allowed for sediment storage and 2 feet (0.6 meters) allowed for dead storage, would be 280 feet by 280 feet (86 meters by 86 meters).

(8) *Intermittent sand filters*. The installation has indicated that the facility need not be fully operational for 7 days after a major washing operation that takes about 2 days (54 hours). The designer chooses two filters, which will allow one filter to operate while the other one is allowed to rest. A loading rate of 8 inches (20.3 centimeters) per filter dose will be used. The filter dose frequency is every 8 hours. The designer calculates the area required for the sand filters:

$$\text{Filter Area} = A_F = V_{max}/\text{Dosing Rate}$$

$$A_F = \frac{724522 \text{ cf}}{(2 \text{ days} + 7 \text{ days})} \times \frac{\text{acre/day}}{650000 \text{ gal}} \times \frac{7.48 \text{ gpcf}}{\text{cu ft}}$$

$$A_F = 0.93 \text{ acres or } 19040 \text{ sf } (1770 \text{ SM})$$

Thus, each filter should be 0.47 acres or 20473 sf(1904 SM).

(9) *Dosing base.* The designer has performed an economic study which showed that a dosing basin would be cost-effective when compared with installing larger pumps. Water can flow by gravity to the sand filter. Small pumps can take water from the equalization basin to the dosing basin. With a dosing basin, the de--signer is able to use smaller pumps for charging the dosing basin over a long period of time. The basin is sized to hold the volume of water to charge one filter. The volume is calculated as follows:

$$\text{Volume} = 20473 \text{ sf} \times \frac{8 \text{ inches}}{\text{charge}} \times \frac{\text{foot}}{12 \text{ inches}} \times \frac{7.48 \text{ gal}}{\text{cu ft}} \text{ gpcf}$$

$$= 102093 \text{ gal } (386422 \text{ L})$$

(10) *Water supply basin.* Design criteria call for the size of the water supply basin to be the larger of V_{max} (724522 cf or 20287 CM); or V_{ave} for a S day wash period.

$$V_{ws} = 5 \times V_{ave} = 5 \times 570042 \text{ gal} = 2850210 \text{ gal } (10788045\text{L}) \text{ or } 381044 \text{ cf } (10669\text{M})$$

Since V_{max} is larger than five times V_{ave}, the designer uses a safety factor of 1.25 times V_{max} to size the water supply basin or 905653 cf (25358 CM). Because of the large water volume required, the designer chooses an effective depth of 10 feet (3.0 meters) with 2.0 feet (0.6 meters) of dead storage for a total depth of 12 feet (3.7 meters). The water surface area can then be calculated as follows:

$$A_{ws} = 905653 \text{ cf}/10 \text{ ft} = 90565 \text{ sf}$$

Using the method described for sizing the equalization basin and assuming a square basin gives the average basin size at the midpoint of water depth is 301 feet by 301 feet (92 meters by 92 meters). With the side slopes of I to 3.5, the dimensions of the basin at the top of the water level would be 336 feet by 336 feet (102.4 meters by 102.4 meters). With the 3 feet (0.9 meters) of freeboard added, the overall top dimension of the basin will be 357 feet by 357 feet (109 meters by 109 meters). The bottom of the basin would be 252 feet by 252 feet (77 meters by 77 meters).

(11) *Makeup water.* An economic analysis has revealed that, if wells are drilled as the primary source of makeup water for the CVWF, the return on investment will be 37 years. Since the design life of the facility is only 20 to 25 years; the installation chooses to use the existing potable water supply as a source of makeup water since the supply is dependable. The existing 10-in (25.4-cm) water line running adjacent to Range Road can be tapped. Makeup water will be added to the water supply basin at night when demand on the potable water supply is lowest.

(12) *Emergency discharge.* The closest sanitary sewer connection is approximately 0.75 mi (1.2 km). The designer decides to provide a sewer from the water supply basin to the existing sanitary sewer line to handle emergency overflows. This will prevent overflows from otherwise being discharged to the environment.

(13) *Checking calculations.* Figure A-l 1 shows the expected water volume in the equalization basin at any given time during the washing activities. This graph confirms that at no time during a major wash will the equalization basin volume of 5.5 mg be exceeded during the peak water usage period. The projected volume for the water supply basin is also plotted (fig A-12). This graph shows that 5.5 Mg is sufficient to ensure that an adequate supply of wash water is available at all times.

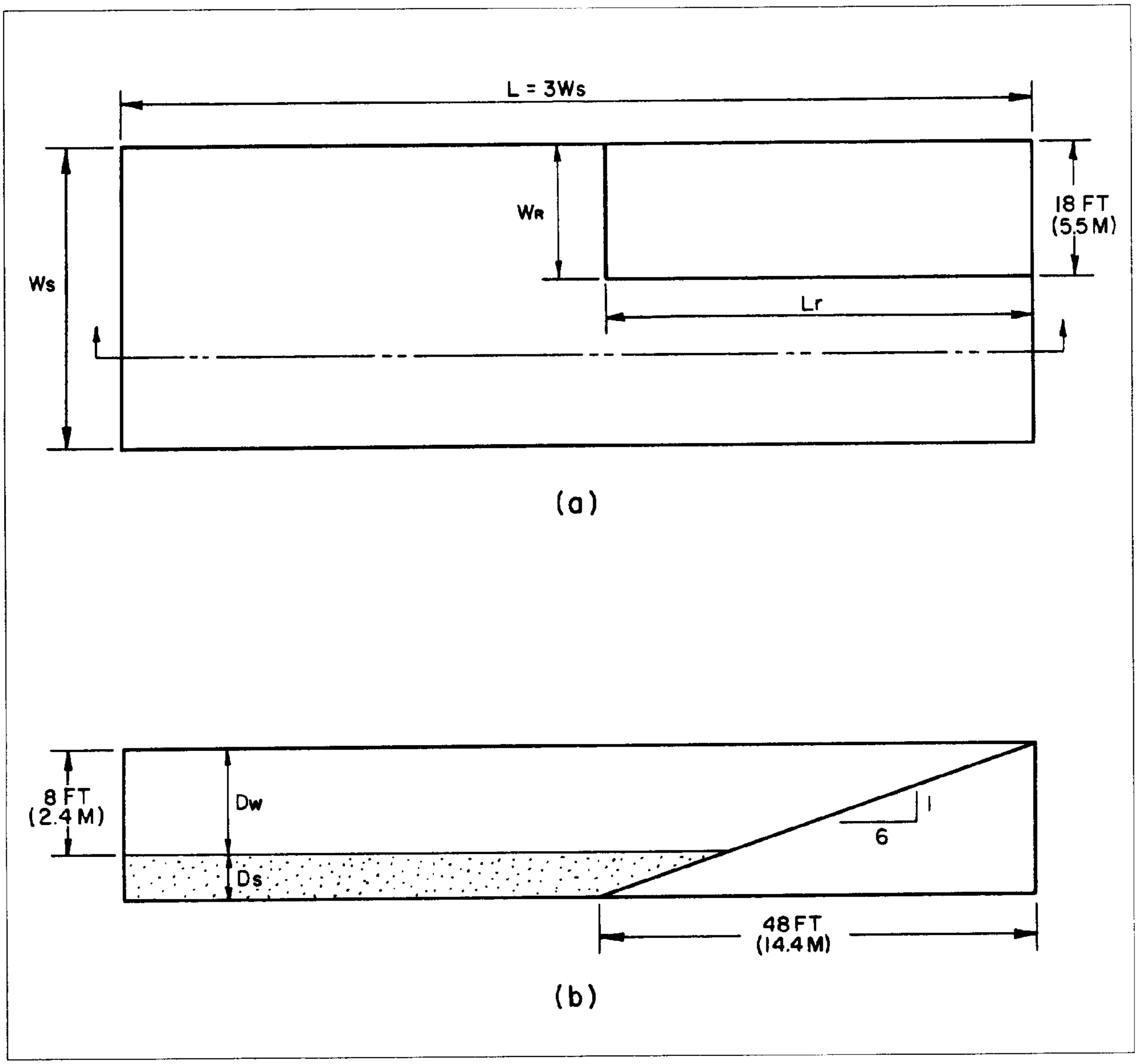


Figure A-7. Water volume configuration: (a) plan view and (b) cross section.

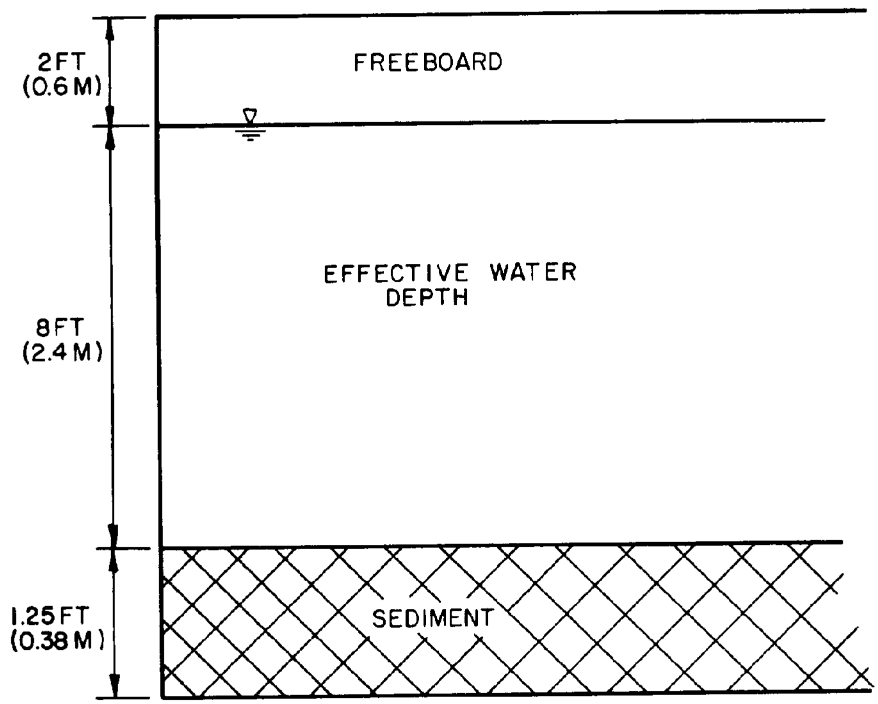
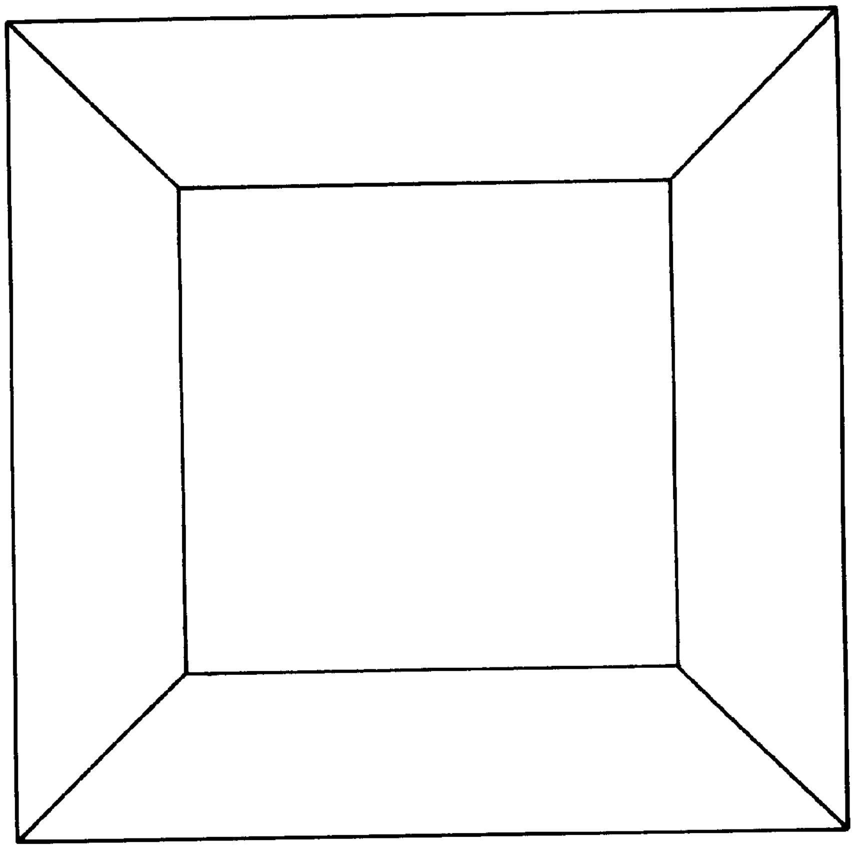
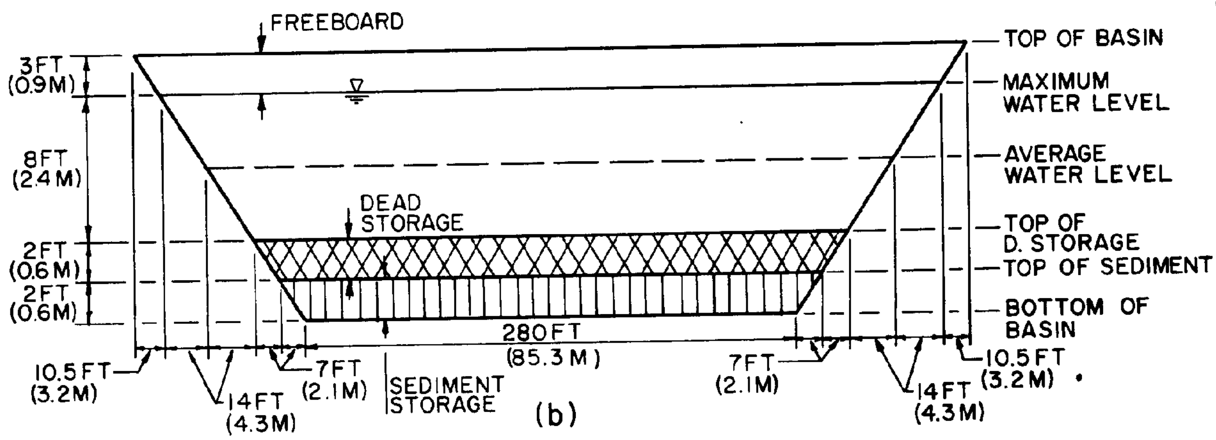


Figure A–8. Overall cell configuration.


(a)



(b)

Figure A–9. Equalization basin: (a) plan view and (b) cross section.

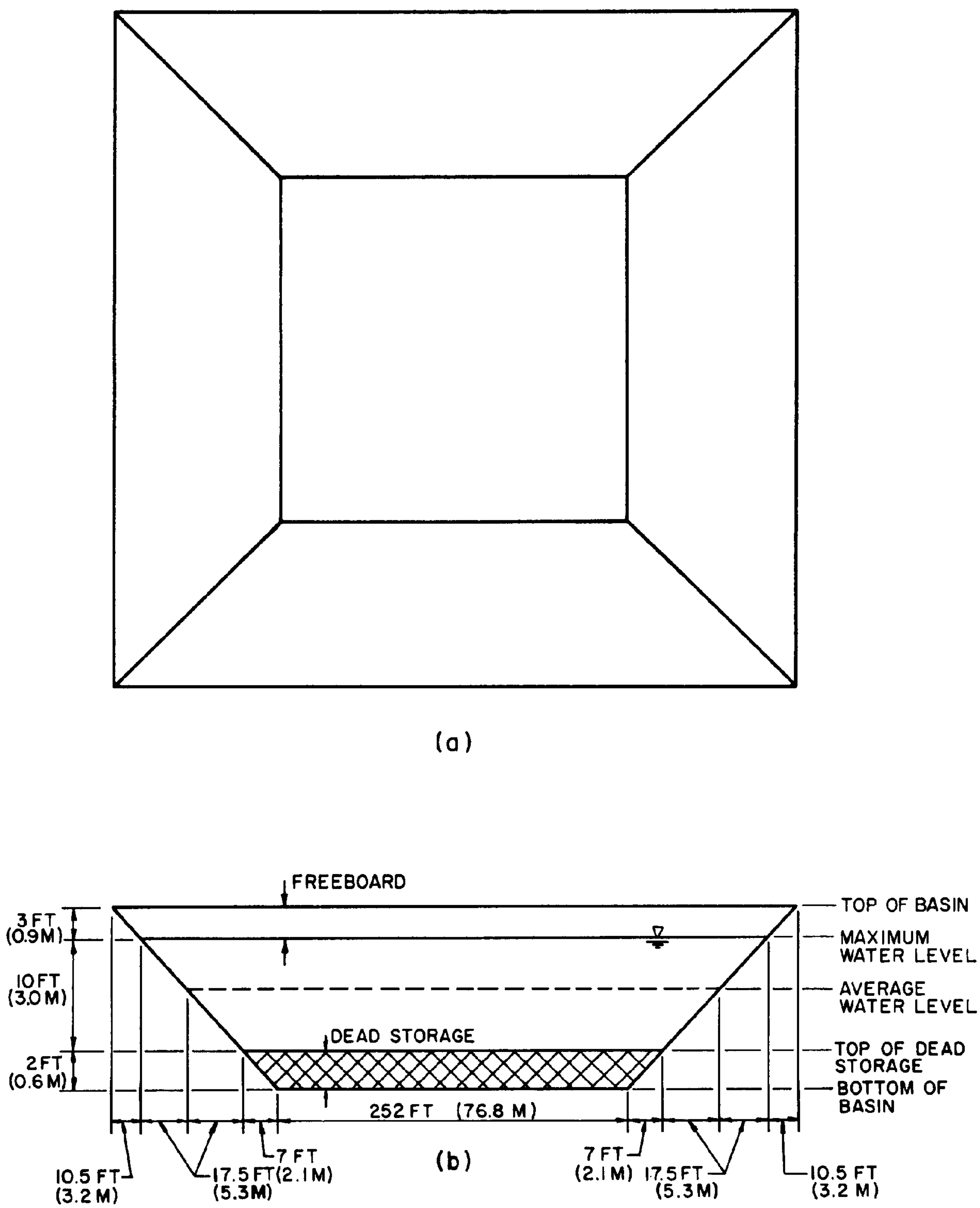


Figure A–10. Water supply basin: (a) plan view and (b) cross section.

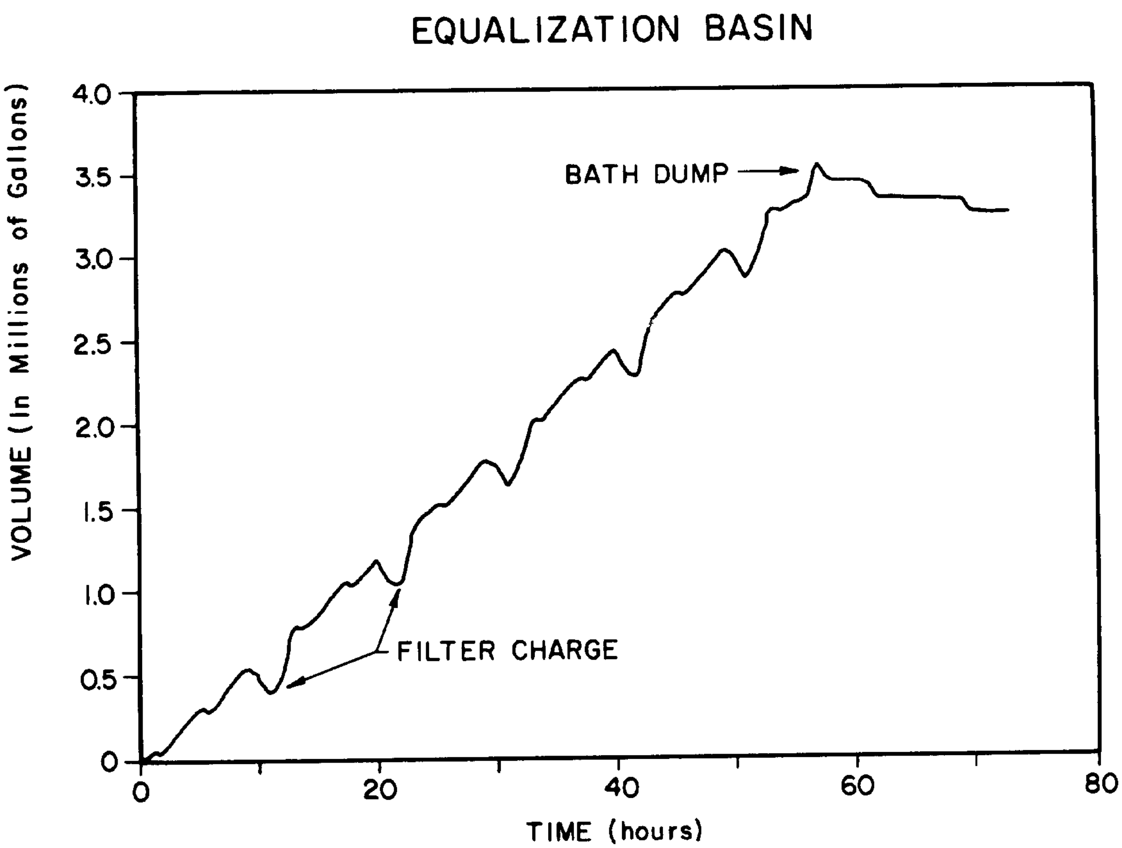


Figure A-11. Equalization basin water balance—water volume versus time.

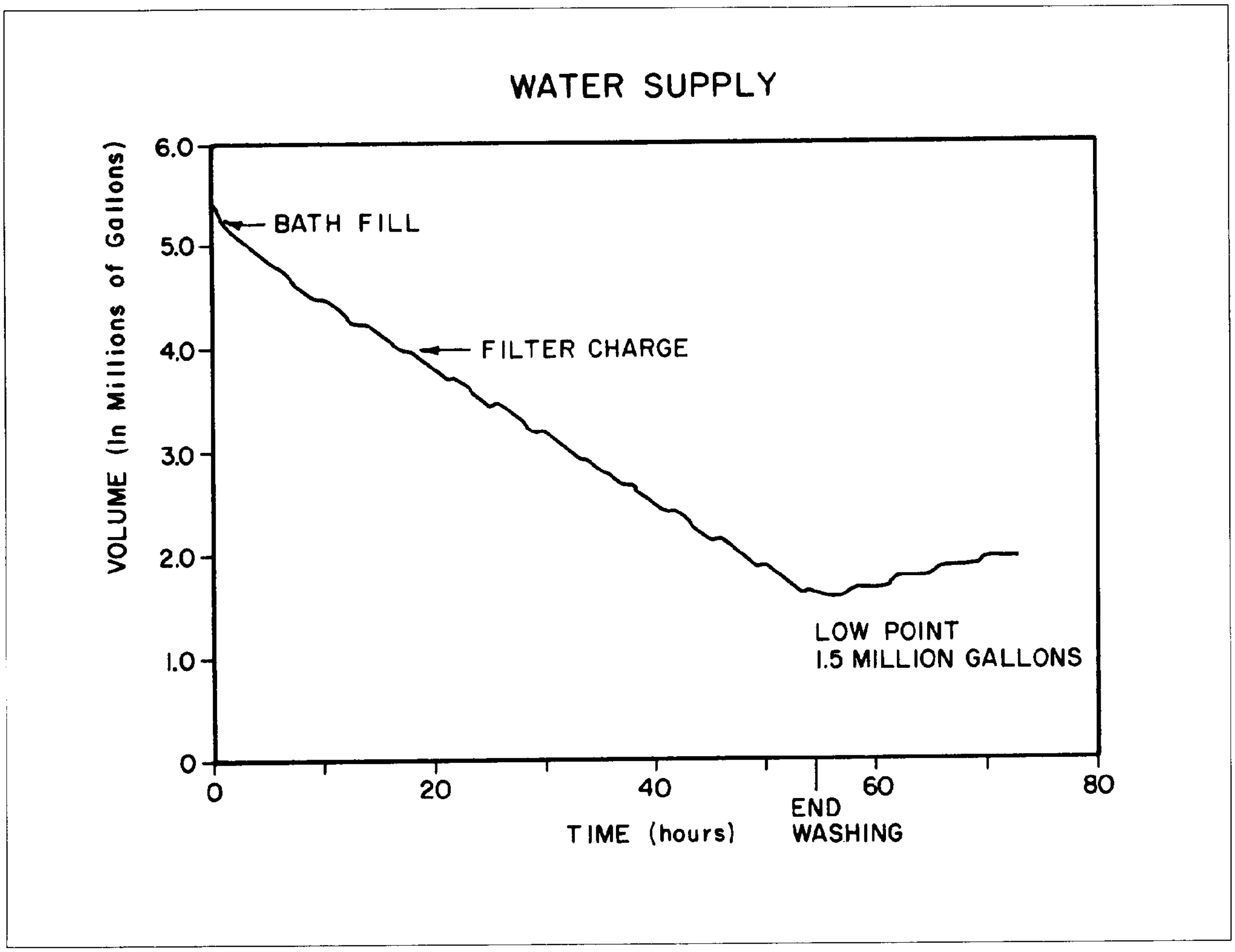


Figure A-12. Water supply basin capacity.