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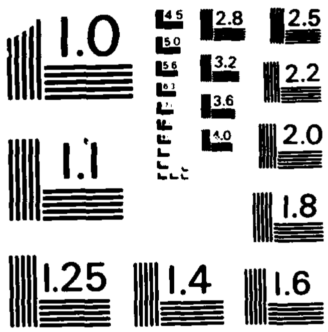

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AD-A169 799

WORKLOAD ESTIMATES FOR COMBAT ENGINEERS IN THE DESERT

Prepared by
Engineer Studies Center
US Army Corps of Engineers

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This analysis defines the engineer workload requirements for 25 tasks traditionally performed in support of maneuver units in the forward combat zone. It focuses on three of the four engineer mission areas: survivability, countermobility, and mobility. It measures the equipment and manpower effort needed for work performed in a common earth (Europe) and for work performed in sandy, rocky plateau, and salt marsh desert soils. In addition, it measures the degradation to work efficiency caused by intense desert heat.

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WORKLOAD ESTIMATES

FOR

COMBAT ENGINEERS

IN THE DESERT

Prepared by
Engineer Studies Center
US Army Corps of Engineers

April 1986

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ABBREVIATIONS AND ACRONYMS

ACE......................armored combat earthmover
AP.......................anti personnel
AT.......................anti tank

BCY......................bank cubic yard

CEV......................combat engineer vehicle

DA.......................Department of the Army

E-FOSS...................Engineer Family of Systems Study
engr.....................engineer
ESC......................Engineer Studies Center

FAAR.....................forward area alerting radar
FCZ......................forward combat zone
FIST.....................fire support team
FM.......................field manual

GEMMS....................Ground Emplaced Mine Scattering System

HEMMS....................Hand Emplaced Minefield Marking System

IOE......................irregular outer edge
IPR......................In-Process Review

LCY......................loose cubic yard

m........................meter
MED......................medical
mm.......................millimeter
MSR......................main supply route

NL.......................no limit

PAR......................pulse acquisition radar
PHEL.....................physiological heat exposure limits

SAG......................Study Advisory Group
SEE......................small emplacement excavator

TB.......................technical bulletin
TOW......................tube launched, optically tracked, wire-guided missile

USARIEM..................US Army Research Institute of Environmental Medicine
USCENTCOM................US Central Command

DEFINITIONS

Irregular Outer Edge: The strip of mines closest to the enemy side of the minefield; usually laid in an irregular pattern.

Slot Dozing: A technique used by dozer operators to increase earth moving efficiency when excavating. The operator excavates a slot approximately the width of the dozer blade. The sides of the slot prevent soil from spilling around the edge of the blade, and thereby increases the volume of material that can be pushed by the dozer.

Cubic Yard Volume Measures

Bank Cubic Yards: The volume of material measured as it lies in its natural condition.

Loose Cubic Yards: The volume of material that results after digging, increased volume is caused by swell or air pockets within the material.

WORKLOAD ESTIMATES FOR COMBAT ENGINEERS

IN THE DESERT

1. Purpose. This study quantifies workload planning factors for survivability, mobility, and countermobility tasks performed by combat engineers under adverse desert conditions. ⟶ {, p. A (1473)

2. Background.

a. In a 4 December 1984 letter, General Kingston, the Commander in Chief of US Central Command (USCENTCOM), asked Engineer Studies Center (ESC) to consider undertaking this study for USCENTCOM. Members of ESC's staff visited HQ USCENTCOM at MacDill Air Force Base, Florida, on 15 February 1985. That visit confirmed that a question of particular interest to USCENTCOM is whether the US Army engineer doctrine, methods, and planning factors described in the engineer literature, but developed primarily for a European conflict, are applicable to the desert battlefield environment.

b. USCENTCOM formally requested ESC's support for this study in an 18 March 1985 letter to the Deputy Chief of Engineers, US Army Corps of Engineers. USCENTCOM also designated a Study Advisory Group (SAG) to guide and review the study's progress. During the first In-Process Review (IPR), the SAG approved ESC's study plan. The study resulted in this publication, which will give USCENTCOM and other engineer planners the data necessary to estimate combat engineering support requirements for contingency forces deployed to desert regions.

3. Scope. This study examines the various engineer tasks associated with the mission areas of survivability, mobility, and countermobility in the

forward combat zone (FCZ), and determines work planning factors for each task. Specifically, this study:

a. Evaluates the traditional engineer support tasks associated with combat forces operating in the European theater and determines whether they can be applied to the desert environment.

b. Identifies special engineer support tasks which are necessary because of the unique terrain and climatic conditions found in the desert.

c. Considers all the tasks which might be required to support combat units assigned to maneuver brigades. (To ensure that the types of tasks analyzed are not limited arbitrarily by the demands of only one or two specific brigade organizations, this analysis is done without regard to any one particular brigade structure.)

d. Identifies modified work methods and design concepts which have been used successfully by engineer crews working in the soils of the loose sandy desert, the rocky plateau desert, or the salt marsh desert.

e. Estimates workload planning factors for both "heavy" and "light" engineer work forces. (Heavy work forces are defined as engineer crews equipped with the M9 armored combat earthmover (ACE) or the D7 dozer and the 5-ton dump truck. These forces can be associated with the divisional engineer battalion for a mechanized or armored division. The light work forces are defined as engineer crews equipped with the D5 dozer and 2.5-ton dump truck. These forces can be associated with the divisional engineer battalion for an airborne, light infantry, or airmobile division.)

4. <u>Assumptions and Their Significance</u>. Four assumptions served as the basis for the analyses conducted during this study:

a. ASSUMPTION: The engineer work effort will not be hampered by enemy suppressive fires. SIGNIFICANCE: Enemy fire is a significant impediment to accomplishing engineer work. If the work site is receiving accurate direct or indirect fire, engineer work activities will be disrupted. Some of the equipment designated for a task by this study, such as the bulldozer and the small emplacement excavator (SEE), should not be used where the operator is exposed to enemy fire. In fact, some of the tasks themselves should not be attempted if the supported combat unit is taking enemy fire.

b. ASSUMPTION: The time spent traveling to the work sites is not included in the estimates of engineer effort. SIGNIFICANCE: Travel can add considerably to the time allotted in the engineer estimates to completing a task--but exactly how much time depends on scenario-driven variables. However, it was beyond the scope of this study to examine the conditions of specific war scenarios.

c. ASSUMPTION: Engineer equipment is fully operational and without defect. SIGNIFICANCE: Over time, equipment operating in the desert will deteriorate because of the stress placed on it by the desert's extreme terrain and weather conditions. Tasks will take longer to complete if engineers must use equipment that is less than fully operational.

d. ASSUMPTION: The persons performing the engineer tasks considered by this study are acclimated to hot weather. SIGNIFICANCE: Hot weather can significantly degrade the performance of persons who are not used to working in a desert climate.

5. <u>How to Use the Study Products</u>. The results of this study are presented in five annexes (see Figure 1).

REPORT ORGANIZATION

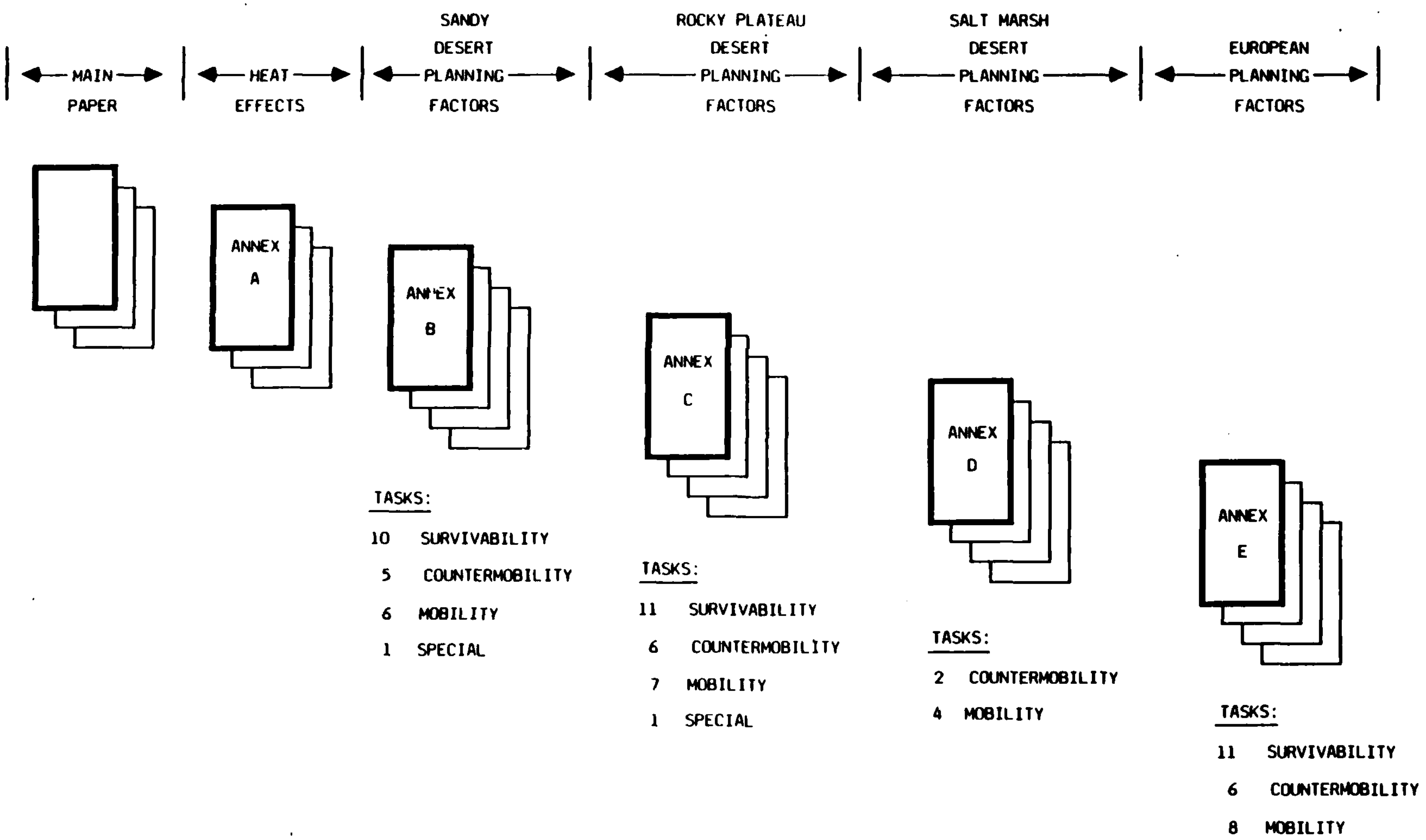

Figure 1

a. Annex A examines the effects of heat on persons required to work in the desert. It presents the methodology used to develop the adjustment factors ESC used to account for the difference in performance expected of a person doing work in a temperate climate and one working in high temperatures. It also provides tables the reader can use to estimate heat degradation factors for desert temperatures other than those selected by ESC as representative of desert conditions.

b. Annexes B through D present detailed workload estimates for specific combat tasks under several terrain and climate conditions typical of desert environments: loose, sandy desert terrain (Annex B); the hard, cemented soil found in the rocky plateau desert (Annex C); and the soils of the salt marsh desert (Annex D). Annex E estimates the workload requirements for those same tasks, but when performed under typically European conditions of terrain and climate. These latter estimates were the base line against which the estimates in Annexes B, C, and D were measured. The reader can use the estimates in Annex E to compare workload requirements in Europe with workload requirements in the desert.

c. Each appendix to Annexes B through E focuses on a single engineer task. Each defines the dimensions of the task, the composition of the engineer work crew, and the algorithms used to compute time and resource estimates. Each annex also includes data tables which the reader can use as a quick reference to estimate combat engineer requirements for tasks not covered by this study.

d. Figure 2 shows how workload data are presented and referenced throughout the annexes and appendices to this report:

STUDY PRODUCT SAMPLE FORMAT

BUILD A PROTECTIVE POSITION FOR A 155-MM TOWED HOWITZER (Sandy Desert + Hot Weather) 1

2 HEAVY EQUIPMENT WORKLOAD RATES

3

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Build Berm	0.85	
Elapsed Time Required To Complete Task		0.85	

4

2 LIGHT EQUIPMENT WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Build Berm	1.25*	
Elapsed Time Required To Complete Task		1.25	

5

6

Figure 2

1 The major heading identifies the name of the task and the terrain and climate in which the task is performed. In Annexes B, C, and D, each appendix has figures for both a temperate and a hot climate.

2 The minor headings indicate whether the estimates pertain to "heavy" or "light" engineer equipment. The heavy equipment data use D7 dozer, M9 ACE, and 5-ton dump truck work rates. The light equipment data use D5 dozer and 2.5-ton truck work rates.

3 The types and numbers of resources which make up the work crew are identified. The composition of the team selected by ESC is only one of many alternatives.

4 The workload requirements, measured in manhours or equipment-hours, are given for each activity or subtask.

5 The asterisk following the workload factor indicates a high potential for heat casualties. (See Annex A for details.)

6 The elapsed time measures the number of hours it takes to finish a task, counting from when work on the task is begun to when the last activity or subtask is completed. (Since work on different subtasks may be performed concurrently, the relationship between the elapsed time and the activity workload factors may not be obvious.)

LAST PAGE OF MAIN PAPER

ANNEX A

EFFECTS OF EXTREME HEAT ON WORK PRODUCTION RATES

ANNEX A

EFFECTS OF EXTREME HEAT ON WORK PRODUCTION RATES

1. Purpose. This annex describes the factors by which work production rates were adjusted to account for how hot, dry climates, typical of the world's deserts, affect the performance of engineer work crews.

2. Scope. The data presented in this annex describe how extreme heat (up to 170^{o}) can degrade work performance. They are used to formulate adjustment factors for activities performed in very hot temperatures under a low relative humidity. These factors are used to estimate workload rates for work performed in the desert terrains described in Annexes B, C, and D of this report.

3. The Body's Cooling Process. When the air temperature is lower than the normal temperature of the human body (about 98.6° F), the body is cooled by the processes of conduction or convection, radiation, and evaporation. Conduction or convection passes heat from the skin surface to adjacent molecules of cooler, moving air. Radiation is the absorption of heat energy by cooler, nearby objects. But when air temperatures are greater than the temperature of the body, both processes increase rather than decrease the body's temperature. Under such conditions, the hotter air and surrounding objects pass heat energy to the body. The body's only remaining cooling mechanism is water evaporation.[1] Water evaporates from the body by two methods--normal breathing (evaporation from the lungs) and perspiration (evaporation from the skin). At high temperatures, sweating is the primary physiological means available to maintain normal body temperatures. The arid climate of the desert causes the sweat to evaporate more quickly than would occur in humid climates. Thus, the sweating process is more efficient in the dry desert air.[2] But the very hot desert air substantially increases the amount of body heat that sweating must dissipate. If persons cannot maintain their normal body temperature by using sweat to cool their bodies, then they may become heat stress casualties.

4. Causes of Heat Stress Casualties.

a. Dehydration. When a person exerts in temperate weather, three of the body's cooling mechanisms--conduction/convection, radiation, and evaporation in the lungs--are usually sufficient to maintain a constant body

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[1]Department of the Army (DA), HQ, TB MED 507, Prevention, Treatment and Control of Heat Injury, Washington, D. C., July 1980, p. 2.

[2]DA, Aberdeen Proving Ground, Human Engineering Laboratory, Human Factors in the Design of Desert Equipment, December 1954, p. 7.

temperature. But in extremely hot temperatures, these three processes alone cannot cool the body. To increase its cooling capacity when these other cooling processes fail, the body sweats. Although sweating cools well, it decreases the body's water content. If the water lost to sweating is not replenished by drinking frequently, dehydration is probable. Drinking adequate amounts of water is extremely important for the survival of soldiers operating in the desert.

> "The amount of water needed is astonishingly large. In an air temperature of 100° F... it can be proved that a man walking at 3.5 miles per hour loses a quart and a half, or a canteen and a half, of water as sweat [each hour]."[3]

> "During the 1967 Six Day War, the Egyptians suffered 20,000 casualties with no visible wounds, apparent victims of dehydration/heatstroke. Hundreds were found lying dead together, all their weapons and training rendered irrelevant by the lack of water."[4]

> "The Israelis, in sharp contrast, followed a program of forced drinking. At frequent intervals during the day, troops were required to consume more water than they wanted since thirst is an inadequate guide to the need for water in humans. The far lower heat casualty rate experienced by the Israelis was almost certainly the result of this policy."[5]

> "...natural thirst makes men want to drink only about two thirds of the water they need in order to maintain maximum combat efficiency."[6]

b. Heat cramps. Sweating spends a disproportionate amount of the body's mineral salt. The sweat of persons not acclimatized to hot weather will contain about 0.2 percent salt.[7] Drinking water only replenishes body

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[3] CPT B. G. Clarke, MC, USNR, "Prevention of Heat Casualties," Marine Corps Gazette, Volume 50, p. 46.

[4] DA, Bright Star 83 After Action Report - Water Management (Production/Consumption) and Heat Stress Management, March 1984, p. 29.

[5] Bright Star 83, p. 189.

[6] Marine Corps Gazette, p. 48.

[7] Marine Corps Gazette, p. 46.

water--not body salt. The ratio of body salt to body water, therefore, decreases as sweating increases. If left untreated, this imbalance will cause heat cramps.

c. Heat exhaustion. Heat exhaustion most commonly strikes persons exposed too long to environmental heat who are also engaged in a physical activity that is strenuous enough to add to the body's heat burden. But it may be triggered solely by environmental heat, or solely by excessive physical exertion (even in relatively mild climatic conditions). Heat exhaustion can occur even in the absence of dehydration or salt depletion. Usually 24 to 48 hours are required to recover from a severe episode of heat exhaustion.[8]

d. Heatstroke. Heatstroke (also called sunstroke) is the greatest danger threatening people exposed to desert heat. It is a medical emergency with a high degree of mortality. Heatstroke can be characterized as the complete shut-down of the body's cooling system: sweating ceases and the internal body temperature rises very rapidly. Organ damage and death follow unless quick action is taken to lower the body's temperature. Heatstroke can be caused by progressive dehydration resulting from inadequate water intake. It can also be caused by working strenuously without balancing rest periods with periods of physical exertion.[9]

5. <u>Ability to Acclimate to Hot Climates</u>. The average person can be substantially (about 78 percent) acclimated to hot climates in about 2 weeks if he or she is exposed to progressively higher temperatures. Levels of physical exertion and durations of work should be less during the first days of exposure to heat and should be increased gradually. In about 3 weeks, the

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[8] DA, <u>Bright Star 83 After Action Report - Water Management (Production/Consumption) and Heat Stress Management</u>, March 1984, p. 176.

[9] <u>Bright Star 83</u>, p. 189.

average person will fully acclimate and will be better able to cope with high temperatures. Although an unacclimated person is more likely to suffer heat injuries than an acclimated person, even a fully acclimated person cannot expend great amounts of energy in hot temperatures without taking periodic rest breaks to allow the body to cool. Drinking water should never be rationed to "harden" or condition troops. This is an extremely dangerous practice that leads to dehydration and heat injuries. Some suspect that the 20,000 Egyptian casualties during the Six Day War were caused, in part, by Egyptian water rationing policies. Water economy can only be achieved safely by reducing physical activity.[10]

> "If men are required to perform heavy physical work before being properly acclimatized, the work is poorly performed, development of the capacity to work effectively is retarded, and the risk of heat injury and disability is high. A period of acclimatization is necessary regardless of the individual's physical condition, although the better the physical condition the quicker acclimatization is completed."[11]

6. Work-Rest Cycles. In hot temperatures or when vigorously active, a person requires periodic rest breaks to cool the body. As the work becomes more strenuous, longer and more frequent rest periods are required. The body provides no obvious signs to alert the person that rest is necessary. Therefore, unaware of the dangers of overheating, the person might continue to work without a break. Although working continuously without breaks might be appropriate under temperate climate conditions, in the desert it can be hazardous.

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[10] DA, Construction Engineering Research Laboratory, Troop Construction in the Middle East, Champaign, IL, October 1982.

[11] DA, TB MED 507, Prevention, Treatment and Control of Heat Injury, Washington, D. C., July 1980, p. 6.

Often, the person will become a heat casualty unless frequent rest breaks are taken.

a. Except for combat exigencies, heavy work should be scheduled for the cooler periods of the day. Soldiers should not work between 1200 and 1500, the time of day when the temperature peaks.

b. Soldiers should be commanded to take frequent rest breaks and drink sufficient liquids. If the urgency of the combat situation demands that a task be completed more quickly, the increased work rates will be paid for in reduced work efficiency, increased risk of heat injury, and greater water consumption.

7. Method Used to Estimate Heat Degradation. The study team was unable to locate any field data which measured actual work degradation caused by heat or that in some way quantitatively defined the effect of heat on work effort. But many sources observed that work crews require more time to complete a task in hot weather conditions than in temperate conditions. Private contractors and military officers with experience in the desert generally agreed with that observation.

a. Information from medical and biological sources suggests that the metabolic work rate and the time required to complete the work are inversely related. Crews performing heavy work must schedule more frequent, longer rest breaks than crews performing moderate work. Likewise, crews performing light work can schedule fewer, shorter rest breaks than crews performing moderate work. The number of rest breaks scheduled and their duration add to the total time required to complete the assigned task.

b. The actual work pace at which a crew member executes a particular activity is unaffected by changes in the climate. This is because crews are trained formally to work at a specific speed--that work pace is reinforced during many field exercises and becomes habitual. Even in the face of extreme temperature hardship, persons will try to keep to that learned routine. Thus, the work pace of crews in hot climates will not differ substantially from the one at which they were trained. The reason tasks performed in hot climates require more time to complete is because longer, more frequent rest breaks are required to keep the workers healthy. Indications are that the increase in time required to finish a task in hot weather is a function of the length and frequency of the rest breaks that are needed by soldiers on an engineer work crew. Theoretically, comparing work-rest cycle requirements for Europe against work-rest cycle requirements for a desert climate yields a fractional value that can subsequently be used to estimate heat degradation.

8. <u>The Work Activity Levels</u>. Body heat is produced through the metabolic process. The amount of heat produced depends on the amount of energy that a person "burns" while working. Even at rest, the body produces heat which must be dissipated. Figure A-1 shows the amount of body heat produced per hour by an average, physically fit person performing different activities.

a. The metabolic rates in Figure A-1 can be used to compare different activities, but should not be viewed as accurate measures of the rates of any particular group of persons. Metabolic rates will differ between people, depending on their physical characteristics.

b. The activities listed in Figure A-1 are divided into three broad categories of light, moderate, and heavy work. These three categories were arbitrarily chosen to simplify degradation estimates. Light work is defined as an activity which produces a metabolic rate of 300 Watts or less; moderate work produces a rate of 301 to 500 Watts; and heavy work produces more than 500 Watts of heat.

ESTIMATED HOURLY METABOLIC RATES*
(Average, Physically Fit Person)

Activity	Watts
LIGHT WORK	
Sleeping	73
Sitting/Standing	105-117
Standing with 66-lb load**	144
Sitting, moderate arm and trunk movements (desk work, typing)	131-162
Standing, light work at machine or bench	162-191
Sitting, heavy arm and leg movements	191-235
Standing, light work at machine or bench, some walking about	191-220
MODERATE WORK	
Standing, moderate work at machine or bench, some walking about	220-411
Walking about with moderate lifting or pushing	293-411
Slow walk (5.5 km/hr), carrying 88 lb down a 10% grade**	324
Digging individual fighting positions with entrenching tool**	375
Slow walk (5.5 km/hr), carrying no load on a smooth surface**	389
HEAVY WORK	
Slow walk (5.5km/hr), carrying no load on a rough surface**	528
Intermittent heavy lifting, pushing, or pulling	440-586
Hardest sustained work	586-704
Low crawl**	633
Walking, carrying a 50-lb load on a sandy surface**	686
Walking, carrying an 88-lb load up a 10% grade**	689

*Except as noted, taken from TB MED 507, p. 16.

**Department of the Navy, Naval Medical Research Development Command, Physical Performance Tasks Required of US Marines Operating In A Desert Environment, Bethesda, MD, November 1981, p. 55.

Figure A-1

9. Explanation of the Work-Rest Cycle Data Tables. Staff researchers at the US Army Research Institute of Environmental Medicine (USARIEM), in Natick, Massachusetts, have developed several work-rest cycle algorithms for different levels of metabolic activity and various climatic conditions. ESC asked USARIEM to use those algorithms to develop work-rest cycle data for different desert climates. A representative relative humidity of 20 percent was chosen with temperatures ranging from 80° F to 170° F. This range covers most temperatures that might be encountered in the desert. The extremely high temperatures are included to account for temperature readings that might occur inside enclosed structures or vehicles. ESC also asked USARIEM for work-rest cycle data on a typical temperate climate--a relative humidity of 50 percent and a temperature of 80° F were selected as representative of the European climate.

a. Figure A-2 shows the USARIEM data. Work-rest cycle data for both acclimated and unacclimated persons on an engineer work crew are included. The data for unacclimated crew members, although not used to estimate work rates in this study, provide a quantitative insight into the debilitating effects of heat. The data represent the acceptable balance necessary for maintaining the work-rest cycle indefinitely.

b. Each entry in the figure shows, in minutes, the portion of the work-rest hour that is work, the portion that is rest, and the maximum amount of continuous time that people can work. The format for each column entry is -- "Work Time", "Rest Time", "Maximum One-Time Work Rate". If, for example, an acclimated crew performs moderate work for 26 minutes and then rests for 34 minutes at a dry desert temperature of 80° F, the members of that crew should be able to maintain that work-rest cycle continuously. No more than 5 percent of the crew can be expected to become heat stress casualties.

WORK-REST-CYCLE DATA FOR VARIOUS TEMPERATURES*

	ACCLIMATED PERSONNEL Work Levels**			UNACCLIMATED PERSONNEL Work Levels**		
Temp	Light	Moderate	Heavy	Light	Moderate	Heavy
			EUROPEAN CLIMATE (BASE CASE)			
80	NL: :NL	18:42:86	11:49:51	NFW: :75	NFW: :45	NFW: :35
			DRY DESERT CLIMATE			
80	NL: :NL	26:34:119	17:43:60	5:55:86	NFW: :48	NFW: :37
90	NL: :NL	17:43:83	9:51:51	NFW: :69	NFW: :44	NFW: :34
100	NL: :NL	NFW: :63	NFW: :43	NFW: :58	NFW: :40	NFW: :32
110	NFW: :89	NFW: :50	NFW: :36	NFW: :50	NFW: :36	NFW: :29
120	NFW: :62	NFW: :40	NFW: :29	NFW: :43	NFW: :32	NFW: :25
130	NFW: :47	NFW: :32	NFW: :20	NFW: :38	NFW: :28	NFW: :19
140	NFW: :37	NFW: :22	NFW: :13	NFW: :33	NFW: :21	NFW: :12
150	NFW: :28	NFW: :15	NFW: : 9	NFW: :26	NFW: :14	NFW: : 9
160	NFW: :19	NFW: :11	NFW: : 7	NFW: :19	NFW: :10	NFW: : 7
170	NFW: :15	NFW: : 9	NFW: : 6	NFW: :15	NFW: : 9	NFW: : 6

*From the US Army Research Institute of Environmental Medicine, Military Ergonomics Division. Data reflects the following assumptions:

Uniform = Desert Camouflage for desert estimates
Battle Dress for European estimates
Wind Speed = Calm
Sky Cover = Clear
Acceptable Casualty Rate = Low (less than 5%)
Relative Humidity = 20% for desert estimates
50% for European estimates

**Estimates are in minutes. The format in each column is:
work time : rest time : maximum one-time work rate

NL = No Limit. People can work continuously with little danger of heat induced injury.

NFW = No Further Work. There is no acceptable balance of work and rest periods which would allow the work-rest cycle to continue indefinitely, and still ensure a low casualty rate.

Figure A-2

c. The maximum one-time work rate is the longest time period that a crew can safely work at a given temperature without any rest breaks. At the end of this continuous work activity, the crew members must spend several hours recuperating before undertaking other activities. If a crew is worked beyond the recommended maximum one-time work rate, then they can be expected to suffer a heat stress casualty rate greater than 5 percent.

d. Figure A-2 shows that beginning at temperatures as low as 100° F, and for moderate and heavy work levels, no work-rest cycle can assure a low casualty rate. There is, therefore, a danger associated with working crews continuously at these temperatures. Even with frequent breaks for rest and drinking, continuous work schedules will very likely result in moderate to heavy numbers of heat casualties.

e. The USARIEM algorithms are based on the following assumptions:

(1) That the level of metabolic exertion remains constant throughout the work-rest cycle. Rarely will a person maintain a constant metabolic rate over the course of a task. Normally crew members will alternate between light, moderate, and heavy work levels during a work-rest cycle. Workers will stop what they are doing to wipe their brows, to remove their shirts, to say a few brief words to a coworker, to receive new guidance, or to perform an unlimited number of other activities that expend little energy. When a person pauses during the task for these other activities, the body rests and cools slightly. These periods, while seeming insignificant in themselves, when totalled over the course of an hour represent a substantial amount of rest.

(2) That the average population is physically fit. Approximately 5 percent of the general population will never acclimate to hot weather--hence, the 5-percent casualty rate.

(3) That the data for Europe measures the effects for workers dressed in Battle Dress Uniform. Engineer crews working in the desert are assumed to wear Desert Camouflage Uniform.

(4) That for both the European and the desert climates, the wind is calm and the sky is clear of cloud cover.

(5) That the typical commander of an engineer work crew wants to limit heat casualties to no more than 5 percent of the work force.

f. Because quantitative work-rest cycle entries are few in number, the maximum one-time work rates are used to develop comparative ratios between European work rates and desert work rates. These ratios can then be used to degrade work effort estimated under European weather conditions.

g. Ratios were obtained by dividing the maximum one-time work rates for each work level and temperature by the maximum one-time work rate for the same work level at the European temperature.

(1) To allow comparisons at all temperatures and work levels, a value of 120 minutes was substituted for the notation "NL" in Figure A-2. The USARIEM algorithms assumed that, if a calculation resulted in a maximum one-time work rate of 2 hours or more, then there was no limit (NL) to the length of the allowable work period.

(2) Each of the maximum one-time work rates for light work was divided by the work rate for acclimated troops performing light work in a European climate. Each of the one-time work rates for moderate work was divided by the rate for moderate work performed in a European climate. Each of the one-time work rates for heavy work was divided by the rate for heavy work performed in a European climate. Figure A-3 shows the resulting ratios.

h. The ratios in Figure A-3 are used in conjunction with Figure A-1 to estimate how much various degrees of heat degrade a worker's performance at different work levels.

(1) Example 1: An acclimated engineer is operating a bulldozer in 120° F heat. Operating a bulldozer requires heavy arm and leg movements, but is basically a sedentary activity. Figure A-1 indicates that "sitting, heavy arm and leg movements" expends from 191 to 235 Watts of energy and falls in the light work category. Figure A-3 gives a factor of 0.52 for light work performed by acclimated workers in 120° F temperatures. Therefore, the bulldozer operator, who would require 1 hour to complete this task in a temperate European climate, completes the task in the desert climate in 1.92 hours--1 hour divided by 0.52.

(2) Example 2: Acclimated engineers are reloading a Ground Emplaced Mine Scattering System (GEMMS) in 110° F heat. They are lifting and carrying heavy cases of mines to the GEMMS, where they break open the case and load the GEMMS conveyor. Figure A-1 indicates that "intermittent heavy lifting, pushing, or pulling" expends from 440 to 586 Watts and falls in the heavy work category. Figure A-3 gives a factor of 0.71 for heavy work performed by acclimated workers in 110° F temperatures. Therefore, the engineers, who would require 0.4 manhours to complete this task in Europe, complete the task in the desert in 0.56 manhours--0.4 divided by 0.71.

i. ESC arbitrarily selected two temperatures as representative of average desert conditions. For tasks performed outside, the air temperature was assumed to be 110° F. For tasks performed in vehicles or inside enclosed structures, the air temperature was assumed to be 120° F. The data in Figures A-2 and A-3 can be used by the reader to examine the work degradation effects at other temperatures.

RATIOS OF DESERT WORK RATES
COMPARED TO EUROPEAN WORK RATES

	ACCLIMATED PERSONNEL Work Levels*			UNACCLIMATED PERSONNEL Work Levels*		
TEMP	Light	Moderate	Heavy	Light	Moderate	Heavy
			EUROPEAN CLIMATE (BASE CASE)			
80	1.00	1.00	1.00	0.62	0.52	0.69
			DRY DESERT CLIMATE			
80	1.00	1.38	1.18	0.72	0.56	0.73
90	1.00	0.97	1.00	0.57	0.51	0.67
100	1.00	0.73	0.84	0.48	0.47	0.63
110**	0.74	0.58	0.71	0.42	0.42	0.57
120	0.52	0.47	0.57	0.36	0.37	0.49
130	0.39	0.37	0.39	0.32	0.33	0.37
140	0.31	0.26	0.25	0.27	0.24	0.24
150	0.23	0.17	0.18	0.22	0.16	0.18
160	0.16	0.13	0.14	0.16	0.12	0.14
170	0.12	0.10	0.12	0.12	0.10	0.12

*These ratios were obtained from the data in Figure A-2. Divide the maximum one-time work rates for each work level and temperature by the maximum one-time work rate for the same work level at the European temperature. A time of 120 minutes is substituted for the "NL" notations in Figure A-2.

Example Number 1: the maximum one-time work rate for light work in 120° F desert temperature is 62 minutes (See Figure A-2). Dividing this by the maximum one-time work rate for light work in Europe, 120 minutes, gives a ratio of 0.52.

Example Number 2: the maximum one-time work rate for heavy work in 130° F desert temperature is 20 minutes. Dividing this by the maximum one-time work rate for heavy work in Europe, 51 minutes, gives a ratio of 0.39.

**At temperatures below the line, there are no work-rest cycles which will hold the heat casualty level to 5 percent or less. Even if commanders enforce rest and drinking periods, work crews worked at these temperatures will suffer moderate to heavy (up to 50%) heat casualties.

Figure A-3

j. Often the task activities identified in this study require longer periods of exertion than are recommended by the maximum one-time work rate specified in Figure A-2. This condition is identified throughout the appendices in this study by an asterisk (*) following the workload factor. If the commander wants to complete the task in the time desired, one of two choices must be made:

(1) The commander of the engineer work crews can knowingly accept moderate-to-heavy numbers of heat casualties. In all likelihood, many crew members will not be available for other activities for several days after. If the commander continues to work the crews at this rate, the engineer force will soon be decimated.

(2) The work crew size can be increased so that two or more shifts can be used to complete the task activity.

10. Engineer Work at Night.

a. Work estimates for work performed during the cooler morning or evening hours of the day are provided in the temperate weather workload charts included in each appendix to Annexes B through D of this report. However, no such estimates are provided for units working at night. FM 5-34 gives several different degradation factors for night work, depending on the activity to which the night factor is applied.[12] The following list of degradation factors was assembled from various sections of the Field Manual.

(1) Hand laying of conventional mines--0.67 (page 56).

(2) Clearing fields of fire--0.67 (page 85).

(3) Emplacing barbed wire entanglement--0.67 (page 109).

(4) River crossing in blackout conditions--0.67 (page 137).

[12] DA, FM 5-34, Engineer Field Data, Washington, D. C., 24 September 1976.

(5) Bailey bridge assembly in blackout conditions--0.67 to 0.5 (page 212).

(6) Heavy equipment efficiency rates--0.9 (page 303).

(7) Night marches in blackout conditions--0.67 to 0.5 (page 381).

(8) Night marches with lights--no degradation (page 381).

b. For estimates of night work degradation, daylight workload estimates should be divided by a degradation factor of 0.67. Since this value is repeated most often in the list above, we assume it is the most accurate for across-the-board applications.

LAST PAGE OF ANNEX A

APPENDIX A-1

WET BULB CHART

APPENDIX A-1

WET BULB CHART

1. Purpose. This appendix presents the traditional Wet Bulb-Dry Bulb chart used to determine if work can be sustained in hot weather.

2. Discussion. Although the chart was not used in the study to estimate workload factors, it is included for information. The Physiological Heat Exposure Limits (PHEL) Chart (Figure A-1-1) linearly describes the safe activity times for acclimated subjects performing relatively easy (A), moderate (B), or heavy work (C).[1]

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[1] DA, Technical Bulletin Medical (TB MED) 507, Prevention, Treatment and Control of Heat Injury, Washington, D. C., July 1980, p. 18.

PHEL CHART

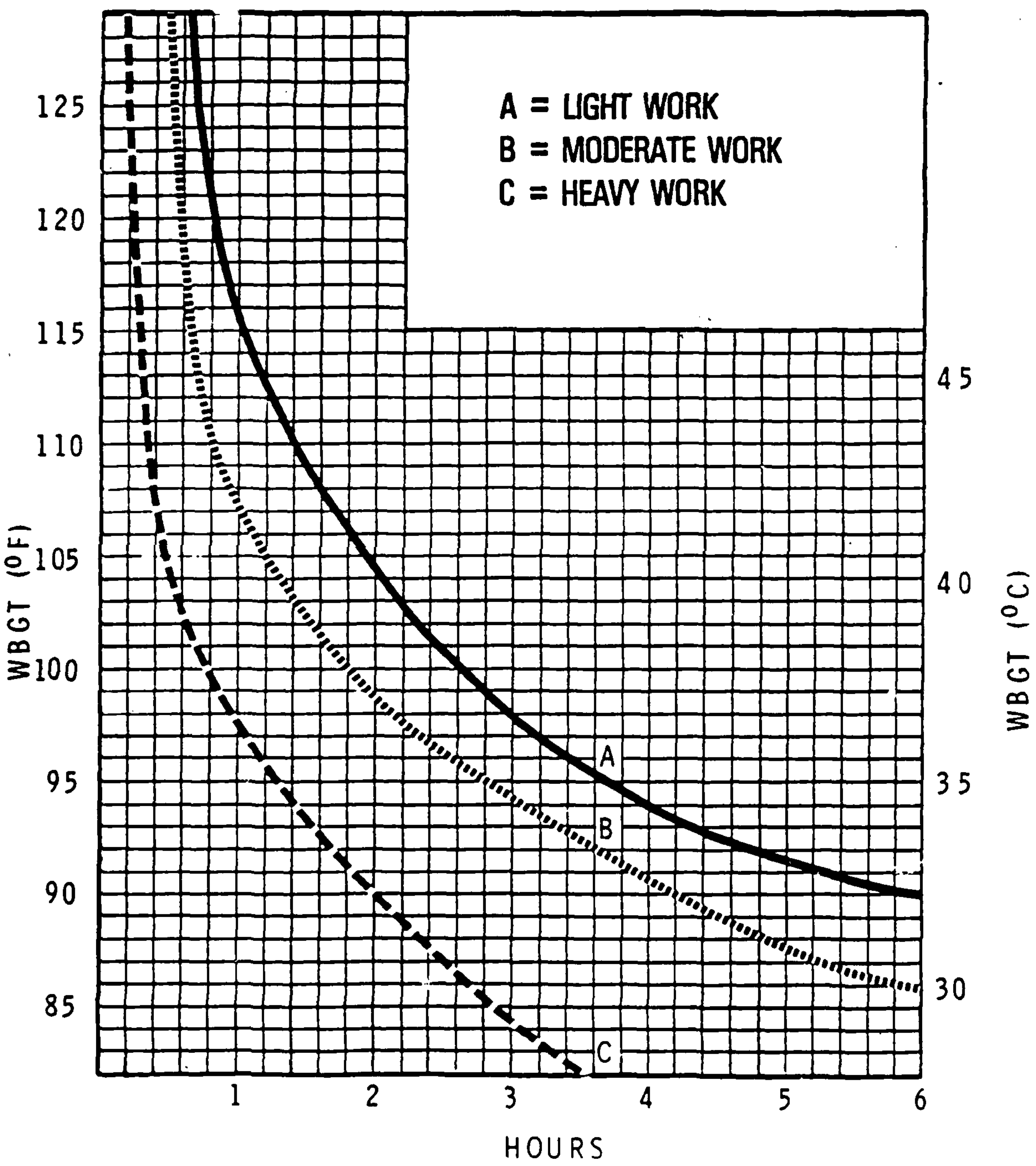

Figure A-1-1

LAST PAGE OF APPENDIX A-1

ANNEX B

SANDY TERRAIN PLANNING FACTORS

ANNEX B

SANDY TERRAIN PLANNING FACTORS

1. Purpose. This annex estimates work production planning factors for combat engineer tasks in the sandy desert.

2. Scope. This analysis quantified the engineer effort required to support committed maneuver brigades and established planning factors for each of those tasks. The time estimates reflect work performed both in temperate weather and in hot, dry weather.

3. Method.

a. The tasks and the workload factors shown in Annex E were the basis for calculating engineer requirements in the sandy desert.

b. Engineering designs were modified, when appropriate, to better protect users and their equipment from the effects of desert winds and intense heat.

c. Workload times were degraded to account for working in both loose sand and intense heat.

4. Discussion.

a. Of the world's 10.5 million square miles of arid land, 20 to 40 percent is covered by deep loose sand in the form of either sand dunes or sandy flats.[1] The largest of these sand expanses are found in the Saharan, Libyan, Syrian, Sinai, and Saudi Arabian deserts. Historically, the sandy deserts have been the land areas the least fought over and the least suitable for protracted warfare. The poor traction of loose sand makes movement by

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[1]DA, YUMA Proving Grounds, Test and Evaluation Directorate, Automotive Division, Desert Testing of Military Vehicles, December 1968, p. 6.

wheeled vehicles extremely slow, while steeply sloped sand dunes make movement difficult for both wheeled and tracked vehicles.

b. Decreased mobility is only one of the problems that face units operating in the sandy desert. Seasonal winds of near-hurricane force generate choking sand and dust storms which impair visibility and damage equipment. The monotony of the landscape and the lack of distinguishable terrain features can easily frustrate navigators. As in all deserts, the sparsity of vegetation for food or shade, the lack of water, and the extreme temperature fluctuations are ever-present deterrents to effective operations.

c. Although sandy deserts are formidable obstacles to operational effectiveness, combat units must be prepared to manuever in those areas. During the North African campaigns, both the Axis and Allied armies conducted successful flanking maneuvers through the sandy interior desert. Today's armies must be prepared to conduct flanking maneuvers around enemy positions which block traditional routes through the deserts. They also must be ready to blunt the enemy's flanking attempts with quick reaction and effective defenses. In both cases, US combat units will need to move quickly and fight effectively in the deep desert sand.

d. As the combat units move into the sandy desert arena they will be accompanied by engineer units. The engineer's ability to provide responsive support to those combat units often will be limited by certain characteristics endemic to the sandy desert. Engineer tasks which require excavation work or earthmoving are more difficult because dry sand is not cohesive like European soils--excavations will fill back up with sand as they are being dug, and the dry sands will flow around the edges of pushing dozer blades.

e. Equipment breaks down more frequently when continuously exposed to blowing sand, dust, and high temperatures. The sand and dust clog air intakes, contaminate fuel and lubricants, abrade exposed surfaces, and scratch lenses and viewports. The hot temperatures cause engines to overheat, lubricants to lose their viscosity, and parts to expand beyond their prescribed tolerances. The Afrika Korps found that Volkswagen engines, which had useful lives of 50 to 70,000 kilometers in other wartime theaters, only lasted 12 to 14,000 kilometers in the North African desert.[2] Tank engines were replaced every 3500 kilometers versus 7 to 8000 kilometers in other theaters of operation.[3]

5. Work Rate Degradation for Sandy Deserts.

a. Work production rates for bulldozers were estimated using the method described on pages 41 through 45 of the Caterpillar Handbook.[4]

(1) Figures E-1 through E-2 in Annex E are reprinted from pages 42 through 44 of the Caterpillar Handbook. Figures E-1 and E-2 display the maximum production rates for the various dozer/blade combinations indicated. Figure E-3 lists the correction factors that may modify the maximum production rates. Finally, Figure E-4 notes the effect on production rates of various slope gradients. The following correction factors are used to typify conditions at work sites in the sandy desert:

(a) Operator (average) = 0.75. Workrate estimates assume that dozer operators have average abilities.

(b) Material = 0.80. Noncohesive sand.

(c) Slot dozing = 1.2. Whenever possible, engineer dozer operators are assumed to use slot dozing techniques.

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[2] Alfred Toppe, Desert Warfare, German Experience in World War II, Manuscript, Historical Division European Command, 1952, p. 56.

[3] Desert Warfare, p. 56.

[4] Caterpillar Tractor Company, Caterpillar Performance Handbook, Edition 15, Peoria, IL, 1984.

(d) Job efficiency (60 minutes/hour) = 1.0. This correction factor is more appropriate for long-term projects. The tasks described in this annex require a much shorter time to complete. This factor, therefore, is set to 1.0 for requirements estimates.

(e) Grade = 1.0. An average grade of 0 percent is assumed for terrain in Sandy Deserts (see Figure E-4).

(f) Soil density (dry sand) = 0.96. The density of the material on which the tables are based (2300 lb/loose cubic yard) (LCY) is divided by the density of dry, loose sand (2400 lb/LCY).

(g) The total correction factor applied to the maximum dozer production rates is:

$$(0.75)\ (0.8)\ (1.2)\ (1.0)\ (1.0)\ (0.96) = 0.69$$

(2) Figures B-1 and B-2 show the production rates for the D7 and D5 dozer, respectively. The rates are shown for various average dozing distances. The values in the first row are read from Figures E-1 and E-2 in Annex E. These values represent, in loose cubic yards per hour, the maximum production rates of the D7 and D5 dozers with straight dozer blades. The values in the second row are the conversion to bank cubic yards per hour; this is done by multiplying the values in the first row by the load factor of 0.89 for dry, loose sand.[5] Finally, the third row displays the production rates which result from multiplying the values in the second row by the correction factor of 0.69. These last rates are used to estimate the dozer excavation requirements for the tasks described in this annex.

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[5] Caterpillar Performance Handbook, p. 586.

PRODUCTION RATES FOR D7 DOZER

(SANDY DESERT)

	PUSH DISTANCE (FEET)					
	50	75	100	125	150	200
LCY/HOUR	760	580	460	400	350	280
BCY/HOUR	676	516	409	356	312	249
CORRECTED RATE	466	356	282	246	215	172

Figure B-1

PRODUCTION RATES FOR D5 DOZER

(SANDY DESERT)

	PUSH DISTANCE (FEET)					
	50	75	100	125	150	200
LCY/HOUR	460	375	300	250	200	150
BCY/HOUR	409	334	267	223	178	134
CORRECTED RATE	282	230	184	154	123	92

Figure B-2

b. The M9 ACE has earthmoving and bulldozing characteristics comparable to the D7 dozer.[6,7] The appendices, therefore, show identical estimates for the D7 and the M9.

c. It was estimated that the excavation rate for the SEE would be the same as its rate in typical European soil. The SEE's decreased bucket payload when working in sand (a 95- to 100-percent versus a 100- to 110-percent fill factor) is offset by an equivalent increase in the number of cycles the SEE can complete per hour.[8] The resistance offered by the sand to the SEE's digging efforts is less than the resistance offered by common earth.

d. The workload estimates given in the appendices for sand excavations take into account the collapsing sides of the excavation by increasing the volume of sand that must be removed.

e. The Caterpillar Handbook was the basis for estimating scoop loader rates for both the 2-1/2 cubic yard scoop loader and the 3/4 cubic yard SEE.

(1) The production rate in sand for the 2-1/2 cubic yard loader is 207.1 LCY per hour. Figure B-3 shows the steps followed to estimate scoop loader and SEE production rates. To account for the poor traction in sand, an average basic cycle time of 0.7 minutes was selected.

(2) The production rate in sand for the SEE is 65.3 LCY/hour.

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[6] DA, Field Manual (FM)-103, Survivability, Draft, p. A-2.
[7] DA, Combat Engineer System Handbook, June 1984, p.67.
[8] Caterpillar Performance Handbook, p. 356.

PRODUCTION ESTIMATES FOR THE 2-1/2-CUBIC-YARD SCOOP LOADER AND THE SEE

(SANDY DESERT)

FACTOR NAME	BASIC CYCLE TIME	+	MATERIAL TYPE (BROKEN EARTH)	+	DOZER PILED	+	CONSTANT OPERATION	=	TOTAL CYCLE TIME
SCOOP LOADER	0.70		0.02		0.01		-0.04		0.69
SEE	0.70		0.02		0.01		-0.04		0.69

FACTOR NAME	(60)	÷	TOTAL CYCLE TIME	=	CYCLES PER HOUR	X	LCY PER CYCLE	=	LCY PER HOUR
SCOOP LOADER			0.69		87.0		2.38		207 1
SEE			0.69		87.0		0.71		65.3

Figure B-3

LAST PAGE OF ANNEX B

APPENDIX B-1

BUILD A PROTECTIVE POSITION FOR AN ARMORED VEHICLE

APPENDIX B-1

BUILD A PROTECTIVE POSITION FOR AN ARMORED VEHICLE

1. Terrain. Sandy Desert.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator and one engineer to confer with users and to guide the equipment to the position site.

a. The planning factors displayed in this appendix are appropriate for:

(1) Personnel carriers

(2) Infantry TOW carriers

(3) Armored car tow carriers

(4) Armored car personnel carriers

(5) Infantry fighting vehicles

(6) Cavalry fighting vehicles

(7) Armored tank

(8) Armored car tank

(9) Artillery personnel carrier (FIST)

(10) Counter battery/counter mortar radar

(11) Self-propelled vulcan

(12) Infantry command post carrier

(13) Armored command post carrier

(14) Towed artillery command post carrier

(15) Infantry mortar carrier

(16) Armored cavalry mortar carrier

(17) Armored mortar carrier

(18) Brigade headquarters command post carrier[1]

b. The excavated position is 4.2 meters wide and 1.5 meters deep. It has a 7-meter-long floor and an entrance ramp with a 9-degree slope. To ease earthmover entry into the excavation a sloped face of 1:1.5 is adequate.[2] These dimensions are identical to those detailed in Appendix E-1. However, because of the non-cohesiveness of the sand, the sides of the excavation are assumed to collapse until they stabilize at an angle of 45^{o} (See Figure B-1-1).

c. The volume of earth that must be excavated is equal to the volume estimated in Appendix E-1 (81.1 m^3) plus the added volume created by the collapsed sides.

$$(81.1) + 2\ [(0.5)\ (d)\ (d)\ (1) + (1/6)\ (d)\ (d)\ (1.5)\ (d) + (0.167)\ (d)\ (d)\ (\mathrm{ctn}\ 9^{o})\ (d)] =$$

$$(8.1) + (2)\ [0.5]\ (1.5)\ (1.5)\ (7) + (0.167)\ (1.5)\ (1.5)\ (1.5)\ (1.5) + (0.167)\ (1.5)\ (1.5)\ (6.3)\ (1.5)] =$$

$$(81.1) + 2\ (7.88 + 0.84 + 3.54) = 105.62\ m^3$$
or 138.15 BCY

3. Workload Estimates.

a. Temperate weather. Figures B-1-2 and B-1-3 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) D7 Dozer and M9 ACE Production.

(a) Assume a push distance of 75 feet which, from Figure B-1, gives a production rate of 356 BCY/hour:

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[1] DA, Survivability--the Effort and the Payoff, June 1981, p. 30.
[2] DA, Engineer Family of Systems Study, Volume N, pp. N-III-q-2 through N-III-q-5.

(138.15 BCY) / (356 BCY/hour) = 0.39 hours

(b) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes locating an appropriate site for the position and guiding the dozer or M9 to the site. Concurrently, the dozer or M9 requires an additional 5 minutes to move from position site to position site within the defensive perimeter:

(0.39) + (0.08) = 0.47 hours

(2) D5 Dozer Production.

(a) Assume a push distance of 75 feet which, from Figure B-2, gives a production rate of 230 BCY/hour:

(138.15 BCY) / (230 BCY/hour) = 0.60 hours

(b) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

(0.60) + (0.08) = 0.68 hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-1-4 and B-1-5. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site in loose sand is moderate work according to Figure A-1. At 110^{o} F, Figure A-3 provides a degradation factor of 0.58.

(0.05) / (0.58) = 0.09 hours

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120^{o} F, Figure A-3 provides a degradation factor of 0.52.

(0.47) / (0.52) = 0.90 hours

(0.68) / (0.52) = 1.31 hours

(3) The 1.31 hours required exceeds the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

PROTECTIVE POSITION FOR AN ARMORED VEHICLE

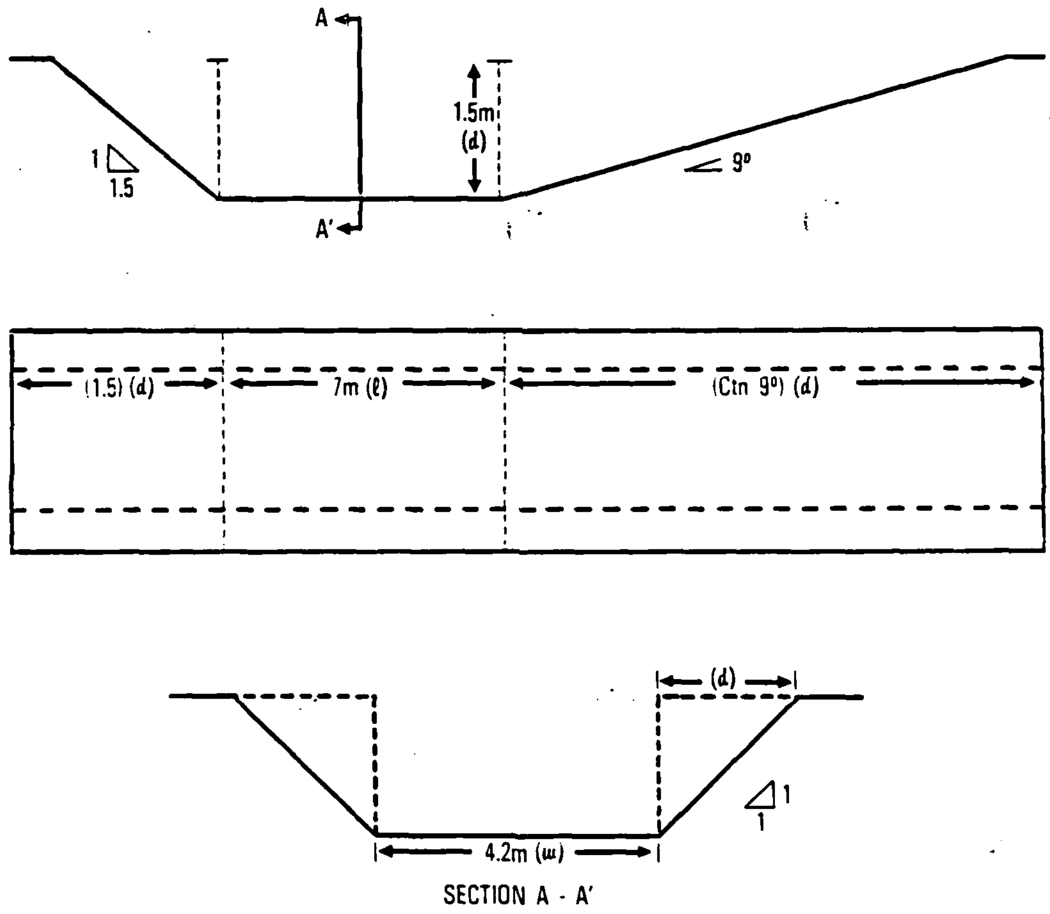

Figure B-1-1

BUILD A PROTECTIVE POSITION
FOR AN ARMORED VEHICLE
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.47	
	Elapsed Time Required To Complete Task	0.47	

Figure B-1-2

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.68	
	Elapsed Time Required To Complete Task	0.68	

Figure B-1-3

BUILD A PROTECTIVE POSITION
FOR AN ARMORED VEHICLE
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Excavate	0.90	
	Elapsed Time Required To Complete Task	0.90	

Figure B-1-4

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Excavate	1.31*	
	Elapsed Time Required To Complete Task	1.31	

Figure B-1-5

LAST PAGE OF APPENDIX B-1

APPENDIX B-2

BUILD A PROTECTIVE POSITION FOR A 1/4-TON MOUNTED TOW

APPENDIX B-2

BUILD A PROTECTIVE POSITION FOR A 1/4-TON MOUNTED TOW

1. Terrain. Sandy Desert.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator and one engineer to confer with users and to guide the equipment to the position site.

a. The excavated position is 5 meters wide and 1 meter deep. It has a 8.5-meter-long floor and an entrance ramp with a 9-degree slope. To ease earthmover entry into the excavation a sloped face of 1:1.5 is adequate.[1] These dimensions are identical to those detailed in Appendix E-2. However, because of the non-cohesiveness of the sand, the sides of the excavation collapse into the dig until they stabilize at an angle of 45°.

b. The volume of earth that must be excavated is equal to the volume estimated in Appendix E-2 (62 m^3) plus the added volume created by the collapsed sides. See Figure B-2-1.

$$(62) + 2\ [(0.5)\ (d)\ (d)\ (1) + (0.167)\ (d)\ (d)\ (1.5)\ (d) + (0.167)\ (d)\ (d)\ (\mathrm{ctn}\ 9^\circ)\ (d)] =$$

$$(62) + (2)\ [(0.5)\ (1)\ (1)\ (8.5) + (0.167)\ (1)\ (1)\ (1.5)\ (1) + (0.167)\ (1)\ (1)\ (6.3)\ (1)] =$$

$$(62) + 2\ (4.25 + 0.25 + 1.05) = 73.10\ m^3$$
or 95.61 BCY

3. Workload Estimates.

a. Temperate weather. Figures B-2-2 and B-2-3 present the workload estimates for sandy desert terrain under temperate weather conditions. The method used to compute estimates is as follows:

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[1] DA, FM 5-103, Survivability, 1985 Draft, pp. 4-18.

(1) D7 Dozer and M9 ACE Production.

(a) Assume a push distance of 75 feet which, from Figure B-1, gives a production rate of 356 BCY/hour:

(95.61 BCY) / (356 BCY/hour) = 0.27 hours

(b) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes locating an appropriate site for the position and guiding the dozer or M9 to the site. Concurrently, the dozer or M9 requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

(0.27) + (0.08) = 0.35 hours

(2) D5 Dozer Production.

(a) Assume a push distance of 75 feet which, from Figure B-2, gives a production rate of 230 BCY/hour:

(95.61 BCY) / (230 BCY/hour) = 0.42 hours

(b) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

(0.42) + (0.08) = 0.50 hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-2-4 and B-2-5. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site in loose sand is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

(0.05) / (0.58) = 0.09 hours

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

$$(0.35) / (0.52) = 0.67 \text{ hours}$$

$$(0.50) / (0.52) = 0.96 \text{ hours}$$

PROTECTIVE POSITION FOR A ¼-TON MOUNTED TOW

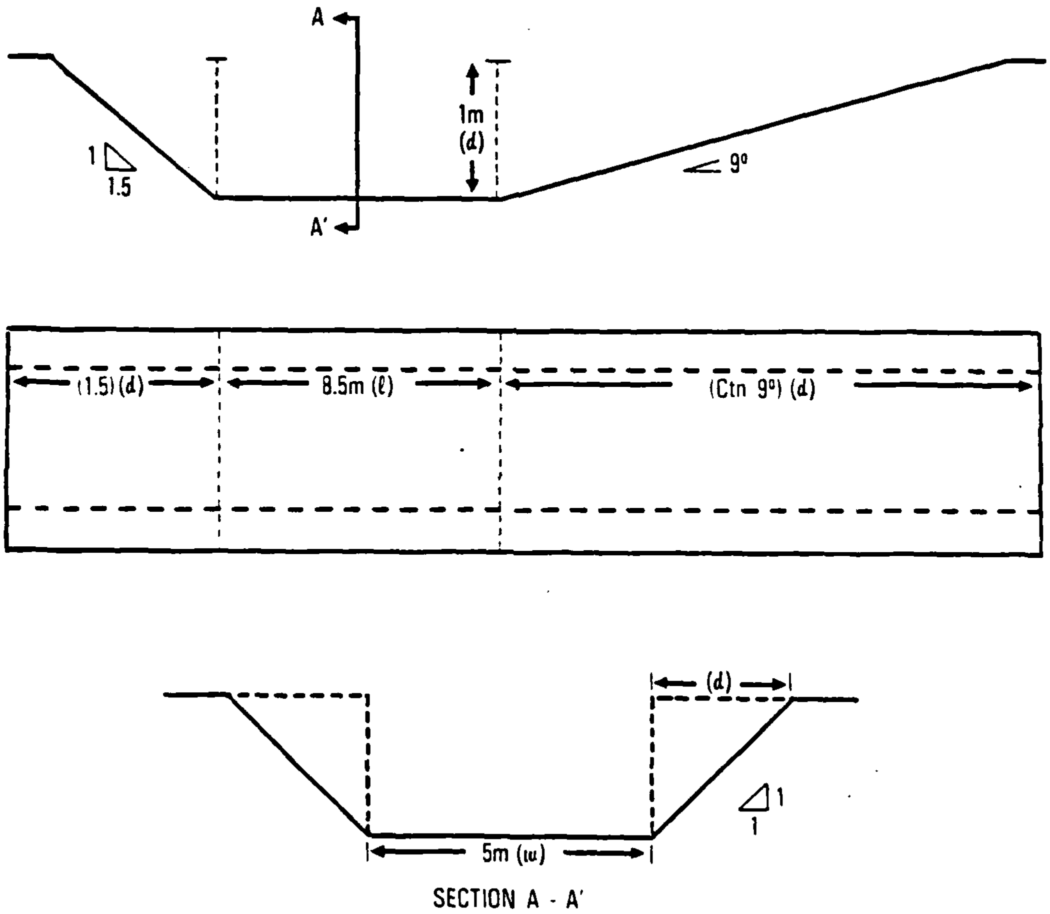

Figure B-2-1

BUILD A PROTECTIVE POSITION FOR A
1/4-TON MOUNTED TOW
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.35	
	Elapsed Time Required To Complete Task	0.35	

Figure B-2-2

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.50	
	Elapsed Time Required To Complete Task	0.50	

Figure B-2-3

BUILD A PROTECTIVE POSITION FOR A
1/4-TON MOUNTED TOW
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Excavate	0.67	
	Elapsed Time Required To Complete Task	0.67	

Figure B-2-4

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Excavate	0.96	
	Elapsed Time Required To Complete Task	0.96	

Figure B-2-5

LAST PAGE OF APPENDIX B-2

APPENDIX B-3

BUILD A PROTECTIVE POSITION FOR A NON-ARMORED VEHICLE

APPENDIX B-3

BUILD A PROTECTIVE POSITION FOR A NON-ARMORED VEHICLE

1. Terrain. Sandy Desert.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator, one 2-1/2-cubic-yard scoop loader with operator, and one engineer to confer with users and to guide the equipment to the position site.

a. The planning factors displayed in Figures B-3-2 through B-3-5 are appropriate for the 1/4-ton, 3/4-ton, 1-1/4-ton, 2-1/2-ton, and 5-ton cargo trucks with their trailers.[1]

b. The excavated position is 3.5 meters wide and 1.5 meters deep. It has a 10.5-meter-long floor and an entrance ramp with a 9-degree slope. There is a 0.75-meter-high parapet along both sides of the cut. To ease earthmover entry into the excavation a sloped face of 1:1.5 is adequate.[2] These dimensions are identical to those detailed in Appendix E-3. However, because of the non-cohesiveness of the sand, the sides of the excavation collapse into the dig until they stabilize at an angle of 45°. See Figure B-3-1.

c. The volume of earth that must be excavated is equal to the volume estimated in Appendix E-3 (85.8 m^3) plus the added volume created by the collapsed sides.

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[1] DA, Engineer Family of Systems Study, Volume N, p. N-III-u-1.
[2] E-FOSS, p. N-III-u-1.

$(85.8) + 2 [(0.5) (d) (d) (1) + (0.167) (d) (d) (1.5) (d) + (0.167) (d) (d) (ctn 9^{o}) (d)] =$

$(85.8) + 2 [(0.5) (1.5) (1.5) (10.5) + (0.167) (1.5) (1.5) (1.5) (1.5) + (0.167) (1.5) (1.5) (6.3) (1.5)] =$

$(85.8) + 2 [(11.81) + (0.84) + (3.54)] = 118.18 \text{ m}^3$
or 154.58 BCY

3. Workload Estimates.

a. Temperate weather. Figures B-3-2 and B-3-3 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) D7 Dozer and M9 ACE Production.

(a) Assume a push distance of 75 feet which, from Figure B-1, gives a production rate of 356 BCY/hour:

(154.58 BCY) / (356 BCY/hour) = 0.43 hours

(b) While the dozer excavates the scoop loader forms the parapets.

(c) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes locating an appropriate site for the position and guiding the dozer or the M9 to the site. Concurrently, the dozer or M9 requires an additional 5 minutes to move from position site to position site within the defensive perimeter:

(0.43) + (0.08) = 0.51 hours

(2) D5 Dozer Production.

(a) Assume a push distance of 75 feet which, from Figure B-2, gives a production rate of 230 BCY/hour:

(154.58 BCY) / (230 BCY/hour) = 0.67 hours

(b) While the dozer excavates the scoop loader forms the parapets.

(c) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

$$(0.67) + (0.08) = 0.75 \text{ hours}$$

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-3-4 and B-3-5. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site in loose sand is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(0.05) / (0.58) = 0.09 \text{ hours}$$

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

$$(0.51) / (0.52) = 0.98 \text{ hours}$$

$$(0.75) / (0.52) = 1.44 \text{ hours}$$

(3) The 1.44 hours required exceeds the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

PROTECTIVE POSITION FOR A NON-ARMORED VEHICLE

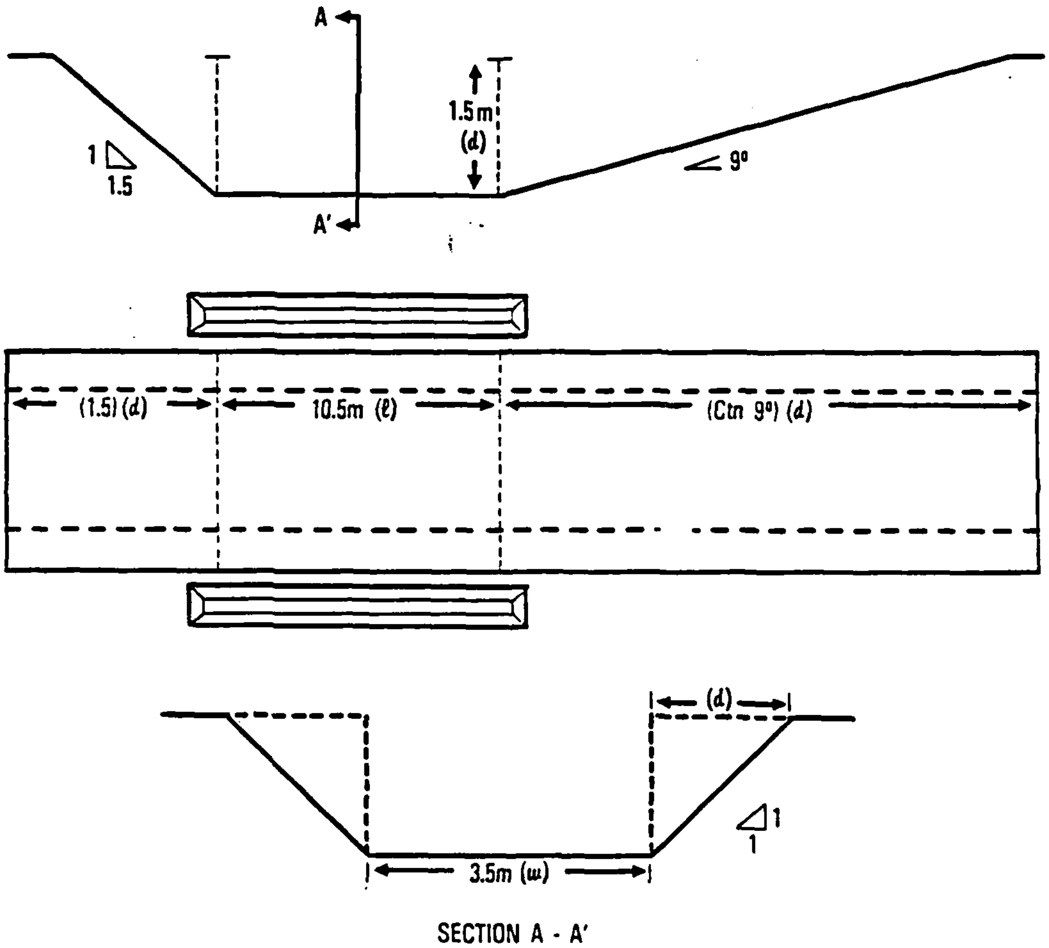

Figure B-3-1

BUILD A PROTECTIVE POSITION FOR A
NON-ARMORED VEHICLE
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	0.51	0.51	
	Elapsed Time Required To Complete Task	0.51		

Figure B-3-2

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	0.75	0.75	
	Elapsed Time Required To Complete Task	0.75		

Figure B-3-3

BUILD A PROTECTIVE POSITION FOR A
NON-ARMORED VEHICLE
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
Number of Items		1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.09
	Excavate	0.98	0.98	
Elapsed Time Required To Complete Task		0.98		

Figure B-3-4

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		D5 Dozer	2.5-CY Loader	Combat Engr
Number of Items		1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.09
	Excavate	1.44*	1.44*	
Elapsed Time Required To Complete Task		1.44		

Figure B-3-5

LAST PAGE OF APPENDIX B-3

APPENDIX B-4

BUILD A PROTECTIVE POSITION FOR A FORWARD AREA ALERTING RADAR (FAAR)

APPENDIX B-4

BUILD A PROTECTIVE POSITION FOR A FORWARD AREA ALEPTING RADAR (FAAR)

1. Terrain. Sandy Desert.

2. Method of Construction.

a. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator, one 2-1/2-cubic-yard scoop loader with operator, and one engineer to confer with users and to guide the equipment to the position site.

b. The position is enclosed by a berm around three sides. The floor of the position is 6.7 meters by 7.6 meters while the berm is 1 meter wide at the top and 2.7 meters high with sloping sides of 1:1.[1] The volume of earth that must be moved to form the berm is equal to the volume estimated in Appendix E-4: 362.7 BCY.

3. Workload Estimates.

a. Temperate weather. Figures B-4-1 and B-4-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) D7 dozer/scoop loader and M9 ACE/scoop loader production.

(a) Assume a push distance of 75 feet which, from Figure B-1, gives a production rate of 356 BCY/hour. Because the operator cannot use slot dozing techniques, this rate is reduced by one-sixth (see Annex B, paragraph 5a(1)(c), page B-4.

(362.7 BCY) (1.2)/ (356 BCY/hour) = 1.22 hours

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[1]Taken from notes written by Mr. Eugene Ehrlich during the preparation of the report, Survivability--the Effort and the Payoff, June 1981.

(b) As the dozer or M9 pushes earth into piles generally conforming to the outline of the position, the scoop loader forms the berm. The scoop loader requires 5 additional minutes after the dozer has finished to complete the shaping of the berm.

(1.22) + (0.08) = 1.30 hours

(c) Assume that the combat engineer spends about 3 minutes with the supported unit locating an appropriate site for the position and guiding the dozer to the site. No additional time is added to account for intra-perimeter movement between positions because of the limited number of such positions within a defensive perimeter.

(2) D5 Dozer/Scoop Loader Production.

(a) Assume a push distance of 75 feet which, from Figure B-2, gives a production rate of 230 BCY/hour. For the same reasons stated above, reduce this rate by one-sixth.

(362.7 BCY) (1.2)/ (230 BCY/hour) = 1.89 hours

(b) As above, the scoop loader forms the berm as the D5 dozer excavates. An additional 5 minutes is required after the dozer is finished.

(1.89) + (0.08) = 1.97 hours

(c) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity and no intra-perimeter movement for the equipment.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-4-3 and B-4-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site in loose sand is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

(0.05) / (0.58) = 0.09 hours

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(1.30) / (0.52) = 2.50 hours

(1.97) / (0.52) = 3.79 hours

(3) The 2.50 and the 3.79 hours required exceeds the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

BUILD A PROTECTIVE POSITION FOR A
FORWARD AREA ALERTING RADAR (FAAR)
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	1.22	1.30	
	Elapsed Time Required To Complete Task	1.30		

Figure B-4-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	1.89	1.97	
	Elapsed Time Required To Complete Task	1.97		

Figure B-4-2

BUILD A PROTECTIVE POSITION FOR A
FORWARD AREA ALERTING RADAR (FAAR)
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.09
	Excavate	2.42*	2.50*	
	Elapsed Time Required To Complete Task	2.50		

Figure B-4-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.09
	Excavate	3.71*	3.79*	
	Elapsed Time Required To Complete Task	3.79		

Figure B-4-4

LAST PAGE OF APPENDIX B-4

APPENDIX B-5

BUILD A PROTECTIVE POSITION FOR A PULSE AQUISITION RADAR (PAR)

APPENDIX B-5

BUILD A PROTECTIVE POSITION FOR A PULSE AQUISITION RADAR (PAR)

1. Terrain. Sandy Desert.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator and one engineer to confer with users and to guide the equipment to the position site. This engineer team is supplemented with the 2-1/2-cubic-yard scoop loader and operator from the Hawk battery.

a. The workload factors shown in Figures B-5-1 through B-5-4 are appropriate for the following components of the Hawk air defense system:

(1) Pulse Aquisition Radar

(2) Range Only Radar

(3) Constant Wave Acquisition Radar

(4) High Power Radar

b. The position is enclosed by a berm around three sides. The floor of the position is 6.7 meters by 7.6 meters while the berm is 1 meter wide at the top and 1.8 meters high with sloping sides of 1:1.[1] The volume of earth that must be moved to form the berm is equal to the volume estimated in Appendix E-5: 164.0 BCY.

3. Workload Estimates.

a. Temperate weather. Figures B-5-1 and B-5-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

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[1]Taken from interview notes written by Mr. Eugene Ehrlich during the preparation of the report, Survivability--the Effort and the Payoff, June 1981.

(1) D7 Dozer and M9 ACE Production.

(a) Assume a push distance of 75 feet which, from Figure B-1, gives a production rate of 356 BCY/hour. Because the dozer operator cannot use slot dozing techniques, this rate is reduced by one-sixth (see Annex B, paragraph 5a(1)(c), page B-4).

(164.0 BCY) (1.2)/ (356 BCY/hour) = 0.55 hours

(b) As the dozer excavates and piles the earth, the loader from the battery forms the berm. The loader continues to work after the dozer has finished piling earth. However, the estimate of engineer effort ends when the dozer is finished.

(c) Assume that the combat engineer spends about 3 minutes with the supported unit locating an appropriate site for the position and guiding the dozer to the site. No additional time is added to account for intra-perimeter movement between positions because of the limited number of such positions within a defensive perimeter.

(2) D5 Dozer Production.

(a) Assume a push distance of 75 feet which, from Figure B-2, gives a production rate of 230 BCY/hour. For the same reasons stated above, reduce this rate by one-sixth.

(164.0 BCY) (1.2)/ (230 BCY/hour) = 0.86 hours

(b) As above, the additional loader time necessary to complete the position is not included in the time estimate.

(c) As above for the D7 and M9, assume the combat engineer takes about 3 minutes to complete his activity and no intra-perimeter movement for the equipment.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-5-3 and B-5-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site in loose sand is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(0.05) / (0.58) = 0.09 \text{ hours}$$

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

$$(0.55) / (0.52) = 1.06 \text{ hours}$$

$$(0.86) / (0.52) = 1.65 \text{ hours}$$

(3) The 1.06 and 1.65 hours required exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

BUILD A PROTECTIVE POSITION FOR A
PULSE AQUISITION RADAR (PAR)
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.55	
	Elapsed Time Required To Complete Task	0.55	

Figure B-5-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.86	
	Elapsed Time Required To Complete Task	0.86	

Figure B-5-2

BUILD A PROTECTIVE POSITION FOR A
PULSE AQUISITION RADAR (PAR)
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Excavate	1.06*	
	Elapsed Time Required To Complete Task	1.06	

Figure B-5-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Excavate	1.65*	
	Elapsed Time Required To Complete Task	1.65	

Figure B-5-4

LAST PAGE OF APPENDIX B-5

APPENDIX B-6

BUILD A PROTECTIVE POSITION FOR A SELF-PROPELLED HOWITZER

APPENDIX B-6

BUILD A PROTECTIVE POSITION FOR A SELF-PROPELLED HOWITZER

1. Terrain. Sandy Desert.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator, one 2-1/2-cubic-yard scoop loader with operator, and one engineer to confer with users and to guide the equipment to the position site.

a. The planning factors displayed in Figures B-6-2 through B-6-5 are appropriate for the following self-propelled artillery pieces. Moreover, the position includes enough room for the M548 6-ton ammunition carrier.

(1) M109 155-mm self-propelled howitzer

(2) M55 8-in self-propelled howitzer

(3) M110 8-in self-propelled howitzer[1]

b. The excavated position is 5.4 meters wide and 1.5 meters deep. It has a 21-meter-long floor and an entrance ramp with a 9-degree slope. To ease earthmover entry into the excavation a sloped face of 1:1.5 is adequate.[2] These dimensions are identical to those detailed in Appendix E-6. However, because of the non-cohesiveness of the sand, the sides of the excavation collapse into the dig until they stabilize at an angle of 45°. See Figure B-6-1.

c. The volume of earth that must be excavated is equal to the volume estimated in Appendix E-6 (217.5 m^3) plus the added volume created by the collapsing sides.

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[1]DA, Engineer Family of Systems Study, Volume N, pp. N-III-v-1 and N-III-v-2.

[2]Engineer Family of Systems Study, p. N-III-v-4.

$$(217.5) + 2\,[(0.5)\,(d)\,(d)\,(1) + (0.167)\,(d)\,(d)\,(1.5)\,(d) + (0.167)\,(d)\,(d)\,(\text{ctn } 9^{o})\,(d)] =$$

$$(217.5) + (2)\,[(0.5)\,(1.5)\,(1.5)\,(21) + (0.167)\,(1.5)\,(1.5)\,(1.5)\,(1.5) + (0.167)\,(1.5)\,(1.5)\,(6.3)\,(1.5)] =$$

$$(217.5) + 2\,[(23.63) + (0.84) + (3.54)] = 273.5 \text{ m}^3$$
or 357.74 BCY

3. Workload Estimates.

a. Temperate weather. Figures B-6-2 and B-6-3 present the workload estimates, under temperate conditions, for heavy and light equipment teams. the method used to compute estimates is as follows:

(1) D7 dozer/scoop loader production.

(a) Assume a push distance of 75 feet which, from Figure B-1, gives a production rate of 356 BCY/hour:

(357.74 BCY) / (356 BCY/hour) = 1.00 hours

(b) As the dozer excavates, the loader spreads the excavated soil to lessen the likelihood of enemy identification. The loader continues to work about 5 minutes after the dozer finishes:

(1.00) + (0.08) = 1.08 hours

(c) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes locating an appropriate site for the position and guiding the dozer or M9 to the site. Concurrently, the dozer or M9 requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

(1.00) + (0.08) = 1.08 hours

(2) D5 dozer/scoop loader production.

(a) Assume a push distance of 75 feet which, from Figure B-2, gives a production rate of 230 BCY/hour:

(357.74 BCY) / (230 BCY/hour) = 1.56 hours

(b) As above, an additional 5 minutes is added to account for the loader's work time:

(1.56) + (0.08) = 1.64 hours

(c) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

(1.56) + (0.08) = 1.64 hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-6-4 and B-6-5. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site in loose sand is moderate work according to Figure A-1. At 110^{o} F, Figure A-3 provides a degradation factor of 0.58.

(0.05) / (0.58) = 0.09 hours

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120^{o} F, Figure A-3 provides a degradation factor of 0.52.

(1.08) / (0.52) = 2.08 hours

(1.64) / (0.52) = 3.15 hours

(3) The 2.08 and 3.15 hours required exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

PROTECTIVE POSITION FOR A SELF-PROPELLED HOWITZER

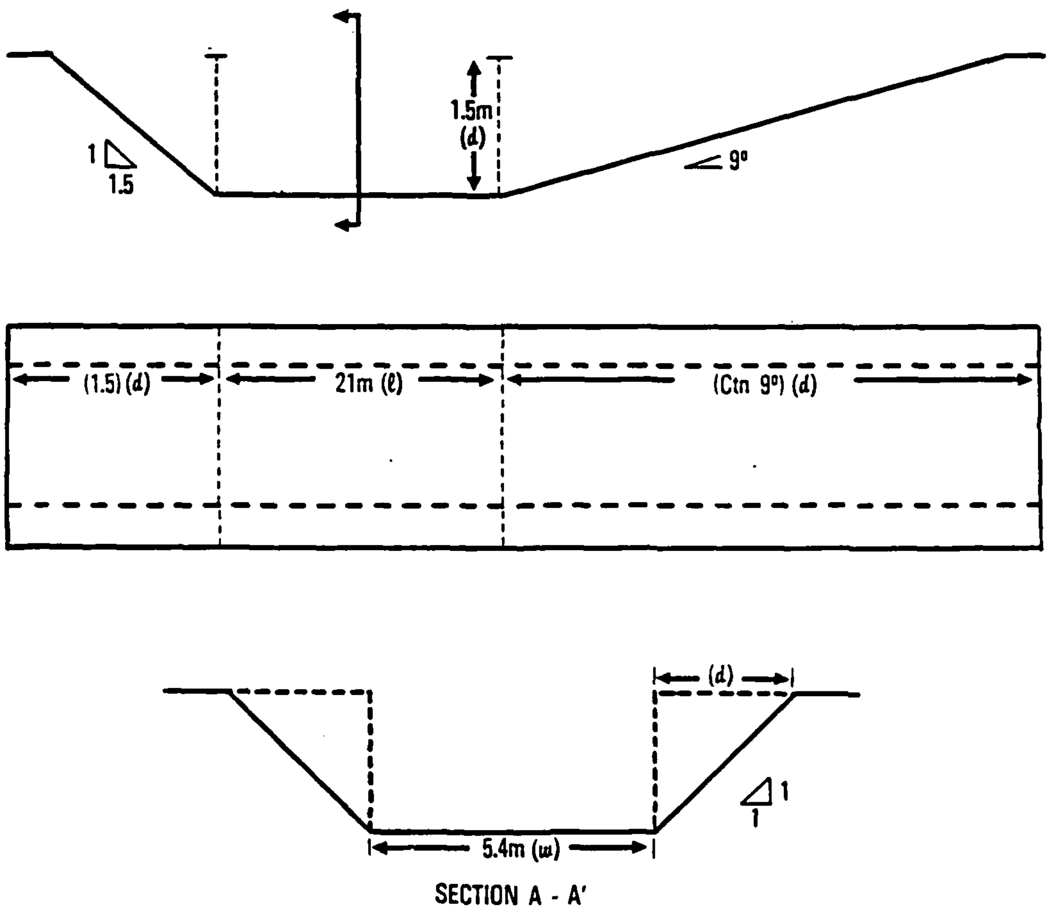

Figure B-6-1

BUILD A PROTECTIVE POSITION FOR A
SELF-PROPELLED HOWITZER
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	1.08	1.08	
	Elapsed Time Required To Complete Task	1.08		

Figure B-6-2

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	1.64	1.64	
	Elapsed Time Required To Complete Task	1.64		

Figure B-6-3

BUILD A PROTECTIVE POSITION FOR A
SELF-PROPELLED HOWITZER
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
Number of Items		1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.09
	Excavate	2.08*	2.08*	
Elapsed Time Required To Complete Task		2.08		

Figure B-6-4

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		D5 Dozer	2.5-CY Loader	Combat Engr
Number of Items		1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.09
	Excavate	3.15*	3.15*	
Elapsed Time Required To Complete Task		3.15		

Figure B-6-5

LAST PAGE OF APPENDIX B-6

APPENDIX B-7

BUILD A PROTECTIVE POSITION FOR A 105-MM TOWED HOWITZER

APPENDIX B-7

BUILD A PROTECTIVE POSITION FOR A 105-MM TOWED HOWITER

1. Terrain. Sandy Desert.

2. Method of Construction.

a. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator and one combat engineer to confer with users and to guide the equipment to the position site.

b. The position is a raised circular earth berm approximately 7 meters in diameter and 0.75 meters high. The berm is 1 meter wide at the top and 3 meters wide at the bottom. There is a 2.5-meter-wide opening in the berm for egress and access.[1] The volume of earth that forms the berm is equal to the volume estimated in Appendix E-7: 45.38 BCY.

3. Workload Estimates.

a. Temperate weather. Figures B-7-1 and B-7-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) D7 dozer and M9 ACE production.

(a) To account for shaping and packing the berm, assume a push distance of 125 feet which, from Figure B-1, gives a production rate of 246 BCY/hour. Because the operator cannot use slot dozing techniques, this rate is reduced by one-sixth (see Annex B, paragraph 5a(1)(c), page B-2.

(45.38 BCY) (1.2)/ (246 BCY/hour) = 0.22 hours

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[1]Taken from notes written by Mr. Eugene Ehrlich during the preparation of the report, Survivability--the Effort and the Payoff, June 1981.

(b) Assume that the combat engineer spends about 3 minutes with the supported unit locating an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer or M9 requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

$$(0.22 \text{ hours}) + (0.08 \text{ hours}) = 0.30 \text{ hours}$$

(2) D5 dozer production.

(a) To account for shaping and packing the berm, assume a push distance of 125 feet which, from Figure B-2, gives a production rate of 154 BCY/hour. For the same reasons stated above, reduce this rate by one-sixth.

$$(45.38)\ (1.2) / \ (154 \text{ BCY/hour}) = 0.35 \text{ hours}$$

(b) As done above for the D7 and M9, assume the combat enigneer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

$$(0.35) + (0.08) = 0.43 \text{ hours}$$

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-7-3 and B-7-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site in loose sand is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(0.05) \ / \ (0.58) = 0.09 \text{ hours}$$

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

$$(0.30) \ / \ (0.52) = 0.58 \text{ hours}$$

$$(0.43) \ / \ (0.52) = 0.83 \text{ hours}$$

BUILD A PROTECTIVE POSITION FOR A
105-MM TOWED HOWITZER
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Build Berm	0.30	
	Elapsed Time Required To Complete Task	0.30	

Figure B-7-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Build Berm	0.43	
	Elapsed Time Required To Complete Task	0.43	

Figure B-7-2

BUILD A PROTECTIVE POSITION FOR A
105-MM TOWED HOWITZER
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Build Berm	0.58	
	Elapsed Time Required To Complete Task	0.58	

Figure B-7-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Build Berm	0.83	
	Elapsed Time Required To Complete Task	0.83	

Figure B-7-4

LAST PAGE OF APPENDIX B-7

APPENDIX B-8

BUILD A PROTECTIVE POSITION FOR A 155-MM TOWED HOWITZER

AD-A169 799 WORKLOAD ESTIMATES FOR COMBAT ENGINEERS IN THE DESERT (U) ARMY ENGINEER STUDIES CENTER FORT BELVOIR VA T O ATKINSON ET AL. APR 86 USAESC-R-86-2 2/6

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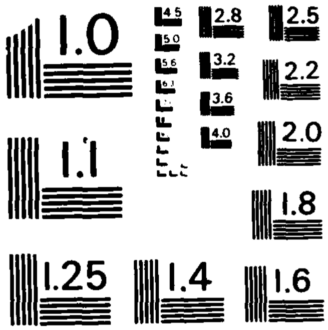

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

APPENDIX B-8

BUILD A PROTECTIVE POSITION FOR A 155-MM TOWED HOWITZER

1. Terrain. Sandy Desert.

2. Method of Construction.

a. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator and one combat engineer to confer with users and to guide the equipment to the position site.

b. The position is a raised circular earth berm approximately 9 meters in diameter and 1 meter high. The berm is 1 meter wide at the top and 3 meters wide at the bottom. There is a 2.5-meter-wide opening in the berm for egress and access.[1] The volume of earth that forms the berm is equal to the volume estimated in Appendix E-8: 73.66 BCY.

3. Workload Estimates.

a. Temperate weather. Figures B-8-1 and B-8-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) D7 dozer and M9 ACE production.

(a) To account for shaping and packing the berm, assume a push distance of 125 feet which, from Figure B-1, gives a production rate of 246 BCY/hour. Because the operator cannot use slot dozing techniques, this rate is reduced by one-sixth (see Annex B, paragraph 5a(1)(c), page B-4.

$$(73.66 \text{ BCY})\ (1.2)/\ (246 \text{ BCY/hour}) = 0.36 \text{ hours}$$

[1]Taken from notes written by Mr. Eugene Ehrlich during the preparation of the report Survivability--the Effort and the Payoff, June 1981.

(b) Assume that the combat engineer spends about 3 minutes with the supported unit locating an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer or M9 requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

(0.36 hours) + (0.08 hours) = 0.44 hours

(2) D5 dozer production.

(a) To account for shaping and packing the berm, assume a push distance of 125 feet which, from Figure B-2, gives a production rate of 154 BCY/hour. For the same reasons stated above, reduce this rate by one-sixth.

(73.66 BCY) (1.2)/ (154 BCY/hour) = 0.57 hours

(b) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

(0.57) + (0.08) = 0.65 hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-8-3 and B-8-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site in loose sand is moderate work according to Figure A-1. At 110° F. Figure A-3 provides a degradation factor of 0.58.

(0.05) / (0.58) = 0.09 hours

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(0.44) / (0.52) = 0.85 hours

(0.65) / (0.52) = 1.25 hours

(3) The 1.25 hours required exceeds the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

BUILD A PROTECTIVE POSITION FOR A
155-MM TOWED HOWITZER
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		D7 Dozer or M9 ACE	Combat Engr
Number of Items		1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Build Berm	0.44	
Elapsed Time Required To Complete Task		0.44	

Figure B-8-1

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		D5 Dozer	Combat Engr
Number of Items		1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Build Berm	0.65	
Elapsed Time Required To Complete Task		0.65	

Figure B-8-2

BUILD A PROTECTIVE POSITION FOR A
155-MM TOWED HOWITZER
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Build Berm	0.85	
	Elapsed Time Required To Complete Task	0.85	

Figure B-8-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Build Berm	1.25*	
	Elapsed Time Required To Complete Task	1.25	

Figure B-8-4

LAST PAGE OF APPENDIX B-8

APPENDIX B-9

BUILD A TWO-MAN FIGHTING POSITION

APPENDIX B-9

BUILD A TWO-MAN FIGHTING POSITION

1. Terrain. Sandy Desert.

2. Method of Construction. This is not a likely task for combat engineers in the sandy desert. If an engineer force tries to excavate a 5-foot-deep fighting position, the resulting hole measures 17 feet long by 12 feet across. Such a hole would provide to the occupants little effective protection from area weapons or air bursts. Fighting positions scooped out of the sand by individual soldiers will offer the same level of protection.

LAST PAGE OF APPENDIX B-9

APPENDIX B-10

BUILD A POSITION FOR A DISMOUNTED TOW

APPENDIX B-10

BUILD A POSITION FOR A DISMOUNTED TOW

1. Terrain. Sandy Desert.

2. Method of Construction.

a. The engineer team assigned to build this position has one SEE with operator and one engineer to confer with users and to guide the SEE to the position site.

b. The position is a rectangular pit 5 feet long, 5-1/2 feet wide, and 2 feet deep. These dimensions are identical to those detailed in Appendix E-10. However, because of the non-cohesiveness of the sand, the sides of the excavation collapse until they stabilize at an angle of 45°. The volume of earth that must be excavated is equal to the volume estimated in Appendix E-10 (2.04 BCY) plus the added volume created by the collapsing sides. See Figure B-10-1.

$$(2.04) + [(2) / (27)] [(0.5) (d) (d) (1) + (0.5) (d) (d) (w)] + [(4) / (27)] [(0.33) (d) (d) (d)] =$$

$$(2.04) + [(2) / (27)] [(.5) (2) (2) (5) + (.5) (2) (2) (5.5)] + [(4) / (81)] (2)^3 =$$

$$(2.04) + [(2) / (27)] [(10.0) + (11.0)] + (0.40) =$$

$$(2.04) + (1.56) + (0.40) = 4.00 \text{ BCY}$$

3. Workload Estimates.

a. Temperate weather. Figures B-10-2 and B-10-3 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows.

(1) Use the SEE excavation rate for simple geometric patterns:

(4.00) / (28) = 0.14 hours

(2) Assume that the combat engineer spends about 3 minutes with the supported unit locating an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer or M9 requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

$$(0.14) + (0.08) = 0.22 \text{ hours}$$

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-10-4 and B-10-5. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site in loose sand is moderate work according to Figure A-1. At 110^{o} F, Figure A-3 provides a degradation factor of 0.58.

$$(0.05) / (0.58) = 0.09 \text{ hours}$$

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120^{o} F, Figure A-3 provides a degradation factor of 0.52.

$$(0.22) / (0.52) = 0.42 \text{ hours}$$

POSITION FOR A DISMOUNTED TOW

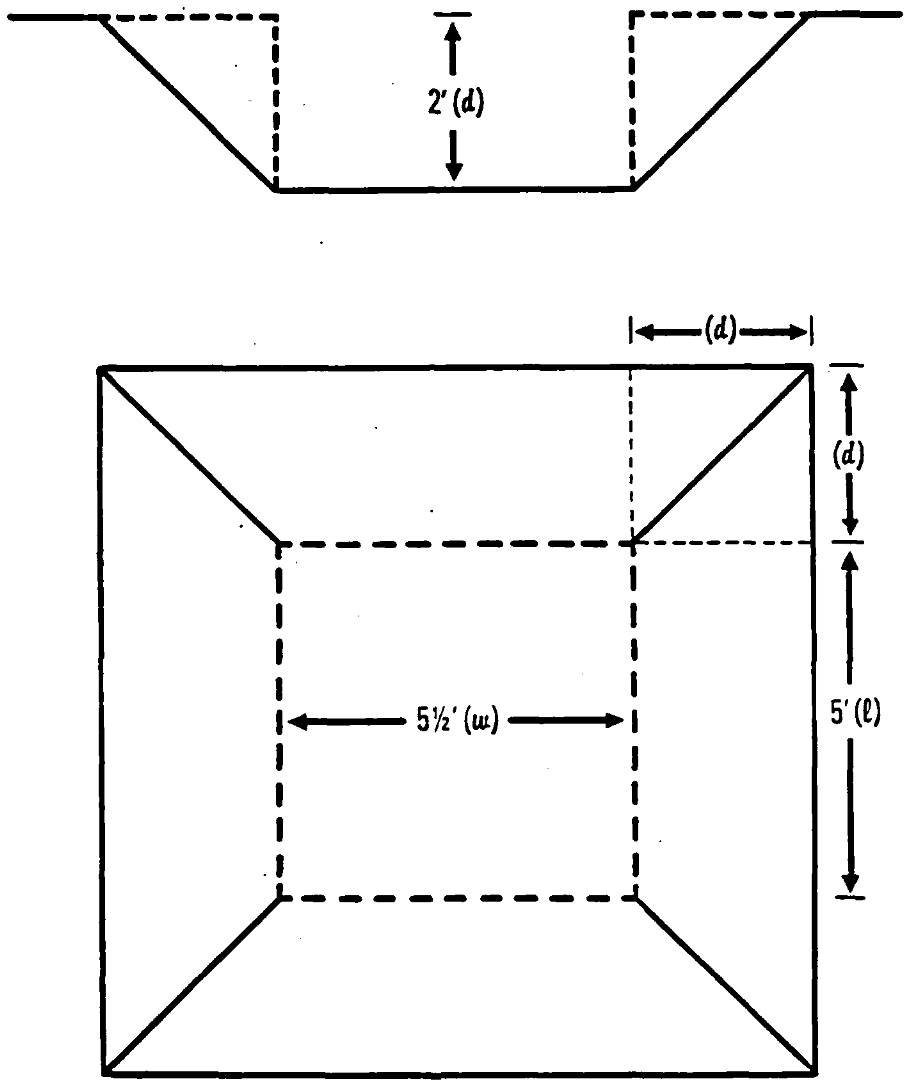

Figure B-10-1

BUILD A POSITION FOR A
DISMOUNTED TOW
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.05
	Excavate	0.22	
	Elapsed Time Required To Complete Task	0.22	

Figure B-10-2

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.05
	Excavate	0.22	
	Elapsed Time Required To Complete Task	0.22	

Figure B-10-3

BUILD A POSITION FOR A
DISMOUNTED TOW
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.09
	Excavate	0.42	
	Elapsed Time Required To Complete Task	0.42	

Figure B-10-4

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.09
	Excavate	0.42	
	Elapsed Time Required To Complete Task	0.42	

Figure B-10-5

LAST PAGE OF APPENDIX B-10

APPENDIX B-11

BUILD A POSITION FOR A MORTAR

APPENDIX B-11

BUILD A POSITION FOR A MORTAR

1. Terrain. Sandy Desert.

2. Method of Construction.

a. The engineer team assigned to build this position has one SEE with operator and one engineer to confer with users and to guide the SEE to the position site.

b. The position is a circular pit 8 feet in diameter and 3 feet deep. These dimensions are identical to those detailed in Appendix E-11. However, because of the non-cohesiveness of the sand, the sides of the excavation collapse until they stabilize at an angle of 45^o. The volume of earth that must be excavated is equal to the volume estimated in Appendix E-11 (5.58 BCY) plus the added volume created by the collapsing sides. See Figure B-11-1.

$$(5.58) + (0.5)\ (d) \left\{(3.1416)\ [(D/2) + (d)\ ^2 - (3.1416)\ (D/2)^2\right\} (27) =$$

$$(5.58) + (.5)\ (3)\ [(3.1416)\ (7)^2 - (3.1416)\ (4)^2]\ /\ (27) =$$

$$(5.58) + (1.5)\ (153.94 - 50.27)\ /\ (27) =$$

$$(5.58) + (5.76) = 11.34 \text{ BCY}$$

3. Workload Estimates.

a. Temperate weather. Figures B-11-2 and B-11-3 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) Use the SEE excavation rate for complex geometric patterns:

(11.34) / (12) = 0.95 hours

(2) Assume that the combat engineer spends about 3 minutes with the supported unit locating an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer or M9 requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

(0.95) + (0.08) = 1.03 hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-11-4 and B-11-5. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site in loose sand is moderate work according to Figure A-1. At 110^{o} F, Figure A-3 provides a degradation factor of 0.58.

(0.05) / (0.58) = 0.09 hours

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120^{o} F, Figure A-3 provides a degradation factor of 0.52.

(1.03) / (0.52) = 1.98 hours

(3) The 1.98 hours required exceeds the maximum one-time work of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

POSITION FOR A MORTAR

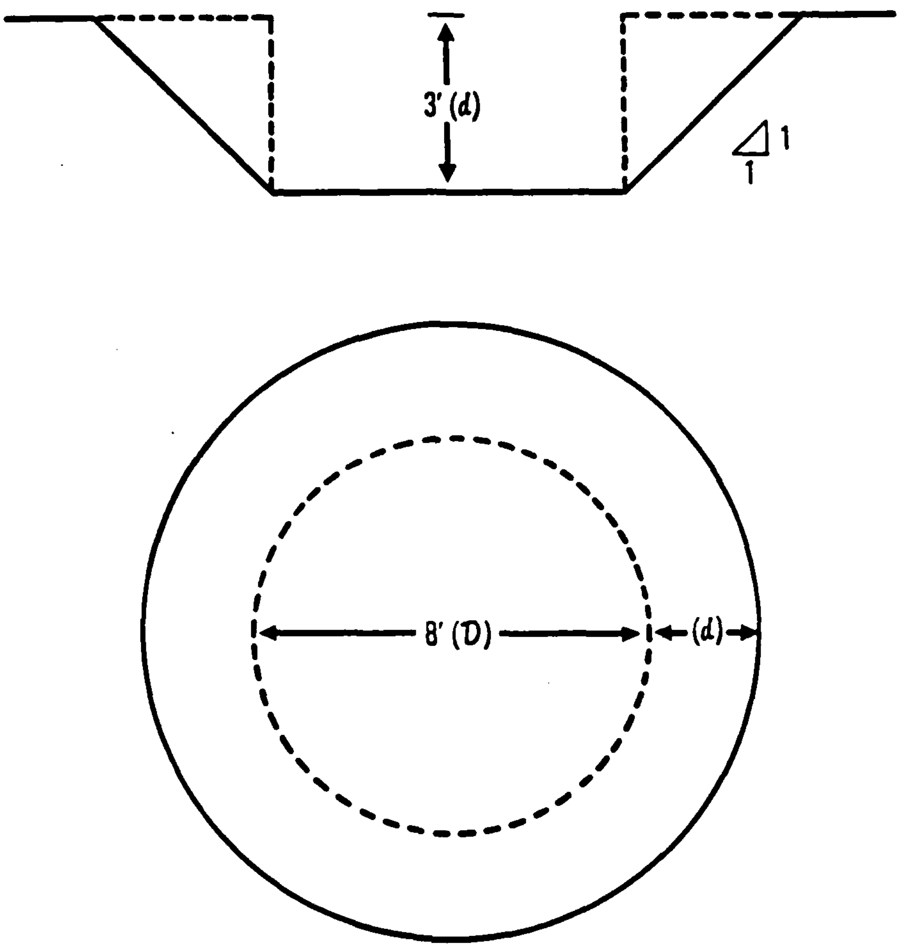

Figure B-11-1

BUILD A POSITION FOR A MORTAR
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

<table>
<tr><th colspan="2">Resource Type</th><th>SEE</th><th>Combat Engr</th></tr>
<tr><td colspan="2">Number of Items</td><td>1</td><td>1</td></tr>
<tr><td rowspan="3">ACTIVITY</td><td>Guide SEE/Locate Site</td><td></td><td>0.05</td></tr>
<tr><td>Excavate</td><td>1.03</td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="2">Elapsed Time Required To Complete Task</td><td colspan="2">1.03</td></tr>
</table>

Figure B-11-2

LIGHT EQUIPMENT
WORKLOAD RATES

<table>
<tr><th colspan="2">Resource Type</th><th>SEE</th><th>Combat Engr</th></tr>
<tr><td colspan="2">Number of Items</td><td>1</td><td>1</td></tr>
<tr><td rowspan="3">ACTIVITY</td><td>Guide SEE/Locate Site</td><td></td><td>0.05</td></tr>
<tr><td>Excavate</td><td>1.03</td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td colspan="2">Elapsed Time Required To Complete Task</td><td colspan="2">1.03</td></tr>
</table>

Figure B-11-3

BUILD A POSITION FOR A MORTAR
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.09
	Excavate	1.98*	
	Elapsed Time Required To Complete Task	1.98	

Figure B-11-4

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.09
	Excavate	1.98*	
	Elapsed Time Required To Complete Task	1.98	

Figure B-11-5

LAST PAGE OF APPENDIX B-11

APPENDIX B-12

BUILD A 100-METER TANK DITCH

APPENDIX B-12

BUILL A 100-METER TANK DITCH

1. Terrain. Sandy Desert.

2. Method of Construction.

a. The engineer team assigned to build this ditch has one bulldozer or M9 ACE with operator, one 2-1/2-cubic-yard scoop loader with operator, and 10 combat engineers to install mines.

b. The tank ditch is 3.5 meters wide, 1.8 meters deep, and 100 meters long.[1] Because of the non-cohesiveness of the sand, the sides of the excavation collapse until they stabilize at an angle of 45°. The volume of earth to be excavated is determined as follows:

(1) (w) (d) + (2) (1/2) (1) (d) (d) =

(100) (3.5) (1.8) + (100) (1.8) (1.8) = 954 m^3 or 1247.83 BCY

3. Workload Estimates.

a. Temperate weather. Figures B-12-1 and B-12-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) D7 dozer/scoop loader production. Assume a push distance of 50 feet which, from Figure B-1, gives a production rate of 466 BCY/hour:

(1247.83 BCY) / (466 BCY/hour) = 2.68 hours

(2) D5 dozer/scoop loader production. Assume a push distance of 50 feet which, from Figure B-2, gives a production rate of 282 BCY/hour:

(1247.83 BCY) / (282 BCY/hour) = 4.42 hours

---

[1]DA, FM 5-102 Countermobility, 1985, p. 122.

(3) As in Appendix E-12, the ditch is mined with 12 AT mines and 6 AP mines per 100 meters of ditch. In sand, mines will be surface laid instead of buried. Laying rates of 8 AT mines per manhour and 16 AP mines per manhour are used. Time to install the mines is estimated as follows:

12 / 8 = 1.50 manhours

6 / 16 = 0.38 manhours

TOTAL = 1.88 manhours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-12-3 and B-12-4. See Annex A for a discussion of the method used.

(1) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(2.68) / (0.52) = 5.15 hours

(4.42) / (0.52) = 8.50 hours

(2) Installing land mines is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71.

(1.88) / (0.71) = 2.65 hours

A team of 10 men will finish this activity in 0.27 hours.

(3) The 5.15 and the 8.50 hours required exceed the maximum one-time work rate of 67 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

BUILD A 100-METER TANK DITCH
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	10
ACTIVITY	Excavate	2.68	2.68	
	Install Minefield			1.88
	Elapsed Time Required To Complete Task	2.68		

Figure B-12-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	10
ACTIVITY	Excavate	4.42	4.42	
	Install Minefield			1.88
	Elapsed Time Required To Complete Task	4.42		

Figure B-12-2

BUILD A 100-METER TANK DITCH
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	10
ACTIVITY	Excavate	5.15*	5.15*	
	Install Minefield			2.65
	Elapsed Time Required To Complete Task	5.15		

Figure B-12-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	10
ACTIVITY	Excavate	8.50*	8.50*	
	Install Minefield			2.65
	Elapsed Time Required To Complete Task	8.50		

Figure B-12-4

LAST PAGE OF APPENDIX B-12

APPENDIX B-13

INSTALL A 2000-METER TACTICAL MINEFIELD USING GEMMS

APPENDIX B-13

INSTALL A 2000-METER TACTICAL MINEFIELD USING GEMMS

1. Terrain. Sandy Desert.

2. Method of Construction.

a. The minefield is installed using the M128 GEMMS and 20 combat engineers.

b. The minefield consists of two belts, each 2000 meters long and 60 meters wide, separated by a distance of 40 meters. A density of 0.005 mines per square meter is used. These dimensions are the same as those used in Appendix E-13.

3. Workload Estimates.

a. Temperate weather. Figures B-13-1 and B-13-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

Dispense 800 mines	= 0.76 hours
Reload	= 0.40 hours
Dispense 520 mines	= 0.50 hours
Reload	= 0.40 hours
TOTAL	= 2.06 hours

(1) The rear boundary of the minefield is marked using the M133 Hand Emplaced Minefield Marking Set (HEMMS). The sand should not affect the installation rate for HEMMS. Therefore, as in Appendix E-13, marking the minefield will require 16.8 manhours.

(2) Figures B-13-1 through B-13-4 reflect a notional 20 man workforce with 10 men assigned to guide, operate, and load the GEMMS and 10 men assigned to mark the rear boundary.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-13-3 and B-13-4. See Annex A for a discussion of the method used.

(1) Reloading the GEMMS with mines is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71. Driving the truck to dispense the mines is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

Dispense 800 mines	= (0.76) / (0.52)	= 1.46 hours
Reload	= (0.40) / (0.71)	= 0.56 hours
Dispense 520 mines	= (0.50) / (0.52)	= 0.96 hours
Reload	= (0.40) / (0.71)	= 0.56 hours
TOTAL		= 3.54 hours

(2) Installing the HEMMS system is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

(16.8) / (0.58) = 28.97 manhours

A team of 10 men will complete this sub-task in 2.88 hours.

(3) The 3.54 hours required exceeds the maximum one-time work rate of 62 minutes listed in Figure A-2. The 2.88 hours required exceeds the maximum one-time work rate of 50 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

INSTALL A 2000-METER TACTICAL MINEFIELD USING GEMMS
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-Ton Truck	Combat Engr	GEMMS
	Number of Items	1	20	1
ACTIVITY	Install Minefield	2.06	20.60	2.06
	Mark the Minefield With HEMMS		16.80	
	Elapsed Time Required To Complete Task		2.06	

Figure B-13-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-Ton Truck	Combat Engr	GEMMS
	Number of Items	1	20	1
ACTIVITY	Install Minefield	2.06	20.60	2.06
	Mark the Minefield With HEMMS		16.80	
	Elapsed Time Required To Complete Task		2.06	

Figure B-13-2

INSTALL A 2000-METER TACTICAL MINEFIELD USING GEMMS
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-Ton Truck	Combat Engr	GEMMS
	Number of Items	1	20	1
ACTIVITY	Install Minefield	3.54*	35.40*	3.54*
	Mark the Minefield With HEMMS		28.97*	
	Elapsed Time Required To Complete Task		3.54	

Figure B-13-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-Ton Truck	Combat Engr	GEMMS
	Number of Items	1	20	1
ACTIVITY	Install Minefield	3.54*	35.40*	3.54*
	Mark the Minefield With HEMMS		28.97*	
	Elapsed Time Required To Complete Task		3.54	

Figure B-13-4

LAST PAGE OF APPENDIX B-13

APPENDIX B-14

INSTALL A 2000-METER TACTICAL MINEFIELD USING VOLCANO

APPENDIX B-14

INSTALL A 2000-METER TACTICAL MINEFIELD USING VOLCANO

1. Terrain. Sandy Desert.

2. Method of Construction.

a. The minefield is installed using the XM139 mine dispenser mounted in a dump truck and 20 combat engineers.

b. The minefield consists of two rows, each 2000 meters long and 40 meters wide, separated by a distance of 40 meters. A density of 0.012 mines per square meter is used.[1] These dimensions are the same as those in Appendix E-14.

3. Workload Estimates.

a. Temperate weather. Figures B-14-1 and B-14-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively.

(1) The total time required to install the minefield is calculated using the method described in Appendix E-14.

Dispense 960 mines	= 0.17
Reload	= 0.25
Dispense 960 mines	= 0.17
Reload	= 0.25
TOTAL	= 0.84

---

[1] US Army Engineer Center and School, The Handbook of Employment for Mine Warfare Systems, September 1985, Ft. Belvoir, VA, p. III-24.

(2) The rear boundary of the minefield is marked using the M133 HEMMS. The sand should not affect the installation rate for HEMMS. Therefore, as in Appendix E-14, marking the minefield will require 16.8 manhours.

(3) Figures B-14-1 through B-14-4 reflect a notional workforce with 10 men initially assigned to guide, operate, and load the VOLCANO system and 10 men initially assigned to mark the rear boundary. After the installation activity is complete, all 20 men complete the marking activity.

b. Hot weather. Adjustments for work production degradatin caused by high temperatures have been applied to the data in Figures B-14-3 and B-14-4. See Annex A for a discussion of the method used.

(1) Reloading the dispenser with mines is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71. Driving the truck to dispense the mines is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

Dispense 960 mines = (0.17) / (0.52) = 0.33

Reload = (0.25) / (0.71) = 0.35

Dispense 960 mines = (0.17) / (0.52) = 0.33

Reload = (0.25) / (0.71) = 0.35

Total = 1.36 hours

(2) Marking the minefield with HEMMS is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

(16.8) / (0.58) = 28.97 manhours

A team of 10 men initially, later expanding to 20 men after the mines have been installed, will complete this activity in 2.13 hours.

(3) The 1.36 hours required exceeds the maximum one-time work rate of 62 minutes listed in Figure A-2. The 2.13 hours required exceeds the maximum one-time work rate of 50 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

INSTALL A 2000-METER TACTICAL MINEFIELD USING VOLCANO
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-Ton Truck	Combat Engr	VOLCANO
	Number of Items	1	20	1
ACTIVITY	Install Minefield	0.84	8.40	0.84
	Mark the Minefield With HEMMS		16.80	
	Elapsed Time Required To Complete Task		1.26	

Figure B-14-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-Ton Truck	Combat Engr	VOLCANO
	Number of Items	1	20	1
ACTIVITY	Install Minefield	0.84	8.40	0.84
	Mark the Minefield With HEMMS		16.80	
	Elapsed Time Required To Complete Task		1.26	

Figure B-14-2

INSTALL A 2000-METER TACTICAL MINEFIELD USING VOLCANO
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-Ton Truck	Combat Engr	VOLCANO
	Number of Items	1	20	1
ACTIVITY	Install Minefield	1.36*	13.60*	1.36*
	Mark the Minefield With HEMMS		28.97*	
	Elapsed Time Required To Complete Task	2.13		

Figure B-14-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-Ton Truck	Combat Engr	VOLCANO
	Number of Items	1	20	1
ACTIVITY	Install Minefield	1.36*	13.60*	1.36*
	Mark the Minefield With HEMMS		28.97*	
	Elapsed Time Required To Complete Task	2.13		

Figure B-14-4

LAST PAGE OF APPENDIX B-14

APPENDIX B-15

INSTALL A 2000-METER TACTICAL MINEFIELD USING CONVENTIONAL MINES

APPENDIX B-15

INSTALL A 2000-METER TACTICAL MINEFIELD USING CONVENTIONAL MINES

1. Terrain. Sandy Desert.

2. Method of Construction.

a. A standard pattern minefield is emplaced by 30 combat engineers using conventional mines. All mines are laid on the surface.

b. The minefield has a length of 2000 meters. The desired density is 1-0.5-0, and the IOE representative cluster composition is 1-1-0. These dimensions are the same as those used in Appendix E-15.

3. Workload Estimates.

a. Temperate weather. Figures B-15-1 and B-15-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) See Appendix E-15 for detailed estimates of the number of mines required.

AT Mines = 3261

AP Mines = 1795

(2) In the sand, mines will be surface laid instead of buried. This method is estimated to be twice as fast. Manhours required are computed using laying rates of 8 AT mines per manhour and 16 AP mines per manhour:

3261 / 8 = 407.63 manhours

1795 / 16 = 112.19 manhours

TOTAL = 519.82 manhours

(3) As described in Appendix E-15, the rear boundary of the minefield is marked with a single strand of barbed wire fence. Sand should

not affect the estimated time for marking the minefield. 150 manhours are required for minefield marking.

(4) The elapsed time to complete this task shown in Figures B-15-1 through B-15-4 reflects a notional 30-man workforce with 23 men assigned to minefield laying and 7 men assigned to marking. This assignment scheme was chosen to minimize the overall time required.

(519.82) / 23 = 22.60 hours

(150) / 7 = 21.43 hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-15-3 and B-15-4. See Annex A for a discussion of the method used.

(1) Laying land mines and installing minefield markers is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71.

(519.82) / (0.71) = 732.14 manhours

(150) / (0.71) = 211.27 manhours

(2) The total elapsed time required is 31.83 hours (732.14 manhours divided by 23 minelayers).

(3) These times greatly exceed the maximum one-time work rate of 36 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

INSTALL A 2000-METER TACTICAL MINEFIELD
USING CONVENTIONAL MINES
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		30
ACTIVITY	Install Minefield	519.82
	Mark the Minefield With Wire	150.00
Elapsed Time Required To Complete Task		22.60

Figure B-15-1

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		30
ACTIVITY	Install Minefield	519.82
	Mark the Minefield With Wire	150.00
Elapsed Time Required To Complete Task		22.60

Figure B-15-2

INSTALL A 2000-METER TACTICAL MINEFIELD
USING CONVENTIONAL MINES
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	30
ACTIVITY	Install Minefield	732.14*
	Mark the Minefield With Wire	211.27*
	Elapsed Time Required To Complete Task	31.83

Figure B-15-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	30
ACTIVITY	Install Minefield	732.14*
	Mark the Minefield With Wire	211.27*
	Elapsed Time Required To Complete Task	31.83

Figure B-15-4

LAST PAGE OF APPENDIX B-15

APPENDIX B-16

DISABLE A BRIDGE

APPENDIX B-16

DISABLE A BRIDGE

1. Terrain. Sandy Desert.

2. Method of Construction. In the sandy desert, flash floods are rare and meandering streams which might reach the sandy desert areas are short-lived.[1] Bridges are unlikely to be found in such an environment. Disabling a bridge, therefore, is not a likely engineer task.

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[1] DA, Theater of Operations Construction in the Desert, January 1981, p. B-9.

LAST PAGE OF APPENDIX B-16

APPENDIX B-17

CRATER A ROAD

APPENDIX B-17

CRATER A ROAD

1. Terrain. Sandy Desert.

2. Method of Construction. A team of eight combat engineers is assigned to crater a road and install a point minefield using conventional explosives and mines.

3. Workload Estimates.

a. Temperate weather. Figures B-17-1 and B-17-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) The road crater is installed to block a two-lane, asphalt road with a traveled width of 25 feet. The time required to install the road crater in sand does not differ substantially from the time estimates in Appendix E-17:

Preparing and firing the shaped charges = 10.00 manhours

Preparing and firing the cratering charges = 2.40 manhours

Total Time required to install the crater = 12.40 manhours

An 8-man team will finish this sub-task in 1.55 hours.

(2) A point minefield is installed in and around the crater. It is assumed that the target is mined with 12 AT mines and 6 AP mines. Effort required is based on an estimated laying rate in sand of 8 AT mines per manhour and 16 AP mines per manhour.

12 / 8 = 1.50 manhours

6 / 16 = 0.38 manhours

TOTAL = 1.88 manhours

An 8-man team will finish this sub-task in 0.24 hours.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-17-3 and B-17-4. See Annex A for a discussion of the method used.3

(1) Preparing explosives in loose sand is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(12.40) / (0.58) = 21.38 \text{ manhours}$$

An 8-man team will finish this sub-task in 2.67 hours.

(2) Laying land mines in loose sand is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71.

$$(1.88) / (0.71) = 2.65 \text{ manhours}$$

An 8-man team will finish this sub-task in 0.33 hours.

(3) The 2.67 hours required exceeds the maximum one-time work rate of 50 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

CRATER A ROAD
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	8
ACTIVITY	Prepare and Fire Demolitions	12.40
	Install Point Minefield	1.88
	Elapsed Time Required To Complete Task	1.79

Figure B-17-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	8
ACTIVITY	Prepare and Fire Demolitions	12.40
	Install Point Minefield	1.88
	Elapsed Time Required To Complete Task	1.79

Figure B-17-2

CRATER A ROAD
(Sandy Desert + Hot Weather)

H E A V Y   E Q U I P M E N T
W O R K L O A D   R A T E S

	Resource Type	Combat Engr
	Number of Items	8
ACTIVITY	Prepare and Fire Demolitions	21.38*
	Install Point Minefield	2.65
	Elapsed Time Required To Complete Task	3.00

Figure B-17-3

L I G H T   E Q U I P M E N T
W O R K L O A D   R A T E S

	Resource Type	Combat Engr
	Number of Items	8
ACTIVITY	Prepare and Fire Demolitions	21.38*
	Install Point Minefield	2.65
	Elapsed Time Required To Complete Task	3.00

Figure B-17-4

LAST PAGE OF APPENDIX B-17

APPENDIX B-18

CLEAR A TANK DITCH

APPENDIX B-18

CLEAR A TANK DITCH

1. Terrain. Sandy Desert.

2. Method of Construction. The team assigned this mission will vary depending on whether the engineer forces involved are heavy or light.

3. Workload Estimates.

a. Temperate weather. Figures B-18-1 and B-18-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) The heavy engineer force has 1 Combat Engineer Vehicle (CEV) with operator, 1 D7 bulldozer or M9 ACE with operator, and 10 combat engineers. The effort required for these forces to clear a tank ditch is determined using the method described in Appendix E-18:

(a) The CEV breaches the tank ditch. The time required to clear a passage using the bullblade is estimated by multiplying the time calculated in Appendix E-18, 0.25 hours, by the ratio of the D7 dozer production rate in earth versus the D7 dozer production rate in sand. The production rates for a push distance of 75 feet were used.

$$(0.25)\ (376)\ /\ (356) = 0.26 \text{ hours}$$

(b) Fifty-meter strips on both sides of the ditch have been mined. The engineer team clears and marks an 8-meter path through both strips to accommodate one-way vehicle traffic. Working in loose sand does not substantially change the time estimate in Appendix E-18: 80 manhours to widen and clear an 8-meter path and 10 manhours to mark. A team of 10 engineers completes these activities in 8 hours and 1 hour, respectively.

(c) Finally, a D7 dozer or an M9 ACE is used to improve the ingress and egress for follow-on vehicles. The estimate in Appendix E-18 of 0.5 hours is degraded by the same factor used to degrade the CEV production.

$$(0.5)\ (376)\ /\ (356) = 0.53 \text{ hours}$$

(2) The light engineer force has a D5 dozer with operator and 10 combat engineers. The initial breach must be wide enough to get assaulting ground troops across the ditch and the minefields. The effort required is determined as follows:

(a) The bangalore torpedo is used to breach an initial 1-meter footpath. The time required is 4 manhours.

(b) The time required to widen and clear an 8-meter one-way vehicle path remains 80 manhours. The marking task also requires 10 manhours.

(c) The remaining work involves improving access and egress for follow-on vehicles. Single-lane approaches are cut through the steep banks. The design cut is the same used in Appendix E-18. The volume of earth excavated is equal to the volume estimated in Appendix E-18: 193 BCY.

(d) Assume a push distance of 75 feet which, from Figure B-2, gives a production rate of 230 BCY/hour. Thus, the time for cutting one bank is determined:

$$193\ /\ 230 = 0.84 \text{ hours}$$

(e) Assume it takes the dozer 5 minutes (0.08 hours) to cross to the other side of the ditch. Therefore, the time required to improve both banks is:

$$0.84 + 0.08 + 0.84 = 1.76 \text{ hours}$$

(3) The estimated elapsed times shown in Figures B-18-1 through B-18-4 assume that the sub-tasks are completed sequentially. First, the

engineer team breaches the ditch and minefields, then it clears and marks an 8-meter-wide path through the minefields, and, finally, it improves the banks for vehicle crossing.

(4) The time and effort required for the initial breach of a tank ditch can be estimated for heavy or light forces by using the first lines of Figures B-18-1/3 and B-18-2/4, respectively.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-18-3 and B-18-4. See Annex A for a discussion of the method used.

(1) Heavy engineer force. Operating the CEV and the dozer or ACE is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52. Clearing and marking the minefield is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

(a) Breach with CEV. (0.26) / (0.52) = 0.50 hours

(b) Clear lane. (80) / (0.58) = 137.9 manhours

(c) Mark lane. (10) / (0.58) = 17.24 manhours

(d) Improve banks with D7 or M9.

(0.53) / (0.52) = 1.02 hours

(e) A 10-man team finishes activities (b) and (c) in 13.79 and 1.72 hours.

(2) The 13.79 and 1.72 hours required exceed the maximum one-time work rate of 50 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

(3) Light engineer force. Placing and detonating a bangalore torpedo is heavy work according to Figure A-1. For 110° F, Figure A-3 provides a degradation factor of 0.71. Clearing and marking the minefield is moderate work according to Figure A-1. For 110° F, Figure A-3 provides a degradation factor of 0.58. Operating the dozer is light work. For 120° F, Figure A-3 provides a degradation factor of 0.52.

(a) Breach with bangalore. (4) / (0.71) = 5.63 manhours

(b) Clear lane. (80) / (0.58) = 137.93 manhours

(c) Mark lane. (10) / (0.58) = 17.24 manhours

(d) Improve banks with D5. (1.76) / (0.52) = 3.38 hours

(e) A 10-man team finishes activities (a), (b), and (c) in 0.56 hours 13.79 hours, and 1.72 hours.

(4) The 13.79 hours and the 1.72 hours required exceed the maximum one-time work rate of 50 minutes listed in Figure A-2. The 3.38 hours required exceeds the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

CLEAR A TANK DITCH
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr	CEV
	Number of Items	1	10	1
ACTIVITY	Breach Tank Ditch With CEV			0.26
	Clear 8-Meter Wide Path		80.0	
	Mark the Lane		10.0	
	Improve Access/Egress	0.53		
	Elapsed Time Required To Complete Task	9.79		

Figure B-18-1

CLEAR A-TANK DITCH
(Sandy Desert + Temperate Weather)

L I G H T   E Q U I P M E N T
W O R K L O A D   R A T E S

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	10
ACTIVITY	Breach 1-Meter Footpath		4.0
ACTIVITY	Clear 8-Meter Wide Path		80.0
ACTIVITY	Mark the Lane		10.0
ACTIVITY	Improve Access/Egress	1.76	
	Elapsed Time Required To Complete Task	11.16	

Figure B-18-2

CLEAR A TANK DITCH
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr	CEV
	Number of Items	1	10	1
ACTIVITY	Breach Tank Ditch With CEV			0.50
	Clear 8-Meter Wide Path		137.90*	
	Mark the Lane		17.24*	
	Improve Access/Egress	1.02		
	Elapsed Time Required To Complete Task	17.03		

Figure B-18-3

CLEAR A TANK DITCH
(Sandy Desert + Hot Weather)

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	10
ACTIVITY	Breach 1-Meter Footpath		5.63
	Clear 8-Meter Wide Path		137.93*
	Mark the Lane		17.24*
	Improve Access/Egress	3.38*	
	Elapsed Time Required To Complete Task	19.45	

Figure B-18-4

LAST PAGE OF APPENDIX B-18

APPENDIX B-19

REPAIR A ROAD CRATER

APPENDIX B-19

REPAIR A ROAD CRATER

1. Terrain. Sandy Desert

2. Method of Construction. The engineer resources used in this task consist of one bulldozer or M9 ACE with operator and 10 combat engineers.

a. The typical road crater is assumed to be a trapezoidal prism with a depth of 2.25 meters, a length of 12.5 meters, a top width of 8.70 meters and a bottom width of 2.25 meters. These dimensions are identical to those detailed in Appendix E-19. The area in and around the crater is seeded with mines. The volume of earth that must be moved to fill the crater is equal to the volume estimated in Appendix E-19: 201.41 BCY.

3. Workload Estimates.

a. Temperate weather. Figures B-19-1 and B-19-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) D7 dozer and M9 ACE production.

(a) Before the dozing can begin the area must be cleared of mines. Combat engineers accomplish this task in 30 manhours.[1]

(b) Assuming that sufficient backfill material is available at the site so that the hauling of aggregate is not required, a push distance of 125 feet is used. Figure B-1 gives a production rate of 246 BCY/hour:

(201.41) / (246) = 0.82 hours

(2) D5 dozer production.

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[1]DA, Analysis of III Corps Combat Engineer Wartime Requirements (U), Volume I, 1984, p. E-2-5.

(a) As above, combat engineers clear the area of mines in 30 man hours.

(b) Assume a push distance of 125 feet which, from Figure B-2, gives a production rate of 154 BCY/hour:

$$(201.41) / (154) = 1.31 \text{ hours}$$

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-19-3 and B-19-4. See Annex A for a discussion of the method used.

(1) Operating a dozer is light work according to Figure A-1. For 120^{o} F, Figure A-3 provides a degradation factor of 0.52.

$$(0.82) / (0.52) = 1.58 \text{ hours}$$

$$(1.31) / (0.52) = 2.52 \text{ hours}$$

(2) Clearing mines is moderate work. For 110^{o} F, Figure A-3 gives a degradation factor of 0.58.

$$(30.0) / (0.58) = 51.72 \text{ manhours}$$

A 10-man team finishes this activity in 5.17 hours

(3) The 1.58 and 2.52 hours required exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The 5.17 hours required exceeds the maximum one-time work rate of 50 minutes. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

REPAIR A ROAD CRATER
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	10
ACTIVITY	Clear Mines		30.0
	Backfill Crater	0.82	
	Elapsed Time Required To Complete Task	3.82	

Figure B-19-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	10
ACTIVITY	Clear Mines		30.0
	Backfill Crater	1.31	
	Elapsed Time Required To Complete Task	4.31	

Figure B-19-2

REPAIR A ROAD CRATER
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	10
ACTIVITY	Clear Mines		51.72*
	Backfill Crater	1.58*	
	Elapsed Time Required To Complete Task	6.75	

Figure B-19-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	10
ACTIVITY	Clear Mines		51.72*
	Backfill Crater	2.52*	
	Elapsed Time Required To Complete Task	7.69	

Figure B-19-4

LAST PAGE OF APPENDIX B-19

APPENDIX B-20

CONSTRUCT 100 METERS OF COMBAT TRAIL

APPENDIX B-20

CONSTRUCT 100 METERS OF COMBAT TRAIL

1. Terrain. Sandy Desert.

2. Method of Construction. The construction of combat trails is not considered a likely engineer task in this environment. Underbrush and vegetation is virtually nonexistent in the sandy desert except for occasional oases. Although cross-country movement may be slower, particularly for wheeled vehicles, it will not be impeded to the extent that combat trail construction is necessary.

LAST PAGE OF APPENDIX B-20

APPENDIX B-21

REPLACE COMBAT BRIDGING

APPENDIX B-21

REPLACE COMBAT BRIDGING

1. Terrain. Sandy Desert.

2. Method of Construction. Flash floods are rare and meandering streams which might reach the sandy desert areas are short-lived.[1] Construction of semi-permanent and permanent bridging to replace combat bridging is not considered a likely engineer task in this environment.

[1] DA, Theater of Operations Construction in the Desert, January 1981, p. B-9.

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APPENDIX B-22

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD

APPENDIX B-22

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD

1. Terrain. Sandy Desert.

2. Method of Construction. An engineer team consisting of heavy equipment and combat engineers is assigned to maintain an unpaved but well-built secondary road that has become rutted and worn from heavy traffic. The road to be maintained is a single-lane track, 10 to 16 feet wide. The surface is thin and supports only light loads (16 to 20 tons). The sandy surface has been stabilized by spraying several coats of crude oil, bitumin, or petroleum products, or by blending the sand with gravel, clay, or cement. Compaction effort is not included in this estimate.

3. Workload Estimates.

a. Temperate weather. Figures B-22-1 and B-22-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) As in Appendix E-22, the estimate is based on the projected maintenance and repair required during a 5-day period for a 10-kilometer section of road. ESC estimates that these roads will deteriorate twice as fast in the sandy desert as a graded earth road in Europe. Repair work done in the sand will take about half again as long as similar work in Europe. The engineer road repair team will, therefore, spend three times the amount of time and effort estimated in Appendix E-22. Figure B-22-1 reflects the engineer resources and effort required for a 10-kilometer section using 5-ton dump trucks.

(a) 2.5-CY loader.

(3.11) (3) = 9.33 equipment hours

(b) Four 5-ton dump trucks.

(12.44) (3) = 37.32 equipment hours

(c) 16 combat engineers.

(49.76) (3) = 149.28 manhours

(d) 4 graders.

(12.44) (3) = 37.32 equipment hours

(2) The number of dump trucks shown in Figure E-22-2 is doubled since a 5-ton dump truck is rated at approximately twice the volume and weight capacity of a 2-1/2-ton dump truck. Eight 2.5-ton dump trucks:

(24.88) (3) = 74.64 equipment hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-22-3 and B-22-4. See Annex A for a discussion of the method used.

(1) The combat engineers are doing pick and shovel work which is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71.

(149.28) / (0.71) = 210.25 manhours

A 16-man team finishes this activity in 13.14 hours.

(2) Operating heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(9.33) / (0.52) = 17.94 hours

(37.32) / (0.52) = 71.77 equipment hours

(37.32) / (0.52) = 71.77 equipment hours

(74.64) / (0.52) = 143.54 equipment hours

The engineer team will finish its activities in 17.94 hours.

(3) The 17.94 hours and the 13.14 hours required both greatly exceed the respective maximum one-time work rates shown in Figure A-2. However, these times are spread over a 5-day period. At a given road repair site the maximum one-time work rates are 36 minutes for the engineer laborers and 62 minutes for the equipment operators. The asterisk in the figures indicates that, if the work at a repair site exceeds these times, the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT WORKLOAD RATES

	Resource Type	2.5-CY Loader	5-Ton Truck	Combat Engr	Grader
	Number of Items	1	4	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	9.33	37.32	149.28	37.32
	Elapsed Time Required To Complete Task	9.33			

Figure B-22-1

LIGHT EQUIPMENT WORKLOAD RATES

	Resource Type	2.5-CY Loader	2.5-Ton Truck	Combat Engr	Grader
	Number of Items	1	8	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	9.33	76.64	149.28	37.32
	Elapsed Time Required To Complete Task	9.33			

Figure B-22-2

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-CY Loader	5-Ton Truck	Combat Engr	Grader
	Number of Items	1	4	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	17.94*	71.77*	210.25*	71.77*
	Elapsed Time Required To Complete Task	17.94			

Figure B-22-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-CY Loader	2.5-Ton Truck	Combat Engr	Grader
	Number of Items	1	8	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	17.94*	71.77*	210.25*	71.77*
	Elapsed Time Required To Complete Task	17.94			

Figure B-22-4

LAST PAGE OF APPENDIX B-22

APPENDIX B-23

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE

APPENDIX B-23

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE

1. Terrain. Sandy Desert.

2. Method of Construction. An engineer team consisting of graders, trucks, and combat engineers is assigned to maintain a paved MSR. The asphalt section of a combat engineer battalion (heavy) will augment the divisional engineer battalion, however, that section's effort is not included in this estimate.

3. Workload Estimates.

a. Temperate weather. Figures B-23-1 and B-23-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) The road to be maintained is a two-lane, bituminous surface road. The estimate is based on the projected maintenance and repair required during a 5-day period for a 10-kilometer section of road. ESC assumes that the road will deteriorate twice as fast in the desert as in Europe. Repair times, however, will remain the same as those for Europe. Time estimates for Europe, shown in Appendix E-23, are doubled for sandy desert. Figure B-23-1 reflects the engineer times and resources required using 5-ton truck.

(2) The number of dump trucks shown in Figure B-23-2 is doubled since a 5-ton dump truck is rated at approximately twice the volume and weight capacity of a 2-1/2-ton dump truck.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-23-4 and B-23-5. See Annex A for a discussion of the method used.

(1) The combat engineers are doing pick and shovel work which is heavy work according to Figure A-1. At 110^{o} F, Figure A-3 provides a degradation factor of 0.71.

$$(99.52) / (0.71) = 140.17 \text{ manhours}$$

A 16-man team finishes this activity in 8.76 hours.

(2) Operating heavy equipment is light work according to Figure A-1. At 120^{o} F, Figure A-3 provides a degradation factor of 0.52.

(a) 5-ton trucks.

$$(49.76) / (0.52) = 95.69 \text{ equipment hours}$$

(b) Graders.

$$(24.88) / (0.52) = 47.85 \text{ equipment hours}$$

(c) 2.5-ton trucks.

$$(99.52) / (0.52) = 191.38 \text{ equipment hours}$$

The engineer team will finish its activities in 11.96 hours.

(3) The 11.96 hours and the 8.76 hours required both greatly exceed the respective maximum one-time work rates shown in Figure A-2. However, these times are spread over a 5-day period. At a given road repair site the maximum one-time work rates are 36 minutes for the engineer laborers and 62 minutes for the equipment operators. The asterisk in the figures indicates that, if the work at a repair site exceeds these times, the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE (MSR)
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-Ton Truck	Combat Engr	Grader
	Number of Items	8	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	49.76	99.52	24.88
	Elapsed Time Required To Complete Task	6.22		

Figure B-23-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-Ton Truck	Combat Engr	Grader
	Number of Items	16	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	99.52	99.52	24.88
	Elapsed Time Required To Complete Task	6.22		

Figure B-23-2

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE (MSR)
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-Ton Truck	Combat Engr	Grader
	Number of Items	8	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	95.69*	140.17*	47.85*
	Elapsed Time Required To Complete Task	11.96		

Figure B-23-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-Ton Truck	Combat Engr	Grader
	Number of Items	16	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	191.38*	140.17*	47.85*
	Elapsed Time Required To Complete Task	11.96		

Figure B-23-4

LAST PAGE OF APPENDIX B-23

APPENDIX B-24

DELIBERATE MINEFIELD BREACH

APPENDIX B-24

DELIBERATE MINEFIELD BREACH

1. Terrain. Sandy Desert.

2. Method of Construction. As in Appendix E-24, 10 combat engineers are assigned to conduct a deliberate breach through a 100-meter-deep minefield. The presence of loose sand does not effect the times and resources estimates in Appendix E-24.

3. Workload Estimates.

a. Temperate weather. Figures B-24-1 and B-24-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The estimates below are identical to those in Appendix E-24:

(1) Breach 1-meter foot path with bangalore torpedo: 4 manhours

(2) Widen the breach to 8 meters using mine detectors and explosives: 80 manhours.

(3) Mark the cleared lane using the HEMMS: 10 manhours.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-24-3 and B-24-4. See Annex A for a discussion of the method used.

(1) Breaching, clearing and marking a lane through a minefield are moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

(4.00) / (0.58) = 6.90 manhours

(80.00) / (0.58) = 137.93 manhours

(10.00) / (0.58) = 17.24 manhours

A 10-man team finishes each activity in 0.69 hours, 13.79 hours, and 1.72 hours, respectively.

(2) The latter two times exceed the maximum one-time work rate of 50 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

c. The time and effort required for a hasty breach to get dismounted assault forces through a 100-meter-deep minefield can be estimated using the first activity of Figures B-24-1 through B-24-4.

DELIBERATE MINEFIELD BREACH
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	10
ACTIVITY	Breach 1-Meter Footpath	4.0
	Clear 8-Meter-Wide Path	80.0
	Mark the Lane	10.0
	Elapsed Time Required To Complete Task	9.4

Figure B-24-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	10
ACTIVITY	Breach 1-Meter Footpath	4.0
	Clear 8-Meter-Wide Path	80.0
	Mark the Lane	10.0
	Elapsed Time Required To Complete Task	9.4

Figure B-24-2

DELIBERATE MINEFIELD BREACH
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		10
ACTIVITY	Breach 1-Meter Footpath	6.90
	Clear 8-Meter-Wide Path	137.93*
	Mark the Lane	17.24*
Elapsed Time Required To Complete Task		16.21

Figure B-24-3

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		10
ACTIVITY	Breach 1-Meter Footpath	6.90
	Clear 8-Meter-Wide Path	137.93*
	Mark the Lane	17.24*
Elapsed Time Required To Complete Task		16.21

Figure B-24-4

LAST PAGE OF APPENDIX B-24

APPENDIX B-25

REDUCE A DRY GAP BANK GRADE FOR VEHICLE PASSAGE

APPENDIX B-25

REDUCE A DRY GAP BANK GRADE FOR VEHICLE PASSAGE

1. Terrain. Sandy Desert.

2. Method of Construction. Dry gaps with steep sandy banks are an unlikely combination. Those sectors of the desert reached by water runoff from the highlands of sufficient quantity to create steep bank gaps would typically be composed of the soils found in the playas and rocky plateaus. Reduction of gap banks is considered an unlikely engineer task in this environment.

LAST PAGE OF APPENDIX B-25

APPENDIX B-26

PREPARE A SITE FOR A 40,000-GALLON BRIGADE WATER POINT

APPENDIX B-26

PREPARE A SITE FOR A 40,000-GALLON BRIGADE WATER POINT

1. Terrain. Sandy Desert.

2. Method of Construction. The engineer team assigned this task has a bulldozer, a 2.5-cubic-yard scoop loader, and a 5-ton or 2.5-ton truck with operators and 32 combat engineers. Compaction requirements are not estimated.

a. The site is constructed to accommodate two 20,000 gallon water bladders, each measuring 28 feet by 32 feet. A 240-foot roadway provides an entrance to and exit from the pumping stations. An area of 48 feet by 120 feet near the pumps is stabilized to prevent deterioration because of the vehicle traffic. See Figure B-26-1.

3. Workload Estimates.

a. Temperate weather. The method used to compute estimates is as follows:

(1) ESC assumed that a 3-foot space separates three of the bladder's edges from the inside edge of the berm. The fourth edge of the bladder aligns with the inside edge of the berm. The berms' dimensions are 13.5 feet wide at the base, 3 feet wide at the top, and 5 feet high.[1] The area inside each berm measures 35 feet by 34 feet. See Figure B-26-2. The volume of sand needed to build one berm is estimated by multiplying the total length of the berm, measured at its mid-point, by the area of the cross-sectional face of the berm.

$$[(l) + (l) + (w) + (w)]\ (0.5)\ (h)\ (a + b)\ /\ 27 =$$

[1]DA, Engineer Family of Systems Study E-FOSS, Volume VII, p. N-III-bb-1.

(48.5 + 48.5 + 47.5 + 47.5) (0.5) (5) (3 + 13.5) / 27 =

(192) (0.5) (5) (16.5) / 27 = 293.33 LCY

Two berms require 586.66 LCY or 522.13 BCY (LCY multiplied by a load factor of 0.89).

(2) D7 dozer and M9 ACE production. To account for shaping and packing the berm, assume a push distance of 125 feet which, from Figure B-1, gives a production rate of 246 BCY/hour. Because the operator cannot use slot dozing techniques, this rate is reduced by one-sixth (see Annex B, paragraph 5a(1)(c), page B-4.

(522.13 BCY) (1.2) / (246 BCY/hour) = 2.55 hours

(3) D5 dozer production. As above, a push distance of 125 feet is assumed. Figure B-2 gives a production rate of 154 BCY/hour. The production rate is reduced by one-sixth for the reasons stated in paragraph (2).

(522.13 BCY) (1.2) / (154 BCY/hour) = 4.07 hours

(4) The surface of the roadway and the area of the pump stations is stabilized using sand-grids. For this estimate, each grid is assumed to weigh 110 pounds and measure 8 feet by 20 feet by 8 inches when expanded. Each grid contains 561 cells, each with a surface area of 40 square inches (see Figure B-26-3). The following procedures are used to build the roadway and the area for the pumps:

(a) Subgrade preparation. The 2.5-CY scoop loader uses backblading to smooth the sand prior to placement of the grids. The total area to be backbladed is approximately 1280 square yards. ESC assumed that the loader could finish this sub-task in 40 minutes or 0.67 hours.

(b) Grid Installation.

1. 36 grids (6 x 6) are needed for the 48' by 120' pump area. 36 grids (3 x 12) are also needed for the 24' by 240' roadway.

2. ESC estimates that a team of eight laborers can fit a grid in place and anchor it by filling several cells with sand. The time required is 0.2 hours or 1.6 manhours per grid. The total amount of effort expended for 72 grids is 115.2 manhours (72 x 1.6).

3. ESC assumed that the workforce is organized into four 8-man teams. Two teams work on the area in front of the pumps; the other two teams work on the roadway. The four teams, using the truck to carry the grids, finish this sub-task in 3.6 hours.

(c) Fill Grids With Sand. The loader operator fills the grid cells with sand. A 4 inch over-fill (1 foot total depth) insures that the grids will support the loader while it works. The volume of sand required to fill 72 grids is, approximately:

$$(8 \text{ ft}) (20 \text{ ft}) (1 \text{ ft}) (72) / 27 = 426.67 \text{ LCY}$$

From Figure B-1, the loader production rate is 207.1 LCY/hour. The time required to fill the grids is:

$$(426.67 \text{ LCY}) / (207.1 \text{ LCY/hour}) = 2.06 \text{ hours}$$

(5) Figures B-26-4 and B-26-5 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures B-26-6 and B-26-7. See Annex A for a discussion of the method used.

(1) Operating heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(a) D7 dozer. (2.55) / (0.52) = 4.90 hours

(b) D5 dozer. (4.07) / (0.52) = 7.83 hours

(c) Loader (sub-grade). (0.67) / (0.52) = 1.29 hours

(d) Truck. (3.60) / (0.52) = 6.92 hours

(e) Loader (filling grids). (2.06) / (0.52) = 3.96 hours

(2) Carrying, placing, and anchoring sand grids is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

(115.2) / (0.58) = 198.62 manhours

32 laborers will finish this task in 6.21 hours.

(3) The three equipment operating times exceed the maximum one-time work rate of 62 minutes, whereas the 6.21 hours of manual labor exceeds the maximum one-time work rate of 50 minutes given in Figure A-3. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

c. The estimates of elapsed time assume that the dozer builds the berms as the roadway and water point areas are stabilized. Each sub-task needed to stabilize the sand is performed sequentially. The total elapsed time is, therefore, the sum of these sub-task times.

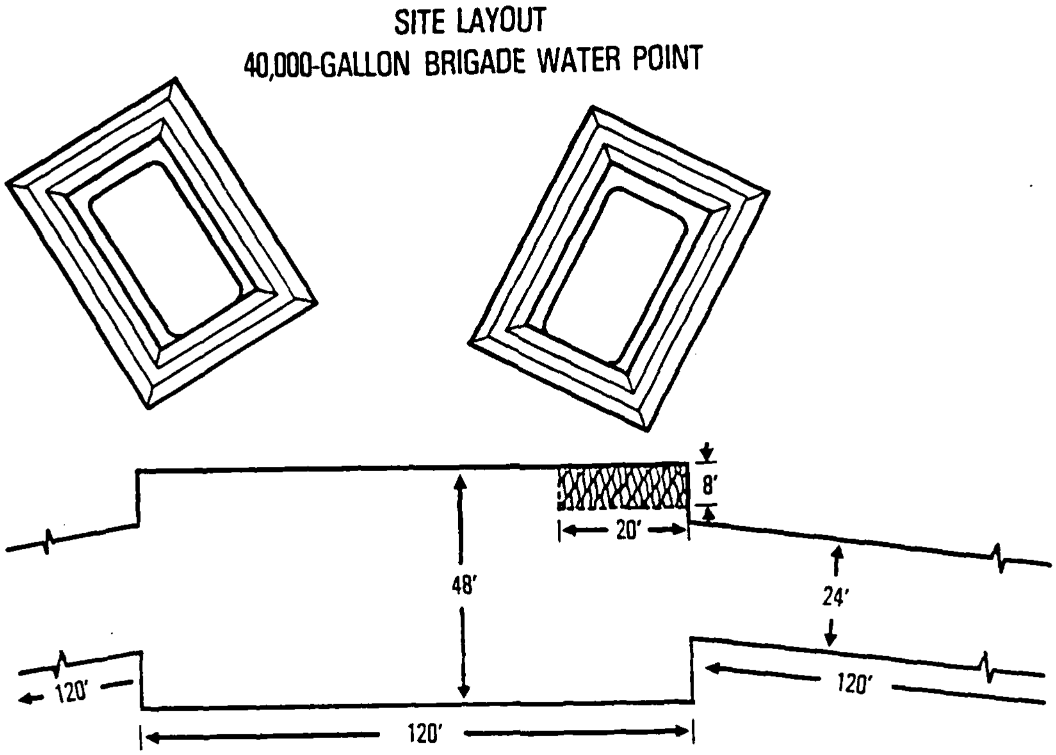

Figure B-26-1

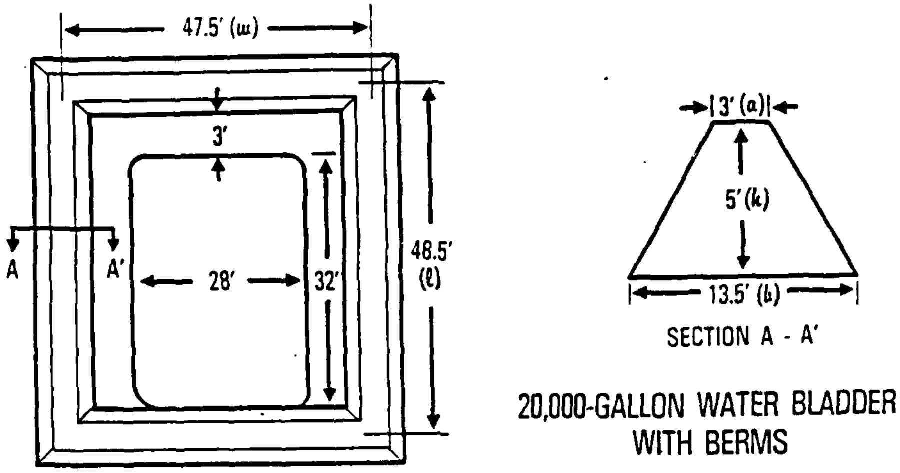

Figure B-26-2

SAND GRID

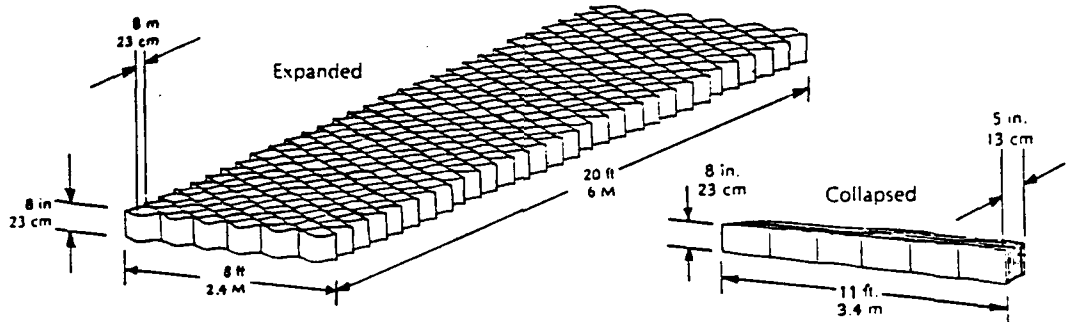

Figure B-26-3

PREPARE A SITE FOR A
40,000-GALLON BRIGADE WATER POINT
(Sandy Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	5-Ton Truck	Combat Engr
	Number of Items	1	1	1	32
ACTIVITY	Build Berms	2.55			
	Prepare Subgrade		0.67		
	Install Sand-Grids			3.60	115.20
	Fill Grids With Sand		2.06		
	Elapsed Time Required To Complete Task	6.33			

Figure B-26-4

PREPARE A SITE FOR A
40,000-GALLON BRIGADE WATER POINT
(Sandy Desert + Temperate Weather)

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	2.5-Ton Truck	Combat Engr
	Number of Items	1	1	1	32
ACTIVITY	Build Berms	4.07			
	Prepare Subgrade		0.67		
	Install Sand-Grids			3.60	115.20
	Fill Grids With Sand		2.06		
	Elapsed Time Required To Complete Task	6.33			

Figure B-26-5

PREPARE A SITE FOR A
40,000-GALLON BRIGADE WATER POINT
(Sandy Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		D7 Dozer or M9 ACE	2.5-CY Loader	5-Ton Truck	Combat Engr
Number of Items		1	1	1	32
ACTIVITY	Build Berms	4.90*			
	Prepare Subgrade		1.29*		
	Install Sand-Grids			6.92*	198.62*
	Fill Grids With Sand		3.96*		
Elapsed Time Required To Complete Task		12.17			

Figure B-26-6

PREPARE A SITE FOR A
40,000-GALLON BRIGADE WATER POINT
(Sandy Desert + Hot Weather)

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	2.5-Ton Truck	Combat Engr
	Number of Items	1	1	1	32
ACTIVITY	Build Berms	7.83*			
	Prepare Subgrade		1.29*		
	Install Sand-Grids			6.92*	198.62*
	Fill Grids With Sand		3.96*		
	Elapsed Time Required To Complete Task	12.17			

Figure B-26-7

LAST PAGE OF APPENDIX B-26

ANNEX C

ROCKY PLATEAU DESERT PLANNING FACTORS

ANNEX C

ROCKY PLATEAU DESERT PLANNING FACTORS

AD-A169 799 WORKLOAD ESTIMATES FOR COMBAT ENGINEERS IN THE DESERT (U) ARMY ENGINEER STUDIES CENTER FORT BELVOIR VA T O ATKINSON ET AL. APR 86 USAESC-R-86-2 3/6

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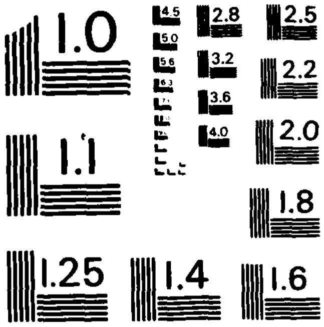
1.0
4.5
5.0
5.6
6.3
2.8
3.2
3.6
4.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

1. Purpose. This annex estimates work production planning factors for combat engineer tasks in a rocky plateau desert.

2. Scope. This analysis quantified the engineer effort required to support committed maneuver brigades and established planning factors for each of those tasks. The time estimates reflect work performed under weather conditions typical of a rocky desert plateau.

3. Method.

a. The tasks and the workload factors shown in Annex E were the basis for calculating engineer requirements in the rocky plateau desert.

b. Engineering designs were modified, when appropriate, to better protect users and their equipment from the effects of desert winds and intense heat.

c. Workload times were degraded to account for working in rocky, cemented soil and intense heat.

4. Discussion.

a. Many distinctive environmental traits distinguish the desert lands of the earth. Although desert terrain, like all terrain, can vary considerably from one place to another, the essential trait, and the one upon which all others depend, is the lack of water.[1] Generally the military literature divides the desert into three types of predominant terrain:

[1] J. Crane, Desert Water Supply, Naval Civil Engineering Laboratory, Port Hueneme, CA, 1982, p. A-3.

(1) Mountain desert

(2) Rocky plateau desert

(3) Sandy desert.

b. Between 35 and 50 percent of the world's 10.5 million square miles of arid land may be categorized as rocky plateau deserts.[2] Rocky plateau deserts have relatively slight relief interspersed by extensive flat areas that have solid or broken rock at or near the surface; granite and lava boulders and sedimentary rocks varying in size from a few inches to several feet in diameter are typical.[3] The area of the Golan Heights is often cited as an example of a rocky plateau desert. (See Figure C-1.)

c. It is the rocky plateau desert which affords the best cross-country mobility for a modern mechanized force. In general, this type of terrain is passable in all directions to both wheeled and tracked vehicles. Therefore, point obstacles will usually be easily bypassed and of little value. This is the type of terrain that Peter W. Rainier, a British engineer in North Africa during World War II, had in mind when he wrote:

> "Just as naval forces can maneuver freely at sea, so can a modern land army maneuver on the desert. But in a naval battle, even a large one, the numbers of ships can be counted by the score, while in those big desert battles, the vehicles were counted by the thousands."[4]

d. The firm foundation of the rocky plateau desert which enhances cross-country mobility also can greatly inhibit engineer efforts to dig. Gravels, pebbles, and sand grains in the rocky plateau desert may be deposited

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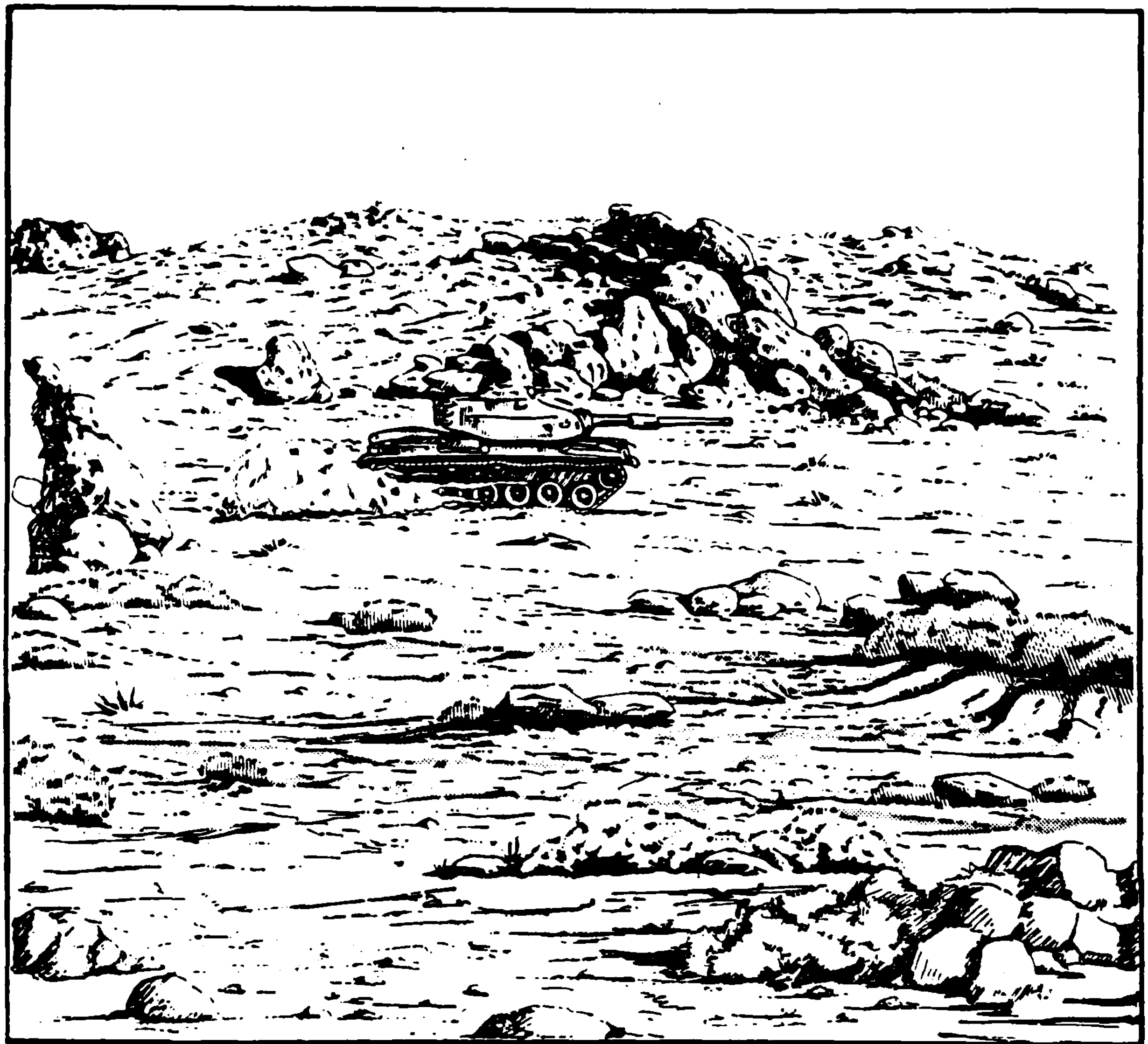
[2] Paul G. Cerjan and Theodore G. Stroup, Employment of the Engineer System in Arid Mountainous and Desert Areas--A Concept Paper, US Army War College, Carlisle Barracks, PA, 1981, p. 18.

[3] US Army Material Development and Readiness Command, Operations in Saudi Arabia--Lessons Learned, Alexandria, VA, 1983, p. 12.

[4] Peter W. Rainier, Pipeline to Battle: An Engineers Adventures with the British Eight Army, Random House, NY, 1943, p. 120.



ROCKY PLATEAU DESERT—THE GOLAN HEIGHTS

Figure C-1

in alluvium hundreds of feet thick.[5] The top layer is likely to be a cemented crust varying in thickness from a few inches to several feet. In its thinnest form, this outer layer is often called "desert pavement." Desert pavement is a mosaic of flat, closely packed, interlocking pebbles and rock fragments, usually only one stone thick. It is created by the actions of desert winds which blow away all the sand and dust, leaving behind a layer which resists further erosion.[6] In its thickest form, this outer layer is often called "surface chalk." Surface chalk is formed by the repeated cycles of dissolving calcium, silicon, and ferric compounds in the soil, followed by rapid evaporation. The result is a cemented top layer. Bulldozers equipped with rippers often will have to be used to dig through this cemented crust. In extreme cases, explosives will be required to punch through. In World War II, fortifications prepared beneath the surface chalk were able to withstand heavy artillery bombardments and air raids.[7]

e. Most of the infrequent rainfall in the rocky plateau desert run off rapidly in the form of flash floods. These floods erode deep, steeply walled gullies known as wadis. The water evaporates rapidly after the floods, leaving the ground in the wadi as barren as before. The following account from an Air Force study on desert survival techniques is typical:

> "One survivor had the rare opportunity of watching a wadi fill with a flood of water following a sudden and torrential rain storm farther inland. He described this onrush of water as being 2-1/2 to 3 feet deep and approximately one-half mile in width. In two hours the wadi was again completely dry."[8]

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[5] US Army Test and Evaluation Command, Background Document-"Desert Terrain", Yuma Proving Ground, AZ, 1969, p. 2.

[6] B.P. Pendergrass, "Assault Landing Zone Construction-Joint Exercise Desert Strike", Military Engineer, January through February 1965, p. 24.

[7] Alfred E. Toppe, Desert Warfare, German Experience in World War II, Historical Division European Command, 1952. p. 19.

[8] Richard A. Howard, Sun, Sand, and Survival: An Analysis of Survival Experiences in Desert Areas, Maxwell Air Force Base, AL, 1953, p. 10.

(1) Great caution should be exercised when selecting the bottom of a wadi for a defensive position. The wadi bottom may consist of a layer of soft sand or miry ground. The narrower wadis can be especially treacherous and become raging torrents without notice. The following excerpt clearly describes the danger involved in occupying a wadi for an extended period:

> "The fact that they very often are sources of water and limited vegetation make wadis all the more tempting as a base of operations. They can be very dangerous however. During a reconnaissance of a Saudi Arabian National Guard training area, a party entered a wadi with six- to eight-foot trees and 12- to 20-foot walls. The tree tops and upper walls had lodged in them corpses of a number of sheep that had been drowned in a flash flood. Signs of this kind of devastion can be found in most dry stream beds in the desert."[9]

(2) The banks of a wadi are generally steep, but not continuous, since they are usually cut by many cross-wadis. Wadis can be considered terrain obstacles, but obstacles that can be overcome easily unless obstinately defended.[10] The preferred method of defeating a wadi obstacle is to build access and egress cuts; however, bulldozers not equipped with rippers may experience difficulty in some areas.

5. Work Rate Degradation for Rocky Plateau Deserts.

a. Work production rates for bulldozers were estimated using the method described on pages 41 through 45 of the Caterpillar Handbook.[11]

(1) Figures E-1 through E-2 in Annex E are reprinted from pages 42 through 44 of the Caterpillar Handbook. Figures E-1 and E-2 display the maximum production rates for the various dozer/blade combinations indicated. Figure E-3 lists the correction factors that may modify the maximum production

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[9] Operations in Saudi Arabia - Lessons Learned, p. 60.
[10] Alfred E. Toppe, pp. 64-65.
[11] Caterpiller Tractor Company, Caterpillar Performance Handbook, Edition 15, 1984, p. 41-45.

rates. Finally, Figure E-4 notes the effects of working on slopes of different grades. The following correction factors were assumed to determine the effort that US engineers will be required to expend to complete combat engineer tasks under the conditions typical of a rocky plateau desert:

(a) Operator (average) = 0.75. Workrate estimates assume that dozer operators have average abilities.

(b) Material: Rock.

<u>1.</u> <u>D7 Dozer = 0.56.</u> Hard to cut with tilt cylinder

(0.80) (0.70) = 0.56

<u>2.</u> <u>D5 Dozer = 0.49.</u> Hard to cut without tilt cylinder

(0.70) (0.70) = 0.49

(c) <u>Slot dozing = 1.2.</u> Whenever possible, engineer dozer operators are assumed to use slot dozing techniques.

(d) <u>Job efficiency (60 minutes/hour) = 1.0.</u> This correction factor is more appropriate for long-term projects; the tasks described in this annex require a much shorter time to complete. This factor, therefore, is set to 1.0 for requirements estimates.

(e) <u>Grade = 1.0.</u> An average grade of 0 percent is assumed for terrain in the rocky plateau desert. (See Figure E-4.)

(f) <u>Soil density (decomposed rock) = 0.79.</u> The density of the material on which the tables are based (2300 lb/LCY) is divided by the density of decomposed rock, which is 50 percent rock and 50 percent earth (2900 lb/LCY).

(g) The total correction factor applied to the maximum dozer production rates is the product of the factor listed above:

1. D7 Dozer:

(0.75) (0.56) (1.2) (1.0) (1.0) (0.79) = 0.40

2. D5 Dozer:

(0.75) (0.49) (1.2) (1.0) (1.0) (0.79) = 0.35

(2) Figures C-2 and C-3 show the production rates for the D7 and D5 dozer, respectively. The rates are shown for various average dozing distances. The values in the first row are taken from Figures E-1 and E-2 in Annex E. These values represent, in loose cubic yards per hour, the maximum production rates of the D7 and D5 dozers that are equipped with straight dozer blades. The values in the second row are the conversion to bank cubic yards per hour, obtained by multiplying the values in the first row by the load factor of 0.75 for decomposed rock.[12] The third row displays the production rates which result from multiplying the value in the second row by the applicable correction factor. These last rates are used as the dozer production rates for the tasks described in this annex.

b. The M9 Armored Combat Earthmover (ACE) is considered to have earthmoving and bulldozing characteristics comparable to the D7 dozer.[13,14]

c. Excavation rates were estimated for the Small Emplacement Excavator (SEE) by using field test data for the JD410 loader/backhoe, and then degrading those results to account for the difficult digging conditions in the rocky plateau desert.[15,16]

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[12] Caterpillar Performance Handbook, p. 586.

[13] DA, FM 5-103, Survivability, Draft, p. A-2.

[14] DA, Combat Engineer System Handbook, June 1984, p. 67.

[15] DA, Final Report of Strongpoint Emplacement Excavation for Defensive Operations (SPEEDO), Concept Evaluation, TRADOC Project Number 7-CEP091, February 1978; and raw test data provided by the US Army Mobility Equipment Research and Development Center, Fort Belvoir, VA.

[16] ESC used the specifications for the military SEE tractor built by the Freightliner Corporation as representative of the fielded SEE.

PRODUCTION RATES FOR D7 DOZER

(ROCKY PLATEAU DESERT)

	PUSH DISTANCE (FEET)					
	50	75	100	125	150	200
LCY/HOUR	760	580	460	400	350	280
BCY/HOUR	570	435	345	300	263	210
CORRECTED RATE	228	174	138	120	105	84

Figure C-2

PRODUCTION RATES FOR D5 DOZER

(ROCKY PLATEAU DESERT)

	PUSH DISTANCE (FEET)					
	50	75	100	125	150	200
LCY/HOUR	460	375	300	250	200	150
BCY/HOUR	345	281	225	188	150	113
CORRECTED RATE	121	98	79	66	53	39

Figure C-3

(1) The field test data suggest that the SEE has two excavation rates. First an estimated rate of 28 BCY/hour is appropriate when excavating, under European conditions, a simple geometric pattern such as a linear trench or a rectangular pit. The Caterpillar Handbook suggests a degradation factor of 0.45 for poorly blasted rock.[17] Thus, an excavation rate of 12.6 BCY/hour is used for simple geometric patterns in the rocky plateau desert:

$$(28)\ (0.45) = 12.6 \text{ BCY/hour}$$

(2) Second, a rate of 12 BCY/hour approximates the production rate of the SEE when it is excavating an emplacement with a more complex geometric pattern, such as a circular or U-shaped pit. A degradation factor of 0.45 is also applied to this rate, resulting in a rate of 5.4 BCY/hour for complex geometric patterns in the rocky plateau desert:

$$(12)\ (0.45) = 5.4 \text{ BCY/ hour}$$

d. As in Annex E, scoop loader rates for both the 2-1/2-cubic-yard loader and the 3/4-cubic-yard SEE were estimated based on the Caterpillar Handbook.[18] Figure C-4 shows the steps followed to estimate scoop loader and SEE production rates. As in Annex E, an average basic cycle time of 0.6 minutes was selected.

(1) The production rate for the 2-1/2-cubic-yard loader is 190.7 LCY/hour in the rocky plateau desert.

(2) The production rate for the SEE is 57.2 LCY/hour in the rocky plateau desert.

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[17] Caterpillar Performance Handbook, p. 110.
[18] Caterpillar Performance Handbook, pp. 354-355.

PRODUCTION ESTIMATES FOR THE 2-1/2-CUBIC-YARD SCOOP LOADER AND THE SEE

(ROCKY PLATEAU DESERT)

FACTOR NAME	BASIC CYCLE TIME	+	MATERIAL TYPE (BROKEN EARTH)	+	DOZER PILED	+	CONSTANT OPERATION	=	TOTAL CYCLE TIME
SCOOP LOADER	0.60		0.02		0.01		−0.04		0.59
SEE	0.60		0.02		0.01		−0.04		0.59

FACTOR NAME	(60)	÷	TOTAL CYCLE TIME	=	CYCLES PER HOUR	X	LCY PER CYCLE	=	LCY PER HOUR
SCOOP LOADER			0.59		101.7		1.88		190.7
SEE			0.59		101.7		0.56		57.2

Figure C-4

LAST PAGE OF ANNEX C

APPENDIX C-1

BUILD A PROTECTIVE POSITION FOR AN ARMORED VEHICLE

APPENDIX C-1

BUILD A PROTECTIVE POSITION FOR AN ARMORED VEHICLE

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator and one engineer to confer with users and to guide the dozer to the position site.

a. The planning factors displayed in Figures C-1-1 through C-1-4 are appropriate for:

(1) Personnel carriers

(2) Infantry TOW carriers

(3) Armored car TOW carriers

(4) Armored car personnel carriers

(5) Infantry fighting vehicles

(6) Cavalry fighting vehicles

(7) Armored tank

(8) Armored car tank

(9) Artillery personnel carrier (FIST)

(10) Counter battery/counter mortar radar

(11) Self-propelled vulcan

(12) Infantry command post carrier

(13) Armored command post carrier

(14) Towed artillery command post carrier

(15) Infantry mortar carrier

(16) Armored cavalry mortar carrier

(17) Armored mortar carrier

(18) Brigade headquarters command post carrier[1]

b. The excavated position is 4.2 meters wide and 1.5 meters deep. It has a 7-meter-long floor and an entrance ramp with a 9-degree slope. To ease earthmover entry into the excavation a sloped face of 1:1.5 was assumed adequate.[2] See Figure E-1-1. The volume of earth that must be excavated is the same as the volume estimated in Appendix E-1 (105.9 BCY).

3. Workload Estimates.

a. Temperate weather. Figures C-1-1 and C-1-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

(1) D7 dozer and M9 ACE production.

(a) Assume a push distance of 75 feet which, from Figure C-2, gives a production rate of 174 BCY/hour:

$$(105.9 \text{ BCY}) / (174 \text{ BCY/hour}) = 0.61 \text{ hours}$$

(b) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

$$(0.61) + (0.08) = (0.69) \text{ hours}$$

(2) D5 dozer production.

(a) Assume a push distance of 75 feet which, from Figure C-3, gives a production rate of 98 BCY/hour:

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[1] DA, Survivability--the Effort and the Payoff, June 1981, p. 30.
[2] DA, Engineer Family of Systems Study, Volume N, pp. N-III-q-2 through N-III-q-5.

$$(105.9 \text{ BCY}) / (98 \text{ BCY/hour}) = 1.08 \text{ hours}$$

(b) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

$$(1.08) + (0.08) = 1.16 \text{ hours}$$

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-1-3 and C-1-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(0.05) / (0.58) = 0.09 \text{ hours}$$

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

$$(0.69) / (0.52) = 1.33 \text{ hours}$$

$$(1.16) / (0.52) = 2.23 \text{ hours}$$

(3) The 1.33 and 2.23 hours required exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

BUILD A PROTECTIVE POSITION
FOR AN ARMORED VEHICLE
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.69	
	Elapsed Time Required To Complete Task	0.69	

Figure C-1-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	1.16	
	Elapsed Time Required To Complete Task	1.16	

Figure C-1-2

BUILD A PROTECTIVE POSITION
FOR AN ARMORED VEHICLE
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		D7 Dozer or M9 ACE	Combat Engr
Number of Items		1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Excavate	1.33*	
Elapsed Time Required To Complete Task		1.33	

Figure C-1-3

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		D5 Dozer	Combat Engr
Number of Items		1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Excavate	2.23*	
Elapsed Time Required To Complete Task		2.23	

Figure C-1-4

LAST PAGE OF APPENDIX C-1

APPENDIX C-2

BUILD A PROTECTIVE POSITION FOR A 1/4-TON MOUNTED TOW

APPENDIX C-2

BUILD A PROTECTIVE POSITION FOR A 1/4-TON MOUNTED TOW

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator and one engineer to confer with users and to guide the dozer to the position site. The excavated position is 5 meters wide and 1 meter deep. It has an 8.5-meter-long floor and an entrance ramp with a 9-degree slope. To ease earthmover entry into the excavation a sloped face of 1:1.5 was assumed adequate.[1] See Figure E-2-1. The volume of earth that must be excavated is the same as the volume estimated in Appendix E-2 (81.1 BCY).

3. Workload Estimates.

a. Temperate weather: C-2-1 and C-2-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

(1) D7 dozer and M9 ACE production.

(a) Assume a push distance of 75 feet which, from Figure C-2, gives a production rate of 174 BCY/hour:

(81.1 BCY) / (174 BCY/hour) = 0.47 hours

(b) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer requires an additional 5 minutes to move from position site to position site within the defensive perimeter:

[1] DA, FM 5-103, Survivability, 1985 Draft, pp. 4-18.

(0.47) + (0.08) = 0.55 hours

(2) D5 dozer production.

(a) Assume a push distance of 75 feet which, from Figure C-3, gives a production rate of 98 BCY/hour:

(81.1 BCY) / (98 BCY/hour) = 0.83 hours

(b) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his acitvity while the dozer takes an additional 5 minutes to move to the next position.

(0.83) + (0.08) = 0.91 hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-2-3 and C-2-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

(0.05) / (0.58) = 0.09 hours

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(0.55) / (0.52) = 1.06 hours

(0.91) / (0.52) = 1.75 hours

(3) The 1.06 and 1.75 hours required exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

BUILD A PROTECTIVE POSITION FOR A 1/4-TON MOUNTED TOW
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.55	
	Elapsed Time Required To Complete Task	0.55	

Figure C-2-1

LIGHT EQUIPMENT WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.91	
	Elapsed Time Required To Complete Task	0.91	

Figure C-2-2

BUILD A PROTECTIVE POSITION FOR A
1/4-TON MOUNTED TOW
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Excavate	1.06*	
	Elapsed Time Required To Complete Task	1.06	

Figure C-2-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Excavate	1.75*	
	Elapsed Time Required To Complete Task	1.75	

Figure C-2-4

LAST PAGE OF APPENDIX C-2

APPENDIX C-3

BUILD A PROTECTIVE POSITION FOR A NON-ARMORED VEHICLE

APPENDIX C-3

BUILD A PROTECTIVE POSITION FOR A NON-ARMORED VEHICLE

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator, one 2-1/2-cubic-yard scoop loader with operator, and one engineer to confer with users and to guide the equipment to the position site.

a. The planning factors displayed in Figures C-3-1 through C-3-4 are appropriate for the 1/4-ton, 3/4-ton, 1-1/4-ton, 2-1/2-ton, and 5-ton cargo trucks with their trailers.[1]

b. The excavated position is 3.5 meters wide and 1.5 meters deep. It has a 10.5-meter-long floor and an entrance ramp with a 9-degree slope. There is a 0.75-meter-high parapet along both sides of the cut. To ease earthmover entry into the excavation a sloped face of 1:1.5 was assumed adequate.[2] See Figure E-3-1. The volume of earth that must be excavated is the same as the volume estimated in Appendix E-3 (112.2 BCY).

3. Workload Estimates.

a. Temperate weather. Figures C-3-1 and C-3-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

(1) D7 dozer/scoop loader and M9 ACE/scoop loader production.

(a) Assume a push distance of 75 feet which, from Figure C-2, gives a production rate of 174 BCY/hour:

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[1] DA, Engineer Family of Systems Study, Volume N, p. N-III-u-1.
[2] Engineer Family of Systems Study, p. N-III-u-1.

(112.2 BCY) / (174 BCY/hour) = 0.64 hours

(b) While the dozer excavates the scoop loader forms the parapets and removes excess spoil.

(c) Assume that, for each site within the supported units perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

(0.64) + (0.08) = 0.72 hours

(2) D5 dozer/scoop loader production.

(a) Assume a push distance of 75 feet which, from Figure C-3, gives a production rate of 98 BCY/hour:

(112.2 BCY) / (98 BCY/hour) = 1.14 hours

(b) While the dozer excavates the scoop loader forms the parapets and removes excess soil.

(c) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

(1.14) + (0.08) = 1.22 hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-3-3 and C-3-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

(0.05) / (0.58) = 0.09 hours

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

$$(0.72) / (0.52) = 1.38 \text{ hours}$$

$$(1.22) / (0.52) = 2.35 \text{ hours}$$

(3) The 1.38 and 2.35 hours required exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

BUILD A PROTECTIVE POSITION FOR A
NON-ARMORED VEHICLE
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	0.72	0.72	
	Elapsed Time Required To Complete Task	0.72		

Figure C-3-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	1.22	1.22	
	Elapsed Time Required To Complete Task	1.22		

Figure C-3-2

BUILD A PROTECTIVE POSITION FOR A
NON-ARMORED VEHICLE
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.09
	Excavate	1.38*	1.38*	
	Elapsed Time Required To Complete Task		1.38	

Figure C-3-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.09
	Excavate	2.35*	2.35*	
	Elapsed Time Required To Complete Task		2.35	

Figure C-3-4

LAST PAGE OF APPENDIX C-3

APPENDIX C-4

BUILD A PROTECTIVE POSITION FOR A FORWARD AREA ALERTING RADAR (FAAR)

APPENDIX C-4

BUILD A PROTECTIVE POSITION FOR A FORWARD AREA ALERTING RADAR (FAAR)

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator, one 2-1/2-cubic-yard scoop loader with operator, and one engineer to confer with users and to guide the equipment to the position site. The position has a berm around three sides. The floor of the position is 6.7 meters by 7.6 meters while the berm is 1 meter wide at the top and 2.7 meters high with sloping sides of 1:1.[1] See Figure E-4-1. The volume of earth that must be excavated is the same as the volume estimated in Appendix E-4 (362.7 BCY).

3. Workload Estimates.

a. Temperate weather. Figures C-4-1 and C-4-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. These estimates were based on the following production rates:

(1) D7 dozer/scoop loader and M9 ACE/scoop loader production.

(a) Assume a push distance of 75 feet which, from Figure C-2, gives a production rate of 174 BCY/hour. Because the dozer operator cannot use slot dozing techniques, this rate is reduced by one-sixth (see Annex C, paragraph 5a(1)(c), page C-7).

$$(362.7 \text{ BCY})\ (1.2)\ /\ (174 \text{ BCY/hour}) = 2.50 \text{ hours}$$

(b) As the dozer pushes earth into piles generally conforming to the outline of the position, the scoop loader forms the berm.

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[1]DA, Engineer Family of Systems Study, Volume N, p. N-III-u-1.

The scoop loader requires 5 additional minutes after the dozer has finished to complete the shaping of the berm.

$$(2.50) + (0.08) = 2.58 \text{ equipment hours}$$

(c) Assume that the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the dozer to the site. No additional time is added to account for intra-perimeter movement between positions because of the limited number of such positions within a defensive perimeter.

(2) D5 dozer/scoop loader production.

(a) Assume a push distance of 75 feet which, from Figure C-3, gives a production rate of 98 BCY/hour. For the same reasons stated above, reduce this rate by one-sixth.

$$(362.7 \text{ BCY}) (1.2) / (98 \text{ BCY/hour}) = 4.44 \text{ hours}$$

(b) As above, the scoop loader forms the berm as the D5 dozer excavates.

$$(4.44) + (0.08) = 4.52 \text{ hours}$$

(c) As done above the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity and no intra-perimeter movement for the equipment.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-4-3 and C-4-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(0.05) / (0.58) = 0.09 \text{ hours}$$

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(a) D7 dozer. (2.50) / (0.52) = 4.80 hours

(b) Scoop loader. (2.58) / (0.52) = 4.96 hours

(c) D5 dozer. (4.44) / (0.52) = 8.54 hours

(d) Scoop loader. (4.52) / (0.52) = 8.69 hours

(3) The 4.80, 4.96, 8.54, and 8.69 hours required exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

BUILD A PROTECTIVE POSITION FOR A
FORWARD AREA ALERTING RADAR (FAAR)
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	2.50	2.58	
	Elapsed Time Required To Complete Task	2.58		

Figure C-4-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	4.44	4.52	
	Elapsed Time Required To Complete Task	4.52		

Figure C-4-2

BUILD A PROTECTIVE POSITION FOR A
FORWARD AREA ALERTING RADAR (FAAR)
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.09
	Excavate	4.80*	4.96*	
	Elapsed Time Required To Complete Task		4.96	

Figure C-4-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.09
	Excavate	8.54*	8.69*	
	Elapsed Time Required To Complete Task		8.69	

Figure C-4-4

LAST PAGE OF APPENDIX C-4

APPENDIX C-5

BUILD A PROTECTIVE POSITION FOR A PULSE AQUISITION RADAR (PAR)

APPENDIX C-5

BUILD A PROTECTIVE POSITION FOR A PULSE AQUISITION RADAR (PAR)

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator and one engineer to confer with users and to guide the dozer to the position site. This engineer team is supplemented with the 2.5-cubic-yard scoop loader and operator from the Hawk battery.

a. The workload factors shown in Figures C-5-1 through C-5-4 are appropriate for the following components of the Hawk air defense system:

(1) Pulse aquisition radar

(2) Range only radar

(3) Constant wave acquisition radar

(4) High power radar

b. The position has a berm around three sides. The floor of the position is 6.7 meters by 7.6 meters while the berm is 1 meter wide at the top and 1.8 meters high with sloping sides of 1:1.[1] See Figure E-5-1. The volume of earth that must be excavated is the same as the volume estimated in Appendix E-5 (164.0 BCY).

3. Workload Estimates.

a. Temperate weather. Figures C-5-1 and C-5-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

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[1]Taken from interview notes written by Mr. Eugene Ehrlich during the preparation of the report, Survivability--the Effort and the Payoff, June 1981.

(1) D7 dozer/scoop loader and M9 ACE/scoop loader production.

(a) Assume a push distance of 75 feet which, from Figure C-2, gives a production rate of 174 BCY/hour. Because the dozer operator cannot use slot dozing techniques, this rate is reduced by one-sixth (see Annex C, paragraph 5a(1)(c), page C-7).

(164.0 BCY) (1.2) / (174 BCY/hour) = 1.13 hours

(b) As the dozer excavates and piles the earth, the loader from the battery forms the berm. The loader continues to work after the dozer has finished piling earth. However, the estimate of engineer effort ends when the dozer is finished.

(c) Assume that the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the dozer to the site. No additional time is added to account for intra-perimeter movement between positions because of the limited numbers of such positions within a defensive perimeter.

(2) D5 dozer/scoop loader production.

(a) Assume a push distance of 75 feet which, from Figure C-3, gives a production rate of 98 BCY/hour. For the same reasons stated above, reduce this rate by one-sixth.

(164.0 BCY) (1.2) / (98 BCY/hour) = 2.01 hours

(b) As above, the additional loader time necessary to complete the position is not included in the time estimate.

(c) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity and no intra-perimeter movement for the equipment.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-5-3 and C-5-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(0.05) / (0.58) = 0.09 \text{ hours}$$

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(a) D7 Dozer. (1.13) / (0.52) = 2.17 hours

(b) D5 Dozer. (2.01) / (0.52) = 3.87 hours

(3) The 2.17 and 3.87 hours required exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

BUILD A PROTECTIVE POSITION FOR A
PULSE AQUISITION RADAR (PAR)
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	1.13	
	Elapsed Time Required To Complete Task	1.13	

Figure C-5-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	2.01	
	-		
	Elapsed Time Required To Complete Task	2.01	

Figure C-5-2

BUILD A PROTECTIVE POSITION FOR A
PULSE AQUISITION RADAR (PAR)
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Excavate	2.17*	
	Elapsed Time Required To Complete Task	2.17	

Figure C-5-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Excavate	3.87*	
	Elapsed Time Required To Complete Task	3.87	

Figure C-5-4

LAST PAGE OF APPENDIX C-5

APPENDIX C-6

BUILD A PROTECTIVE POSITION FOR A SELF-PROPELLED HOWITZER

APPENDIX C-6

BUILD A PROTECTIVE POSITION FOR A SELF-PROPELLED HOWITZER

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator, one 2-1/2-cubic-yard scoop loader with operator, and one engineer to confer with users and to guide the dozer to the position site.

a. The planning factors displayed in Figures C-6-1 through C-6-4 are appropriate for the following self-propelled artillery pieces. Moreover, the position includes enough room for the M548 6-ton ammunition carrier.

(1) M109 155-mm self-propelled howitzer

(2) M55 8-in self-propelled howitzer

(3) M110 8-in self-propelled howitzer[1]

b. The excavated position is 5.4 meters wide and 1.5 meters deep. It has a 21-meter-long floor and an entrance ramp with a 9-degree slope. To ease earthmover entry into the excavation a sloped face of 1:1.5 is assumed adequate.[2] See Figure E-6-1. The volume of earth that must be excavated is the same as the volume estimated in Appendix E-6 (284.5 BCY).

3. Workload Estimates.

a. Temperature weather. Figures C-6-1 and C-6-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams respectively. These estimates were based on the following production rates.

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[1] DA, Engineer Family of Systems Study, Volume N, pp. N-III-v-1 and N-III-v-2.

[2] Engineer Family of Systems Study, p. N-III-v-4.

(1) D7 dozer/scoop loader and M9 ACE/scoop loader production.

(a) Assume a push distance of 75 feet which, from Figure C-2, gives a production rate of 174 BCY/hour:

(284.5 BCY) / (174 BCY/hour) = 1.64 hours

(b) As the dozer excavates, the loader spreads the excavated soil to reduce the possibility of enemy identification. The loader continues to work about 5 minutes after the dozer finishes:

(1.64) + (0.08) = 1.72 hours

(c) Assume that for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

(1.64) + (0.08) = 1.72 hours

(2) D5 dozer/scoop loader production.

(a) Assume a push distance of 75 feet which, from Figure C-3, gives a production rate of 98 BCY/hour:

(284.5 BCY) / (98 BCY/hour) = 2.90 hours

(b) As above, an additional 5 minutes is added to account for the loader's work time:

(2.90) + (0.08) = 2.98 hours

(c) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

(2.90) + (0.08) = 2.98 hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-6-3 and C-6-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(0.05) / (0.58) = 0.09 \text{ hours}$$

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(a) D7 dozer/scoop loader. (1.72) / (0.52) = 3.31 hours

(b) D5 dozer/scoop loader. (2.98) / (0.52) = 5.73 hours

(3) The 3.31 and 5.73 hours required exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

BUILD A PROTECTIVE POSITION FOR A
SELF-PROPELLED HOWITZER
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	1.72	1.72	
	Elapsed Time Required To Complete Task	1.72		

Figure C-6-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	2.98	2.98	
	Elapsed Time Required To Complete Task	2.98		

Figure C-6-2

BUILD A PROTECTIVE POSITION FOR A
SELF-PROPELLED HOWITZER
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.09
	Excavate	3.31*	3.31*	
	Elapsed Time Required To Complete Task	3.31		

Figure C-6-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.09
	Excavate	5.73*	5.73*	
	Elapsed Time Required To Complete Task	5.73		

Figure C-6-4

LAST PAGE OF APPENDIX C-6

APPENDIX C-7

BUILD A PROTECTIVE POSITION FOR A 105-MM TOWED HOWITZER

APPENDIX C-7

BUILD A PROTECTIVE POSITION FOR A 105-MM TOWED HOWITZER

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator and one combat engineer to confer with users and to guide the dozer to the position site. The position is a raised circular earth berm approximately 7 meters in diameter and 0.75 meters high. The berm is 1 meter wide at the top and 3 meters wide at the bottom. There is a 2.5-meter-wide opening in the berm for egress and access.[1] See Figure E-7-1. The volume of earth that must be excavated is the same as the volume estimated in Appendix E-7 (45.38 BCY).

3. Workload Estimates.

a. *Temperate weather. Figures C-7-1 and C-7-2 present the workload* estimates, under temperate conditions, for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

(1) D7 dozer and M9 ACE production.

(a) To account for shaping and packing the berm, assume a push distance of 125 feet which, from Figure C-2, gives a production rate of 120 BCY/hour. Because the dozer operator cannot use slot dozing techniques, this rate is reduced by one-sixth (see Annex C, paragraph 5a(1)(c), page C-7).

(45.38 BCY) (1.2) / (120 BCY/hour) = 0.45 hours

(b) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating

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[1]Taken from notes written by Mr. Eugene Ehrlich during the preparation of the report, Survivability--the Effort and the Payoff, June 1981.

an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

$$(0.95) + (0.08) = 0.53 \text{ hours}$$

(2) D5 dozer production.

(a) To account for shaping and packing the berm, assume a push distance of 125 feet which, from Figure C-3, gives a production rate of 66 BCY/hour. For the same reasons stated above, reduce this rate by one-sixth.

$$(45.38)\ (1.2)\ /\ (66 \text{ BCY/hour}) = 0.83 \text{ hours}$$

(b) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

$$(0.83) + (0.08) = 0.91 \text{ hours}$$

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-7-3 and C-7-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(0.05)\ /\ (0.58) = 0.09 \text{ hours}$$

(2) Berm construction with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(a) D7 dozer. $(0.53)\ /\ (0.52) = 1.02$ hours

(b) D5 dozer. $(0.91)\ /\ (0.52) = 1.75$ hours

(3) The 1.75 hours required exceeds the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

BUILD A PROTECTIVE POSITION FOR A
105-MM TOWED HOWITZER
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Build Berm	0.53	
	Elapsed Time Required To Complete Task	0.53	

Figure C-7-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Build Berm	0.91	
	Elapsed Time Required To Complete Task	0.91	

Figure C-7-2

BUILD A PROTECTIVE POSITION FOR A
105-MM TOWED HOWITZER
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		D7 Dozer or M9 ACE	Combat Engr
Number of Items		1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Build Berm	1.02	
	Elapsed Time Required To Complete Task	1.02	

Figure C-7-3

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		D5 Dozer	Combat Engr
Number of Items		1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Build Berm	1.75*	
	Elapsed Time Required To Complete Task	1.75	

Figure C-7-4

LAST PAGE OF APPENDIX C-7

APPENDIX C-8

BUILD A PROTECTIVE POSITION FOR A 155-MM TOWED HOWITZER

APPENDIX C-8

BUILD A PROTECTIVE POSITION FOR A 155-MM TOWED HOWITZER

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator and one combat engineer to confer with users and to guide the dozer to the position site. The position is a raised circular earth berm approximately 9 meters in diameter and 1 meter high. The berm is 1 meter wide at the top and 3 meters wide at the bottom. There is a 2.5-meter-wide opening in the berm for egress and access.[1] See Figure E-8-1. The volume of earth that must be excavated is the same as the volume estimated in Appendix E-8 (73.66 BCY).

3. Workload Estimates.

a. Temperate weather. Figures C-8-1 and C-8-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams respectively. These estimates were based on the following production rates.

(1) D7 dozer and M9 ACE production.

(a) To account for shaping and packing the berm, assume a push distance of 125 feet which, from Figure C-2, gives a production rate of 120 BCY/hour. Because the dozer operator cannot use slot dozing techniques, this rate is reduced by one-sixth (see Annex C, paragraph 5a(1)(c), page C-7).

(73.66 BCY) (1.2) / (120 BCY/hour) = 0.74 hours

(b) Assume that for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating

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[1]Taken from notes written Mr. Eugene Ehrlich during the preparation of the report Survivability--the Effort and the Payoff, June 1981.

an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer requires an additional 5 minutes to move from position site within the defensive perimeter.

$$(0.74) + (0.08) = 0.82 \text{ hours}$$

(2) D5 dozer production.

(a) To account for shaping and packing the berm, assume a push distance of 125 feet which, from Figure C-3, gives a production rate of 66 BCY/hour. For the same reasons stated above, reduce this rate by one-sixth.

$$(73.66 \text{ BCY})\ (1.2)\ /\ (66 \text{ BCY/hour}) = 1.34 \text{ hours}$$

(b) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

$$(1.34) + (0.08) = 1.42 \text{ hours}$$

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-8-3 and C-8-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(0.05)\ /\ (0.58) = 0.09 \text{ hours}$$

(2) Berm construction with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(a) D7 dozer. (0.82) / (0.52) = 1.58 hours

(b) D5 dozer. (1.42) / (0.52) = 2.73 hours

(3) The 1.58 and 2.73 hours required exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

BUILD A PROTECTIVE POSITION FOR A
155-MM TOWED HOWITZER
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Build Berm	0.82	
	Elapsed Time Required To Complete Task	0.82	

Figure C-8-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Build Berm	1.42	
	Elapsed Time Required To Complete Task	1.42	

Figure C-8-2

BUILD A PROTECTIVE POSITION FOR A
155-MM TOWED HOWITZER
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Build Berm	1.58*	
	Elapsed Time Required To Complete Task	1.58	

Figure C-8-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Build Berm	2.73*	
	Elapsed Time Required To Complete Task	2.73	

Figure C-8-4

LAST PAGE OF APPENDIX C-8

APPENDIX C-9

BUILD A TWO-MAN FIGHTING POSITION

APPENDIX C-9

BUILD A TWO-MAN FIGHTING POSITION

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer team assigned to build this position has one Small Emplacement Excavator (SEE) with operator and one engineer to confer with users and to guide the SEE to the position site. The position is a linear trench 7 feet long, 2 feet wide, and 5 feet deep. The volume of earth that must be excavated is estimated as follows:

$$(7)\ (2)\ (5)\ /\ 27 = 2.59\ \text{BCY}$$

3. Workload Estimates.

a. Temperate weather. Figures C-9-1 and C-9-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

(1) Using the excavation rate for the SEE shown in paragraph 5c(1), page C-10.

$$(2.59\ \text{BCY})\ /\ (12.6\ \text{BCY/Hour}) = 0.21\ \text{hours}$$

(2) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the SEE to the site. Concurrently, the SEE requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

$$(0.21) + (0.08) = 0.29\ \text{hours}$$

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-9-3 and C-9-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(0.05) / (0.58) = 0.09 \text{ hours}$$

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

$$(0.29) / (0.52) = 0.56 \text{ hours}$$

BUILD A 2-MAN FIGHTING POSITION
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.05
	Excavate	0.29	
	Elapsed Time Required To Complete Task	0.29	

Figure C-9-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.05
	Excavate	0.29	
	Elapsed Time Required To Complete Task	0.29	

Figure C-9-2

BUILD A 2-MAN FIGHTING POSITION
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.09
	Excavate	0.56	
	Elapsed Time Required To Complete Task	0.56	

Figure C-9-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.09
	Excavate	0.56	
	Elapsed Time Required To Complete Task	0.56	

Figure C-9-4

LAST PAGE OF APPENDIX C-9

APPENDIX C-10

BUILD A POSITION FOR A DISMOUNTED TOW

APPENDIX C-10

BUILD A POSITION FOR A DISMOUNTED TOW

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer team assigned to build this position has one Small Emplacement Excavator (SEE) with operator and one engineer to confer with users and to guide the SEE to the position site. The position is a rectangular pit 5 feet long, 5-1/2 feet wide, and 2 feet deep. The volume of earth that must be excavated is estimated as follows:

$$(5)\ (5.5)\ (2)\ /\ 27 = 2.04\ \text{BCY}$$

3. Workload Estimates.

a. Temperate weather. Figures C-10-1 and C-10-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams respectively. These estimates were based on the following production rates.

(1) Using the excavation rate for the SEE shown in paragraph 5c(1), page C-10.

$$(2.04\ \text{BCY})\ /\ (12.6\ \text{BCY/Hour}) = 0.16\ \text{hours}$$

(2) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the SEE to the site. Concurrently, the SEE requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

$$(0.16) + (0.08) = 0.24\ \text{hours}$$

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-10-3 and C-10-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(0.05) / (0.58) = 0.09 \text{ hours}$$

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

$$(0.24) / (0.52) = 0.46 \text{ hours}$$

BUILD A POSITION FOR A
DISMOUNTED TOW
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.05
	Excavate	0.24	
	Elapsed Time Required To Complete Task	0.24	

Figure C-10-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.05
	Excavate	0.24	
	Elapsed Time Required To Complete Task	0.24	

Figure C-10-2

BUILD A POSITION FOR A
DISMOUNTED TOW
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.09
	Excavate	0.46	
	Elapsed Time Required To Complete Task	0.46	

Figure C-10-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.09
	Excavate	0.46	
	Elapsed Time Required To Complete Task	0.46	

Figure C-10-4

LAST PAGE OF APPENDIX C-10

APPENDIX C-11

BUILD A POSITION FOR A MORTAR

APPENDIX C-11

BUILD A POSITION FOR A MORTAR

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer team assigned to build this position has one Small Emplacement Excavator (SEE) with operator and one engineer to confer with users and to guide the SEE to the position site. The position is a 3-foot-deep circular pit with a radius of 4 feet. The volume of earth that must be excavated is estimated as follows:

$$(4)\ (2)\ (3.1416)\ (3)\ /\ 27 = 5.58 \text{ BCY}$$

3. Workload Estimates.

a. Temperate weather. Figures C-11-1 and C-11-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

(1) Using the SEE excavation rate for complex geometric patterns shown in paragraph 5c(2), page C-10.

$$(5.58 \text{ BCY})\ /\ (5.4 \text{ BCY/Hour}) = 1.03 \text{ hours}$$

(2) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the SEE to the site. Concurrently, the SEE requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

$$(1.03) + (0.08) = 1.11 \text{ hours}$$

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-11-3 and C-11-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(0.05) / (0.58) = 0.09 \text{ hours}$$

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

$$(1.11) / (0.52) = 2.13 \text{ hours}$$

(3) The 2.13 hours required exceeds the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

BUILD A POSITION FOR A MORTAR
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		SEE	Combat Engr
Number of Items		1	1
ACTIVITY	Guide SEE/Locate Site		0.05
	Excavate	1.11	
Elapsed Time Required To Complete Task		1.11	

Figure C-11-1

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		SEE	Combat Engr
Number of Items		1	1
ACTIVITY	Guide SEE/Locate Site		0.05
	Excavate	1.11	
Elapsed Time Required To Complete Task		1.11	

Figure C-11-2

BUILD A POSITION FOR A MORTAR
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.09
	Excavate	2.13*	
	Elapsed Time Required To Complete Task	2.13	

Figure C-11-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.09
	Excavate	2.13*	
	Elapsed Time Required To Complete Task	2.13	

Figure C-11-4

LAST PAGE OF APPENDIX C-11

APPENDIX C-12

BUILD A 100-METER TANK DITCH

APPENDIX C-12

BUILD A 100-METER TANK DITCH

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer team assigned to build this ditch consists of one bulldozer or M9 ACE with operator, one 2-1/2-cubic-yard scoop loader with operator, and 10 combat engineers to install mines. The tank ditch is 3.5 meters wide, 1.5 meters deep and 100 meters long. The volume of earth that must be excavated is the same as the volume estimated in Appendix E-12 (686.70 BCY).

3. Workload Estimates.

a. Temperate weather. The planning factors for temperate climate conditions are displayed in Figures C-12-1 and C-12-2.

(1) *D7 dozer/scoop loader production. Assume a push distance of* 50 feet which, from Figure C-2 gives a production rate of 228 BCY/hour:

686.70 / 228 = 3.01 hours

(2) D5 dozer/scoop loader production. Assume a push distance of 50 feet which, from Figure C-3, gives a production rate of 121 BCY/hour:

686.70 / 121 = 5.68 hours

(3) As in the engineer assessment for III CORPS, the ditch is mined with 12 AT mines and 6 AP mines per 100 meters of ditch.[1] It is not necessary to increase the amount of time required to emplace the mines. The digging action of the dozer will have sufficiently broken up the soil so that no additional work effort due to the hard or rocky soil is anticipated. Laying rates

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[1]DA, Analysis of III Corps Combat Engineer Wartime Requirements (U), Volume 1, 1984, p. F-10.

of four AT mines per manhour and eight AP mines per manhour are used.[2] Time to install the mines is estimated as follows:

$$12 \; / \; 4 = 3.00 \text{ manhours}$$

$$6 \; / \; 8 = 0.75 \text{ manhours}$$

$$\text{TOTAL} = 3.75 \text{ manhours}$$

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-12-3 and C-12-4. See Annex A for a discussion of the method used.

(1) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

$$(3.01) \; / \; (0.52) = 5.79 \text{ hours}$$

$$(5.68) \; / \; (0.52) = 10.92 \text{ hours}$$

(2) Installing land mines is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71.

$$(3.75) \; / \; (0.71) = 5.28 \text{ hours}$$

A team of 10 men will complete this activity in 0.53 hours.

(3) The 5.79 and 10.92 hours required exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

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[2] DA, FM 20-32 Mine/Countermine Operations at the Company Level., 1976, p. 204.

BUILD A 100-METER TANK DITCH
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	10
ACTIVITY	Excavate	3.01	3.01	
	Install Minefield			3.75
	Elapsed Time Required To Complete Task	3.01		

Figure C-12-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	10
ACTIVITY	Excavate	5.68	5.68	
	Install Minefield			3.75
	Elapsed Time Required To Complete Task	5.68		

Figure C-12-2

BUILD A 100-METER TANK DITCH
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	10
ACTIVITY	Excavate	5.79*	5.79*	
	Install Minefield			5.28
	Elapsed Time Required To Complete Task	5.79		

Figure C-12-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	10
ACTIVITY	Excavate	10.92*	10.92*	
	Install Minefield			5.28
	Elapsed Time Required To Complete Task	10.92		

Figure C-12-4

LAST PAGE OF APPENDIX C-12

APPENDIX C-13

INSTALL A 2000-METER TACTICAL MINEFIELD USING GEMMS

APPENDIX C-13

INSTALL A 2000-METER TACTICAL MINEFIELD USING GEMMS

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The minefield is installed using the M128 Ground Emplaced Mine Scattering System (GEMMS) and 20 combat engineers. The minefield consists of two belts, each 2000 meters long and 60 meters wide, separated by a distance of 40 meters. A density of 0.005 mines per square meter is used.[1] These dimensions are the same as those in Appendix E-13.

3. Workload Estimates.

a. Temperate weather.

(1) The effort required to emplace the mines is calculated using the method described in Appendix E-13. Thus the total time required to install the minefield is calculated as follows:

Dispense 800 mines	= 0.76
Reload	= 0.40
Dispense 520 mines	= 0.50
Reload	= 0.40
TOTAL	= 2.06 hours

(2) The rear boundary of the minefield is marked using the M133 Hand Emplaced Minefield Marking Set (HEMMS). Due to the hard, rocky ground in the rocky plateau desert, ESC estimates a 50 percent increase in the amount of time required to mark the minefield as compared to European-type terrain. Thus a marking rate of 12.6 manhours per 1000 meters is used, and marking the minefield will require 25.2 manhours.[2]

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[1] DA, Analysis of III Corps Combat Engineer Wartime Requirements (U), Volume 1, 1984, p. F-10.

[2] DA, FM 20-32, Mine/Countermine Operations at the Company Level, 1976, p. 204.

(3) Figures C-13-1 and C-13-2 reflect a notional 20 man work-force with 10 men assigned to guide, operate, and load the GEMMS and 10 men assigned to mark the rear boundary.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-13-3 and C-13-4. See Annex A for a discussion of the method used.

(1) Reloading the GEMMS with mines is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71. Driving the truck to dispense the mines is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

Dispense 800 mines	= (0.76) / (0.52)	= 1.46
Reload	= (0.40) / (0.71)	= 0.56
Dispense 520 mines	= (0.50) / (0.52)	= 0.96
Reload	= (0.40) / (0.71)	= 0.56
TOTAL		= 3.54 hours

(2) Marking the minefield with HEMMS is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(25.2) / (0.58) = 43.44$$

A team of 10 men will complete this activity in 4.34 hours.

(3) The 3.54 hours required exceeds the maximum one-time work rate of 62 minutes listed in Figure A-2. The 4.34 hours required exceeds the maximum one-time work rate of 50 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

INSTALL A 2000-METER TACTICAL MINEFIELD USING GEMMS
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-Ton Truck	Combat Engr	GEMMS
	Number of Items	1	20	1
ACTIVITY	Install Minefield	2.06	20.6	2.06
	Mark the Minefield With HEMMS		25.2	
	Elapsed Time Required To Complete Task	2.52		

Figure C-13-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-Ton Truck	Combat Engr	GEMMS
	Number of Items	1	20	1
ACTIVITY	Install Minefield	2.06	20.6	2.06
	Mark the Minefield With HEMMS		25.2	
	Elapsed Time Required To Complete Task	2.52		

Figure C-13-2

INSTALL A 2000-METER TACTICAL MINEFIELD USING GEMMS
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-Ton Truck	Combat Engr	GEMMS
	Number of Items	1	20	1
ACTIVITY	Install Minefield	3.54*	35.40*	3.54
	Mark the Minefield With HEMMS		43.44*	
	Elapsed Time Required To Complete Task	4.34		

Figure C-13-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-Ton Truck	Combat Engr	GEMMS
	Number of Items	1	20	1
ACTIVITY	Install Minefield	3.54*	35.40*	3.54
	Mark the Minefield With HEMMS		43.44	
	Elapsed Time Required To Complete Task	4.34		

Figure C-13-4

LAST PAGE OF APPENDIX C-13

APPENDIX C-14

INSTALL A 2000-METER TACTICAL MINEFIELD USING VOLCANO

APPENDIX C-14

INSTALL A 2000-METER TACTICAL MINEFIELD USING VOLCANO

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The minefield is installed using the XM139 mine dispenser mounted in a dump truck and 20 combat engineers. The minefield consists of two rows, each 2000 meters and 40 meters wide, separated by a distance of 40 meters. A density of 0.012 mines per square meter is used.[1] These dimensions are the same as those in Appendix E-14.

3. Workload Estimates.

a. Temperate weather.

(1) The effort required to emplace the mines is calculated using the method described in Appendix E-14. Thus the total time required to install the minefield is calculated as follows:

Dispense 960 mines	= 0.17
Reload	= 0.25
Dispense 960 mines	= 0.17
Reload	= 0.25
TOTAL	= 0.84

(2) The rear boundary of the minefield is marked using the M133 Hand Emplaced Minefield Marking Set (HEMMS). Due to the hard, rocky ground in the rocky plateau desert, ESC estimates a 50 percent increase in the amount of time required to mark the minefield as compared to a European-type terrain. Thus, a marking rate of 12.6 manhours per 1000 meters is used[2], and marking the minefield will require 25.2 manhours.

[1]US Army, Engineer Center and School, The Handbook of Employment Concepts for Mine Warfare Systems, Sept. 1985, Ft. Belvoir, VA., p. III-24.
[2]DA, Engineer Family of Systems Study (E-FOSS), 1979, p. N-III-c-4.

(3) Figures C-14-1 and C-14-2 reflect a notional work force with 10 men initially assigned to guide, operate, and load the VOLCANO system and 10 men initially assigned to mark the rear boundary. After the installation activity is complete, then all 20 men complete the marking activity.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-14-3 and C-14-4. See Annex A for a discussion of the method used.

(1) Reloading the dispenser with mines is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71. Driving the truck to dispense the mines is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

Dispense 960 mines	= (0.17) / (0.52)	= 0.33
Reload	= (0.25) / (0.71)	= 0.35
Dispense 960 mines	= (0.17) / (0.52)	= 0.33
Reload	= (0.25) / (0.71)	= 0.35
TOTAL	=	= 1.36 hours

(2) Marking the minefield with HEMMS is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(25.2) / (0.58) = 43.44$$

A team of 10 men initially, later expanding to 20 men upon completion of the installation activity, will complete this activity in 2.85 hours.

(3) The 1.36 hours required exceeds the maximum one-time work rate of 62 minutes listed in Figure A-2. The 2.85 hours required exceeds the maximum one-time work rate of 50 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

INSTALL A 2000-METER TACTICAL MINEFIELD USING VOLCANO
(Rocky Plateau Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-T Truck	Combat Engr	VOLCANO
	Number of Items	1	20	1
ACTIVITY	Install Minefield	0.84	8.40	0.84
	Mark the Minefield With HEMMS		25.2	
	Elapsed Time Required To Complete Task	1.68		

Figure C-14-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-T Truck	Combat Engr	VOLCANO
	Number of Items	1	20	1
ACTIVITY	Install Minefield	0.84	8.40	0.84
	Mark the Minefield With HEMMS		25.2	
	Elapsed Time Required To Complete Task	1.68		

Figure C-14-2

INSTALL A 2000-METER TACTICAL MINEFIELD USING VOLCANO
(Rocky Plateau Terrain + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-T Truck	Combat Engr	VOLCANO
	Number of Items	1	20	1
ACTIVITY	Install Minefield	1.36*	13.60*	1.36*
	Mark the Minefield With HEMMS		43.44*	
	Elapsed Time Required To Complete Task		2.85	

Figure C-14-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-T Truck	Combat Engr	VOLCANO
	Number of Items	1	20	1
ACTIVITY	Install Minefield	1.36*	13.60*	1.36*
	Mark the Minefield With HEMMS		43.44*	
	Elapsed Time Required To Complete Task		2.85	

Figure C-14-4

LAST PAGE OF APPENDIX C-14

APPENDIX C-15

INSTALL A 2000-METER TACTICAL MINEFIELD USING CONVENTIONAL MINES

APPENDIX C-15

INSTALL A 2000-METER TACTICAL MINEFIELD USING CONVENTIONAL MINES

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. A standard pattern minefield is emplaced by 30 combat engineers using conventional mines.

a. The minefield has a length of 2000 meters. The desired density is 1-0.5-0, and the IOE representative cluster composition is 1-1-0. The minefield is installed in paces.

b. The total number of mines to be installed is calculated using the method described in Appendix E-15:

AT = 3261

AP = 1795

3. Workload Estimates.

(1) Temperate weather. Cemented or gravelly soils such as those in the rocky plateau desert are difficult to dig for underground emplacement of mines and, when dug, will leave an obvious signature.[1] Historical experience in the desert suggests that conventional mines, surface laid and properly camouflaged are as effective as conventional buried minefields.[2] Using surface laying, ESC estimates a laying rate of eight AT mines per manhour. U.S. antipersonnel fragmentation mines must, however, be dug in to function properly since they are the bounding type. Due to the difficult digging conditions, ESC estimates a laying rate of four AP mines per manhour. Thus, the effort required to install the mines is calculated as follows:

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[1]DA, FM 20-32, Mine/Countermine Operations at the Company Level, 1976, pp. 203-207.

[2]DA, Theater of Operations Construction in the Desert: A Handbook of Lessons Learned in the Middle East, 1981, p. 3-4.

3261 / 8 = 407.63 manhours

1795 / 4 = 448.75 manhours

TOTAL = 856.38 manhours

(2) The rear boundary of the minefield is marked with a single strand of barbed wire fence. Due to the hard, rocky ground in the rocky plateau desert, ESC estimates a 50 percent increase in the amount of time required to mark the minefield as compared to European-type terrain. Thus a marking rate of 112.5 manhours per 1000 meters is used, and marking the minefield will require 225 manhours.[3]

(3) The elapsed time to complete this task shown in Figures C-15-1 through C-15-4 reflects a notional 30 man workforce with 23 men assigned to minefield laying and 7 men assigned to marking. This assignment scheme was chosen to minimize the overall time required.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-15-3 and C-15-4. See Annex A for a discussion of the method used.

(1) Installing a minefield is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71.

(856.38) / (0.71) = 1206.17 manhours

A team of 23 men will complete this activity in 52.44 hours.

(2) Marking the minefield with wire is heavy work according to Figure A-1. AT 110° F, Figure A-3 provides a degradation factor of 0.58.

(225.00) / (0.71) = 316.90 manhours

A team of 7 men will complete this activity in 45.27 hours.

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[3] Paul G. Cerjan and Theodore G. Stroup, Employment of the Engineer System in Arid Mountainous and Desert Areas--A Concept Paper, 1981, p. 56.

(3) The 52.44 and 45.27 hours required exceed the maximum one-time work rate of 36 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

INSTALL A 2000-METER TACTICAL MINEFIELD
USING CONVENTIONAL MINES
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	30
ACTIVITY	Install Minefield	856.38
	Mark the Minefield With Wire	225.00
	Elapsed Time Required To Complete Task	37.23

Figure C-15-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	30
ACTIVITY	Install Minefield	856.38
	Mark the Minefield With Wire	225.00
	Elapsed Time Required To Complete Task	37.23

Figure C-15-2

INSTALL A 2000-METER TACTICAL MINEFIELD
USING CONVENTIONAL MINES
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	30
ACTIVITY	Install Minefield	1206.17*
	Mark the Minefield With Wire	316.90*
	Elapsed Time Required To Complete Task	52.44

Figure C-15-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	30
ACTIVITY	Install Minefield	1206.17*
	Mark the Minefield With Wire	316.90*
	Elapsed Time Required To Complete Task	52.44

Figure C-15-4

LAST PAGE OF APPENDIX C-15

APPENDIX C-16

DISABLE A BRIDGE

APPENDIX C-16

DISABLE A BRIDGE

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. Ten combat engineers are assigned to disable the bridge and install a point minefield. Reconnaissance effort is not included in this estimate.

3. Workload Estimates.

a. Temperate weather.

(1) The target is a two-lane, class 60 highway bridge. Variations in length, design, materials, and type of gap crossed make it impossible to describe a typical bridge or a typical demolition method. An ESC analysis of 16 bridges in the Middle East resulted in an average time requirement of 19.19 manhours, assuming that a gap greater than 18 meters was desirable.[1] The planning factors for temperate climate conditions are displayed in Figures C-16-1 and C-16-2.

(2) The target is mined with 12 AT mines and 6 AP mines. Because of the difficult digging conditions in the rocky plateau desert, laying rates of two AT mines per manhour and four AP mines per manhour are used:

12 / 2 = 6.00 manhours
6 / 4 = 1.50 manhours
TOTAL = 7.50 manhours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-16-3 and C-16-4. See Annex A for a discussion of the method used.

---

[1]DA, Middle East Target Analysis (U), Volume III, Appendix C-1.

(1) Preparing the demolition charges is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(19.19) / (0.58) = 33.09 \text{ manhours}$$

A team of 10 men will complete this activity in 3.31 hours.

(2) Installing land mines is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71.

$$(7.50) / (0.71) = 10.56 \text{ manhours}$$

A team of 10 men will complete this activity in 1.06 hours.

(3) The 3.31 hours required exceeds the maximum one-time work of 50 minutes listed in Figure A-2. The 1.06 hours required exceeds the maximum one-time work rate of 36 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

AD-A169 799 WORKLOAD ESTIMATES FOR COMBAT ENGINEERS IN THE DESERT 4/6
(U) ARMY ENGINEER STUDIES CENTER FORT BELVOIR VA
T O ATKINSON ET AL. APR 86 USAESC-R-86-2

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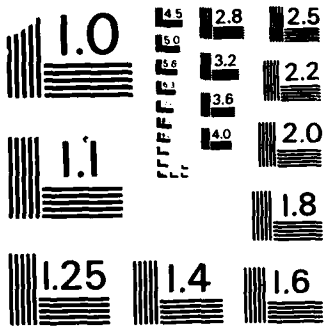

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

DISABLE A 2-LANE, CLASS 60 BRIDGE
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		10
ACTIVITY	Prepare and Fire Demolitions	19.19
	Install Point Minefield	7.50
Elapsed Time Required To Complete Task		2.67

Figure C-16-1

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		10
ACTIVITY	Prepare and Fire Demolitions	19.19
	Install Point Minefield	7.50
Elapsed Time Required To Complete Task		2.67

Figure C-16-2

DISABLE A 2-LANE, CLASS 60 BRIDGE
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	10
ACTIVITY	Prepare and Fire Demolitions	33.09*
	Install Point Minefield	10.56*
	Elapsed Time Required To Complete Task	4.37

Figure C-16-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	10
ACTIVITY	Prepare and Fire Demolitions	33.09*
	Install Point Minefield	10.56*
	Elapsed Time Required To Complete Task	4.37

Figure C-16-4

LAST PAGE OF APPENDIX C-16

APPENDIX C-17

CRATER A ROAD

APPENDIX C-17

CRATER A ROAD

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. A team of eight combat engineers is assigned to crater a road and install a point minefield using conventional explosives and mines.

3. Workload Estimates.

a. Temperate weather.

(1) The road crater is installed to block a two-lane, asphalt road with a traveled width of 25 feet. Using E-FOSS, the time required to install the road crater is estimated as follows:[1]

Preparing and firing the shaped charges = 10.00 manhours

Preparing and firing the cratering charges = 2.40 manhours

Total Time required to install the crater = 12.40 manhours.

(2) A point minefield is installed in and around the crater. It is assumed that the target is mined with 12 AT mines and 6 AP mines. Because of the difficult digging conditions in the rocky plateau desert, laying rates of two AT mines per manhour and four AP mines per manhour are used:

12 / 2 = 6.00 manhours

6 / 4 = 1.50 manhours

TOTAL = 7.50 manhours

(3) The planning factors for temperate climate conditions are displayed in Figures C-17-1 and C-17-2.

---

[1]DA, Engineer Family of Systems Study (E-FOSS), Volume VII, Appendix N, 1979, p. N-III-g-6.

b. Hot weather.

(1) Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-17-3 and C-17-4. See Annex A for a discussion of the method used.

(2) Preparing the demolition charges is moderate work according to Figure A-1. At 110^{o} F, Figure A-3 provides a degradation factor of 0.58.

$$(12.40) / (0.58) = 21.38 \text{ manhours}$$

A team of 8 men will complete this activity in 2.67 hours.

(3) Installing land mines is heavy work according to Figure A-1. At 110^{o} F, Figure A-3 provides a degradation factor of 0.71.

$$(7.50) / (0.71) = 10.56 \text{ manhours}$$

A team of eight men will complete this activity in 1.32 hours.

(4) The 2.67 hours required exceeds the maximum one-time work rate of 50 minutes listed in Figure A-2. The 1.32 hours required exceeds the maximum one-time work of 36 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

CRATER A ROAD
(Rocky Plateau Desert + Temperate Weather)

H E A V Y   E Q U I P M E N T
W O R K L O A D   R A T E S

	Resource Type	Combat Engr
	Number of Items	8
ACTIVITY	Prepare and Fire Demolitions	12.40
	Install Point Minefield	7.50
	Elapsed Time Required To Complete Task	2.49

Figure C-17-1

L I G H T   E Q U I P M E N T
W O R K L O A D   R A T E S

	Resource Type	Combat Engr
	Number of Items	8
ACTIVITY	Prepare and Fire Demolitions	12.40
	Install Point Minefield	7.50
	Elapsed Time Required To Complete Task	2.49

Figure C-17-2

CRATER A ROAD
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		8
ACTIVITY	Prepare and Fire Demolitions	21.38*
	Install Point Minefield	10.56*
Elapsed Time Required To Complete Task		3.99

Figure C-17-3

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		8
ACTIVITY	Prepare and Fire Demolitions	21.38*
	Install Point Minefield	10.56*
Elapsed Time Required To Complete Task		3.99

Figure C-17-4

LAST PAGE OF APPENDIX C-17

APPENDIX C-18

CLEAR A TANK DITCH

APPENDIX C-18

CLEAR A TANK DITCH

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The team assigned this mission will vary depending on whether the engineer forces involved are heavy or light.

3. Workload Estimates.

a. Temperate weather. The planning factors for temperate climate conditions are displayed in Figures C-18-1 and C-18-2.

(1) The heavy engineer force has one combat engineer vehicle (CEV) with operator, one D7 bulldozer or M9 ACE with operator, and ten combat engineers. The effort required for these forces to clear a tank ditch is determined using the method described in Appendix E-18.

(a) The CEV breaches the tank ditch. The time required to clear a passage using the bullblade is estimated by multiplying the time calculated in Appendix E-18, 0.25 hours, by the ratio of the D7 dozer rate in earth to the D7 dozer rate in the rocky plateau desert. The production rates for a push distance of 75 feet were used.

$$(0.25)\ (376)\ /\ (174) = 0.54 \text{ hours}$$

(b) 50 meters on both sides of the ditch are mined. An 8-meter path is completely cleared of mines and marked to accommodate one-way vehicle traffic. The engineer assessment for III Corps allows 80 manhours to widen and clear an 8-meter path and 10 manhours for marking.[1] A team of 10 men will complete this activity in 8 hours and 1 hour respectively.

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[1] DA, Analysis of III Corps Combat Engineer Wartime Requirements (U), Volume 1, 1984, p. E-2-4, E-2-5.

(c) Finally, a D7 dozer or M9 ACE is used to further improve the access and egress for follow-on vehicles. The estimate in Appendix E-18 of 0.5 hours is degraded by the same factor used to degrade the CEV production.

$$(0.5)\ (376)\ /\ (356) = 1.08 \text{ hours}$$

(2) The light engineer force has a D5 Dozer with operator and 10 combat engineers. The initial breach must be wide enough to get assaulting ground troops across the ditch and the minefields. The effort required is determined as follows:

(a) The bangalore torpedo is used to breach an initial 1-meter footpath. The time required is 4 manhours.

(b) The time required to widen and clear an 8-meter one-way vehicle path remains 80 manhours. The marking task also requires 10 manhours.

(c) The remaining work involves improving access and egress for follow on vehicles. Single-lane approaches are cut through the steep banks. The design cut is shown in Figure E-18-1.[2] The volume of earth that must be excavated is the same as the volume estimated in Appendix E-18 (137.34 BCY).

1. Assume a push distance of 75 feet which, from Figure C-3, gives a production rate of 98 BCY/hour. Thus the time for cutting one bank is determined:

$$137.34\ /\ 98 = 1.40 \text{ hours}$$

2. The time required to gain access to the far bank is 5 minutes (0.08 hours). Thus the time required to improve access/egress is:

$$1.40 + 0.08 + 1.40 = 2.88 \text{ hours}$$

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[2] DA, Engineer Family of Systems Study (E-FOSS), Volume VII, Appendix N, 1979, p. N-III-hh-1 through N-III-hh-5.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-18-3 and C-18-4. See Annex A for a discussion of the method used.

(1) Heavy engineer force. Operating the CEV and the D7 dozer or ACE is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52. Clearing and marking a lane through a minefield is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

(a) Breach with CEV.

(0.54) / (0.52) = 1.04 hours

(b) Clear the lane.

(80.0) / (0.58) = 137.93 manhours

(c) Mark the lane.

(10.0) / (0.58) = 17.24 manhours

A team of 10 men will complete the latter two activities in 13.79 and 1.72 hours.

(2) The 13.79 and 1.72 hours required exceed the maximum one-time work rate of 50 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

(3) Light engineer force.

(a) Breaching a footpath with a bangalore torpedo is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

(4.0) / (0.58) = 6.90 manhours

A team of 10 men will complete this activity in 0.69 hours.

(b) Clearing and marking the minefield is moderate work according to Figure A-1. At 110^{o} F, Figure A-3 provides a degradation factor of 0.58.

Clear lane = (80.0) / (0.58) = 137.93 manhours

Mark lane = (10.0) / (0.58) = 17.24 manhours

A team of 10 men will complete these activities in 13.79 and 1.72 hours.

(c) Operating the D5 dozer is light work according to Figure A-1. At 120^{o} F, Figure A-3 provides a degradation factor of 0.52.

(2.88) / (0.52) = 5.54 hours

(4) The 13.79 and 1.72 hours required exceed the maximum one-time work rate of 50 minutes listed in Figure A-2. The 5.54 hours required exceeds the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

c. The time and effort required for the initial breach of a tank ditch can be estimated for heavy or light forces by using the first line of Figures C-18-3 or Figures C-18-4, respectively.

d. The elapsed time required shown in Figures C-18-1 through C-18-4 is based on the task being completed in a sequential manner. First the initial breach is accomplished, then the 8-meter-wide path is cleared and marked, and finally access and egress is improved.

CLEAR A TANK DITCH
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr	CEV
	Number of Items	1	10	1
ACTIVITY	Breach Tank Ditch With CEV			0.54
	Clear 8-Meter-Wide Path		80.0	
	Mark the Lane		10.0	
	Improve Access/Egress	1.08		
	Elapsed Time Required To Complete Task	10.62		

Figure C-18-1

CLEAR A TANK DITCH
(Rocky Plateau Desert + Temperate Weather)

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	10
ACTIVITY	Breach 1-Meter Footpath		4.0
	Clear 8-Meter-Wide Path		80.0
	Mark the Lane		10.0
	Improve Access/Egress	2.88	
	Elapsed Time Required To Complete Task	12.28	

Figure C-18-2

CLEAR A TANK DITCH
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr	CEV
	Number of Items	1	10	1
ACTIVITY	Breach Tank Ditch With CEV			1.04
	Clear 8-Meter-Wide Path		137.93*	
	Mark the Lane		17.24*	
	Improve Access/Egress	2.08*		
	Elapsed Time Required To Complete Task	18.64		

Figure C-18-3

CLEAR A TANK DITCH
(Rocky Plateau Desert + Hot Weather)

L I G H T   E Q U I P M E N T
W O R K L O A D   R A T E S

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	10
ACTIVITY	Breach 1-Meter Footpath		6.90
	Clear 8-Meter-Wide Path		137.93*
	Mark the Lane		17.24*
	Improve Access/Egress	5.54*	
	Elapsed Time Required To Complete Task	21.75	

Figure C-18-4

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APPENDIX C-19

REPAIR A ROAD CRATER

APPENDIX C-19

REPAIR A ROAD CRATER

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer resources used in this task consist of one bulldozer or M9 ACE and 10 combat engineers. The typical road crater is assumed to be a trapezoidal prism with a depth of 2.25 meters, a length of 12.5 meters, a top width of 8.70 meters and a bottom width of 2.25 meters. See Figure E-19-1. The volume of earth that must be excavated is the same as the volume estimated in Appendix E-19 (201.41 BCY). The area in and around the crater is seeded with mines.

3. Workload Estimates.

a. Temperate weather. Figures C-19-1 and C-19-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

(1) D7 dozer and M9 ACE production.

(a) Before the dozer work can begin the area must be cleared of mines. Combat engineers accomplish this task in 30 man-hours.[1]

(b) Assuming that sufficient backfill material is available at the site so that the hauling of aggregate is not required, a push distance of 125 feet is used. Figure C-2 gives a production rate of 120 BCY/hour:

$$201.41 / 120 = 1.68 \text{ hours}$$

[1] DA, Analysis of III Corps Combat Engineer Wartime Requirements (U), Volume I, 1984, p. E-2-5.

(2) D5 dozer production.

(a) As above, combat engineers clear the area of mines in 30 man hours.

(b) Assume a push distance of 125 feet which, from Figure C-3 gives a production rate of 66 BCY/hour:

$$201.41 / 66 = 3.05 \text{ hours}$$

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-19-3 and C-19-4. See Annex A for a discussion of the method used.

(1) Clearing the mines is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(30.0) / (0.58) = 51.72 \text{ manhours}$$

A team of 10 men will complete this activity in 5.17 hours.

(2) Backfilling the crater using heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

$$(1.68) / (0.52) = 3.23 \text{ hours}$$

$$(3.05) / (0.52) = 5.87 \text{ hours}$$

(3) The 5.17 hours required exceeds the maximum one-time work rate of 50 minutes listed in Figure A-2. The 3.23 and 5.87 hours required exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

REPAIR A ROAD CRATER
(Rocky Plateau Desert + Temperate Weather)

H E A V Y E Q U I P M E N T
W O R K L O A D R A T E S

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	10
ACTIVITY	Clear Mines		30.0
	Backfill Crater	1.68	
	Elapsed Time Required To Complete Task	4.68	

Figure C-19-1

L I G H T E Q U I P M E N T
W O R K L O A D R A T E S

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	10
ACTIVITY	Clear Mines		30.0
	Backfill Crater	3.05	
	Elapsed Time Required To Complete Task	6.05	

Figure C-19-2

REPAIR A ROAD CRATER
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	10
ACTIVITY	Clear Mines		51.72*
	Backfill Crater	3.23*	
	Elapsed Time Required To Complete Task	8.40	

Figure C-19-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	10
ACTIVITY	Clear Mines		51.72*
	Backfill Crater	5.87*	
	Elapsed Time Required To Complete Task	11.04	

Figure C-19-4

LAST PAGE OF APPENDIX C-19

APPENDIX C-20

CONSTRUCT 100 METERS OF COMBAT TRAIL

APPENDIX C-20

CONSTRUCT 100 METERS OF COMBAT TRAIL

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The construction of combat trails is considered an unlikely engineer task since the rocky plateau desert will usually allow good cross-country mobility in all directions. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX C-20

APPENDIX C-21

REPLACE COMBAT BRIDGING

APPENDIX C-21

REPLACE COMBAT BRIDGING

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. Combat engineers are used to replace combat bridging with fixed bridging. Fixed bridging can be constructed from several types of bridging and in many configurations making it impossible to describe a "typical" mission.

3. Workload Estimates.

a. Temperate weather. The planning figures given in Appendix E-21 are reasonable estimates for the rocky plateau desert under temperate weather conditions and are therefore not changed. They are displayed in Figures C-21-1 and C-21-2.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-21-3 and C-21-4. See Annex A for a discussion of the method used.

(1) Bridge construction is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71.

$$(50.0) / (0.71) = 70.42 \text{ manhours}$$

A team of 10 men will accomplish this task in 7.04 hours.

(2) The 7.04 hours required exceeds the maximum one-time work of 36 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

REPLACE COMBAT BRIDGING
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		10
ACTIVITY	Effort for a 10-Meter Section Of Fixed Bridging	50.0
Elapsed Time Required To Complete Task		5.0

Figure C-21-1

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		10
ACTIVITY	Effort for a 10-Meter Section Of Fixed Bridging	50.0
Elapsed Time Required To Complete Task		5.0

Figure C-21-2

REPLACE COMBAT BRIDGING
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		10
ACTIVITY	Effort for a 10-Meter Section Of Fixed Bridging	70.42*
Elapsed Time Required To Complete Task		7.04

Figure C-21-3

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		10
ACTIVITY	Effort for a 10-Meter Section Of Fixed Bridging	70.42*
Elapsed Time Required To Complete Task		7.04

Figure C-21-4

LAST PAGE OF APPENDIX C-21

APPENDIX C-22

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD

APPENDIX C-22

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. An engineer team consisting of heavy equipment and combat engineers is assigned to maintain an unpaved but well-built secondary road that has become rutted and worn from heavy traffic. The road to be maintained is a two-lane, graded and drained earth road over average rolling terrain. Compaction effort is not included in this estimate.

3. Workload Estimates.

a. Temperate weather. As in Appendix E-22, the estimate is based on the projected maintenance and repair required during a 5-day period for a 10-kilometer section of road. ESC estimates that the roads will deteriorate twice as fast in the rocky plateau desert as in Europe. Repair times, however, will remain the same as those for Europe. The engineer road repair team will, therefore, spend twice the amount of time and effort estimated in Appendix E-22. Figure C-22-1 reflects the engineer resources and effort required for a 10-kilometer section using 5-ton dump trucks.

(1) 2.5-CY loader.

(3.11) (2) = 6.22 equipment hours

(2) Four 5-ton dump trucks.

(12.44) (2) = 24.88 equipment hours

(3) 16 combat engineers.

(49.76) (2) = 99.52 manhours

(4) 4 graders.

(12.44) (2) = 24.88 equipment hours

(5) The number of dump trucks shown in Figure C-22-2 is doubled since a 5-ton dump truck is rated at approximately twice the volume and weight capacity of a 2-1/2-ton dump truck. Eight 2.5-Ton dump trucks:

(24.88) (2) = 49.76 equipment hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-22-3 and C-22-4. See Annex A for a discussion of the method used.

(1) Operating engineer equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(a) Scoop loader.

(6.22) / (0.52) = 11.96 equipment hours

(b) Graders.

(24.88) / (0.52) = 47.85 equipment hours

(c) 5-ton dump trucks.

(24.88) / (0.52) = 47.85 equipment hours

(d) 2.5-ton dump trucks.

(49.76) / (0.52) = 95.69 equipment hours

The engineer equipment will require 11.96 hours to complete their activities.

(2) Manual labor by combat engineers is heavy work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.71.

(99.52) / (0.71) = 140.17 manhours

A team of 16 men will require 8.76 hours to complete this activity.

(3) The 11.96 hours and the 8.76 hours required both greatly exceed the respective maximum one-time work rates shown in Figure A-2. However, these times are spread over a five-day period. At a given road repair site the maximum one-time work rates are 36 minutes for the combat engineers

and 62 minutes for the equipment operators. The asterisk in the figures indicates that, if the work at a repair site exceeds these times, the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT WORKLOAD RATES

	Resource Type	2.5-CY Loader	5-Ton Truck	Combat Engr	Grader
	Number of Items	1	4	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	6.22	24.88	99.52	24.88
	Elapsed Time Required To Complete Task	6.22			

Figure C-22-1

LIGHT EQUIPMENT WORKLOAD RATES

	Resource Type	2.5-CY Loader	2.5-Ton Truck	Combat Engr	Grader
	Number of Items	1	8	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	6.22	[illegible]	99.52	24.88
	Elapsed Time Required To Complete Task	6.22			

Figure C-22-2

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		2.5-CY Loader	5-Ton Truck	Combat Engr	Grader
Number of Items		1	4	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	11.96*	47.85*	140.17*	47.85*
	Elapsed Time Required To Complete Task	11.96			

Figure C-22-3

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		2.5-CY Loader	2.5-Ton Truck	Combat Engr	Grader
Number of Items		1	8	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	11.96*	95.69*	140.17*	47.85*
	Elapsed Time Required To Complete Task	11.96			

Figure C-22-4

LAST PAGE OF APPENDIX C-22

APPENDIX C-23

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE

APPENDIX C-23

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. An engineer team consisting of graders, trucks, and combat engineers is assigned to maintain a paved MSR. The asphalt section of a combat engineer battalion (heavy) will augment the divisional engineer battalion, however, that section's effort is not included in this estimate.

3. Workload Estimates.

a. Temperate weather. The road to be maintained is a two-lane, bituminous surface road. The estimate is based on the projected maintenance and repair required during a 5-day period for a 10-kilometer section of road. ESC assumes that the road will deteriorate twice as fast in the rocky plateau desert as in Europe. Repair times, however, will remain the same as those for Europe. Time estimates for Europe, shown in Appendix E-23, are, therefore, doubled for the rocky plateau desert. Figure C-23-1 reflects the engineer times and resources required using 5-ton dump trucks.

(1) Eight 5-ton dump trucks.

(24.88) (2) = 49.76 equipment hours

(2) 16 combat engineers.

(49.76) (2) = 99.52 manhours

(3) 4 graders.

(12.44) (2) = 24.88 equipment hours

(4) The number of dump trucks shown in Figure C-23-2 is doubled since a 5-ton dump truck is rated at approximately twice the volume and weight capacity of a 2-1/2-ton dump truck. Sixteen 2.5-ton dump trucks.

(49.76) (2) = 99.52 equipment hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-23-3 and C-23-4. See Annex A for a discussion of the method used.

(1) Operating engineer equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(a) 5-ton dump trucks.

(49.76) / (0.52) = 95.69 equipment hours

(b) Graders.

(24.88) / (0.52) = 47.85 equipment hours

(c) 2.5-ton dump truck.

(99.52) / (0.52) = 191.38 equipment hours

The engineer equipment will require 11.96 hours to complete these activities.

(2) Manual labor by combat engineers is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71.

(99.52) / (0.71) = 140.17 manhours

A team of 16 men will require 8.76 hours to complete this activity.

(3) The 11.96 hours and the 8.76 hours required both greatly exceed the respective maximum one-time work rates shown in Figure A-2. However, these times are spread over a five day period. At a given road repair site the maximum one-time work rates are 36 minutes for the combat engineers and 62 minutes for the equipment operators. The asterisk in the figures indicates that, if the work at a repair site exceeds these times, the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE (MSR)
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-Ton Truck	Combat Engr	Grader
	Number of Items	8	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	49.76	99.52	24.88
	Elapsed Time Required To Complete Task	6.22		

Figure C-23-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-Ton Truck	Combat Engr	Grader
	Number of Items	16	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	99.52	99.52	24.88
	Elapsed Time Required To Complete Task	6.22		

Figure C-23-2

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE (MSR)
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-Ton Truck	Combat Engr	Grader
	Number of Items	8	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	95.69*	140.17*	47.85*
	Elapsed Time Required To Complete Task	11.96		

Figure C-23-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-Ton Truck	Combat Engr	Grader
	Number of Items	16	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	191.38*	140.17*	47.85*
	Elapsed Time Required To Complete Task	11.96		

Figure C-23-4

LAST PAGE OF APPENDIX C-23

APPENDIX C-24

DELIBERATE MINEFIELD BREACH

APPENDIX C-24

DELIBERATE MINEFIELD BREACH

1. Terrain. Rocky Plateau

2. Method of Construction. Combat engineers are assigned to conduct a deliberate breach through a 100-meter-deep minefield.[1]

3. Workload Estimates:

a. Temperate weather. The planning factors for temperate climate conditions are displayed if Figures C-24-1 and C-24-2.

(1) The bangalore torpedo is used to get dismounted assault forces through a 100-meter-deep minefield. The time required is 4 manhours.[2]

(2) To accomodate vehicles, combat engineers then widen the breach to 8 meters using mine detectors and explosives. 10 manhours are required to clear a 1-meter lane in this manner.[3] Thus the time required to widen the breach to 8 meters is 80 manhours.

(3) The cleared lane is marked using the Hand Emplaced Minefield Marking Set (HEMMS). ESC estimates a 50 percent increase in the amount of time required to mark the lane in the rocky plateau desert as compared to European-type terrain. Thus 15 man-hours are allowed for marking.[4]

b. Hot weather. In addition to the adjustments above, adjustments for work production degradation caused by high temperatures have been applied

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[1] DA, Analysis of III Corps Combat Engineer Wartime Requirements (U), Volume I, 1984, pp. E-2-1 and E-2-2.
[2] DA, FM 5-34 Engineer Field Data, 1976, p. 81.
[3] DA, TC 5-101 Mobility Drills, Coordinating Draft, 1983, p. 1-1.
[4] TC 5-101, Mobility Drills, Coordinating Draft, 1983, p. 6-1.

to the data in Figures C-24-3 and C-24-4. See Annex A for a discussion of the method used.

(1) Breaching, clearing, and marking a lane through a minefield is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

(a) Breach.

(4.00) / (0.58) = 6.90 manhours

(b) Clear lane.

(80.0) / (0.58) = 137.93 manhours

(c) Mark lane.

(15.0) / (0.58) = 25.86 manhours

A team of 10 men will complete each activity in 0.69 hours, 13.79 hours, and 2.59 hours, respectively.

(2) The 13.79 and 2.59 hours required exceed the maximum one-time work rate of 50 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

c. The time and effort required for a hasty breach to get dismounted assault forces through a 100-meter-deep minefield can be estimated by using the first line of Figure C-24-1 through C-24-4.

DELIBERATE MINEFIELD BREACH
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		10
ACTIVITY	Breach 1-Meter Footpath	4.0
	Clear 8-Meter-Wide Path	80.0
	Mark the Lane	15.0
Elapsed Time Required To Complete Task		9.9

Figure C-24-1

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		10
ACTIVITY	Breach 1-Meter Footpath	4.0
	Clear 8-Meter-Wide Path	80.0
	Mark the Lane	15.0
Elapsed Time Required To Complete Task		9.9

Figure C-24-2

DELIBERATE MINEFIELD BREACH
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		10
ACTIVITY	Breach 1-Meter Footpath	6.90
	Clear 8-Meter-Wide Path	137.93*
	Mark the Lane	25.86*
Elapsed Time Required To Complete Task		17.07

Figure C-24-3

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		10
ACTIVITY	Breach 1-Meter Footpath	6.90
	Clear 8-Meter-Wide Path	137.93*
	Mark the Lane	25.86*
Elapsed Time Required To Complete Task		17.07

Figure C-24-4

LAST PAGE OF APPENDIX C-24

APPENDIX C-25

REDUCE A DRY GAP BANK GRADE FOR VEHICLE PASSAGE

APPENDIX C-25

REDUCE A DRY GAP BANK GRADE FOR VEHICLE PASSAGE

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer team assigned to this task consists of one bulldozer or M9 ACE with operator and one combat engineer to guide the dozer to the crossing site.

a. The task consists of cutting single-lane approaches through steep banks to provide access and egress from a dry streambed or a streambed containing a shallow, fordable stream. The design cut is shown in Figure E-25-1.[1] The volume of earth that must be excavated is the same as the volume estimated in Appendix E-25 (193 BCY).

3. Workload Estimates.

a. Temperate weather. Figures C-25-1 and C-25-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

(1) D7 dozer and M9 ACE production. Assume a push distance of 75 feet, which from Figure C-2 gives a production rate of 174 BCY/hour. Thus the time for cutting one bank is determined:

$$193 / 174 = 1.11 \text{ hours}$$

The total time required is equal to the sum of the times to cut the the approach passage, to gain access to the far bank, and to cut the exit passage.

[1]DA, Engineer Family of Systems Study (E-FOSS), Volume VII, Appendix N, 1979, p. N-III-hh-1 thorugh N-III-hh-5.

Assuming the time required to gain access to the far bank is 5 minutes (0.08 hours), then the total time required is:

$$1.11 + 0.08 + 1.11 = 2.30 \text{ hours}$$

(2) D5 dozer production. Assume a push distance of 75 feet which, from Figure C-3, gives a production rate of 98 BCY/hour. Thus the time for cutting one bank is determined:

$$193 / 98 = 1.97 \text{ hours}$$

The total time required is:

$$1.97 + 0.08 + 1.97 = 4.02$$

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-25-3 and C-25-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a site is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(0.05) / (0.58) = 0.09 \text{ hours}$$

(2) Excavation with heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

$$(2.30) / (0.52) = 4.42 \text{ hours}$$

$$(4.02) / (0.52) = 7.73 \text{ hours}$$

(3) The 4.42 and 7.73 hours required exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

REDUCE A DRY GAP BANK GRADE
FOR VEHICLE PASSAGE
(Rocky Plateau Desert + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Reduce Bank Grade	2.30	
	Elapsed Time Required To Complete Task	2.30	

Figure C-25-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Reduce Bank Grade	4.02	
	Elapsed Time Required To Complete Task	4.02	

Figure C-25-2

REDUCE A DRY GAP BANK GRADE
FOR VEHICLE PASSAGE
(Rocky Plateau Desert + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		D7 Dozer or M9 ACE	Combat Engr
Number of Items		1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Reduce Bank Grade	4.42*	
Elapsed Time Required To Complete Task		4.42	

Figure C-25-3

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		D5 Dozer	Combat Engr
Number of Items		1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Reduce Bank Grade	7.73*	
Elapsed Time Required To Complete Task		7.73	

Figure C-25-4

LAST PAGE OF APPENDIX C-25

APPENDIX C-26

PREPARE A SITE FOR A 40,000-GALLON BRIGADE WATER POINT

APPENDIX C-26

PREPARE A SITE FOR A 40,000-GALLON BRIGADE WATER POINT

1. Terrain. Rocky Plateau Desert.

2. Method of Construction. The engineer team assigned this task has a bulldozer or M9 ACE with operator and one engineer to confer with the users and guide the dozer to the site.

a. As in Appendix B-26, the site is constructed to accommodate two 20,000 gallon water bladders, each measuring 28 feet by 32 feet. See Figure B-26-1.

b. ESC assumed that a 3-foot space separates three of the bladders' edges from the inside edge of the berm. The fourth edge of the bladder aligns with the inside edge of the berm. The berms' dimensions are 13.5 feet wide at the base, 3 feet wide at the top, and 5 feet high.[1] The area inside the berm measures 35 feet by 34 feet. See Figure B-26-2. The volume of earth that must be excavated is the same as the volume estimated in Appendix B-26 (293.33 LCY). Two berms require 586.66 LCY or 522.13 BCY (multiplied by a load factor of 0.89).

3. Workload Estimates.

a. Temperate weather. The planning factors ior temperate climate conditions are displayed in Figures C-26-1 and C-26-2.

(1) D7 dozer production. To account for shaping and packing the berm, assume a push distance of 125 feet which, from Figure C-2, gives a reproduction rate of 120 BCY/hour. Because the dozer operator cannot use slot

[1] DA, Engineer Family of Systems Study (E-FOSS), Volume VII, p. N-III-bb-1.

dozing techniques, this rate is reduced by one-sixth (see Annex C, paragraph 5a(1)(c), page C-7.

(522.13 BCY) (1.2) / (120 BCY/hour) = 5.22 hours

(2) D5 dozer production. As above, a push distance of 125 feet is assumed. Figure C-3 gives a production rate of 66 BCY/hour. The production rate is reduced by one-sixth for the reasons stated in paragraph c.

(522.13 BCY) (1.2) / (66 BCY/hour) = 9.49 hours

(3) ESC assumes that the entrance and exit from the water point site will require no additional construction effort due to the excellent cross-country mobility provided by the rocky plateau desert. It is expected, however, that a dust palliative will be required on a continuing basis. That effort is not included in this estimate.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures C-26-3 and C-26-4. See Annex A for a discussion of the method used.

(1) Guiding heavy equipment to a position site is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

(0.05) / (0.58) = 0.09 hours

(2) Operating heavy equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(5.22) (0.52) = 10.04 hours

(9.49) (0.52) = 18.25 hours

(3) Both equipment operating times exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

PREPARE A SITE FOR A
40,000-GALLON BRIGADE WATER POINT
(Rocky Plateau Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Build Berms	5.22	
	Elapsed Time Required To Complete Task	5.22	

Figure C-26-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Build Berms	9.49	
	Elapsed Time Required To Complete Task	9.49	

Figure C-26-2

PREPARE A SITE FOR A
40,000-GALLON BRIGADE WATER POINT
(Rocky Plateau Terrain + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Build Berms	10.04*	
	Elapsed Time Required To Complete Task	10.04	

Figure C-26-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.09
	Build Berms	18.25*	
	Elapsed Time Required To Complete Task	18.25	

Figure C-26-4

LAST PAGE OF APPENDIX C-26

ANNEX D

SALT MARSH DESERT PLANNING FACTORS

ANNEX D

SALT MARSH DESERT PLANNING FACTORS

1. Purpose. This annex estimates work production planning factors for tasks assigned to combat engineers in support of committed maneuver brigades.

2. Scope. This analysis quantified the engineer effort required to support committed maneuver brigades and established planning factors for each of those tasks. The time estimates reflect work performed under weather and terrain conditions typical of a the salt marsh areas of the desert.

3. Method.

a. The tasks and the workload factors shown in Annex E were used as a basis for calculating engineer requirements in the salt marsh areas of the desert.

b. Engineering designs were modified, when appropriate, to better protect users and their equipment from the effects of desert winds and intense heat.

c. Workload times were degraded to account for the unique conditions found in the salt marshes.

4. Discussion.

a. Salt marshes (also called subkhahs) are usually considered impassable to wheeled and tracked vehicles. These marshes are generally flat, usually located at or below sea level, and can be near the seacoast or far inland at the center of a drainage basin.[1] Salt marshes form in places where the ground water in the subsoil of the desert has risen to the surface.[2] In inland areas, the marshes are created when salts from the local bedrocks are dissolved by the rising ground water. Near the coast, the marshes develop

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[1]DA, US Army War College, Employment of the Engineer System in Arid Mountainous and Desert Areas--A Concept Paper, Carlisle Barracks, PA, 1981, p. 20.

[2]DA, Historical Division European Command, Desert Warfare, German Experience in World War II, Washington, D. C., 1952, p. 20.

when the ground water mixes with seawater salt.[3] As a result of the constant evaporation which takes place in the desert, the salts carried by the ground water are deposited in the soil, forming a brine.[4]

b. Salt marshes may vary in appearance from season to season. In the wet season, the brine may appear as a shallow lake, unless it mixes with sand and clay--then it becomes a patch of thick, tough mud on which salt marsh vegetation may take root.[5] In the dry season, a thin, dry salt crust is usually formed on the surface. This crust is underlain in most places by a brine-saturated soil. Salt water can be found in this soil as deep as 1 meter.[6] In some locations during the dry season, the salt marshes may dry out completely. Then they present no obstacle at all to wheeled vehicle traffic.[7] These dry areas, however, may not be easy to spot from the surface.

c. Salt marshes are one of the few natural obstacles likely to be encountered in desert areas. They were used by both the Germans and the British during the North African campaigns of World War II to anchor an exposed flank or protect against frontal attack. Although they are tough natural obstacles, salt marshes are usually not completely impenetrable. In the dry season, some wheeled traffic can pass over the dry crust before breaking through, although the passage of one vehicle usually is sufficient to break the crust and make further traffic impossible.[8] Most of the salt marshes also

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[3] P.G. Fookes, "Road Geotechnics in Hot Deserts," The Highway Engineer, Journal of the Institution of Highway Engineers, Volume XXXIII, October 1976, p. 21.

[4] Desert Warfare, German Experience in World War II, p. 20.

[5] The Highway Engineer, Journal of the Institution of Highway Engineers, p. 20.

[6] The Highway Engineer, Journal of the Institution of Highway Engineers, p. 65.

[7] The Highway Engineer, Journal of the Institution of Highway Engineers, p. 21.

[8] DA, US Army War College, Employment of the Engineer System in Arid Mountains and Desert Areas--A Concept Paper, Carlisle Barracks, PA, 1981, p. 20.

are crossed by fords, many of which can sustain vehicular traffic. The locations of these fords are usually indicated by old trails or paths and are known to the local inhabitants. A careful reconnaissance is always required before attempting to cross a salt marsh at a possible ford site. It is especially difficult to recover a vehicle that has become mired in a salt marsh because the marsh has no firm anchorages and no bottom. Even a man accidently caught in a salt marsh may find it impossible to escape without help.[9]

d. In terrain such as salt marshes where cross country movement is severely restricted, the relatively few ford sites capable of supporting vehicular traffic are key terrain. Engineer missions in salt marshes will likely involve mobility and countermobilty tasks aimed at controlling this key terrain. The extremely poor soil conditions in the salt marshes themselves and the narrow area of the ford sites will likely preclude any engineer survivability missions.

e. Mobility tasks would seek to overcome any reinforcing obstacles installed by the enemy and to maintain the ford sites in a condition that allow friendly vehicles to pass. Likely tasks would include breaching minefields, reducing point obstacles, and repairing and maintaining ford sites.

f. Countermobility tasks would seek to reinforce the natural obstacle posed by salt marshes by ensuring that the enemy cannot use any possible ford sites. Typical tasks would likely include installing point obstacles and point minefields. Because the marshes have high water tables and offer limited operating space, it is unlikely that the engineers will try to dig tank ditches.

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[9]DA, Historical Division European Command, Desert Warfare, German Experience in World War II, Washington, D. C., 1952, p. 21.

5. Work Rate Degradation for Salt Marshes.

a. Engineer work in the salt marshes will be confined to those areas which can support men and equipment. Any tasks that require digging with engineer equipment to a depth that exceeds the thickness of the top layer of crust will probably not be possible due to the high water table and saturated soil conditions found beneath this top crust. However, under temperate conditions, tasks that do not involve substantial digging could be done within the same time frame as estimated for those same tasks under the conditions of a European environment (Annex E). Therefore, under temperate weather conditions, a degradation factor of 1.0 should be applied to those tasks that do not involve digging with engineer equipment.

b. Extreme heat will degrade the performance of men and machines in the salt marshes. The factors developed in Annex A should be applied to engineer missions performed in the salt marshes under extremely hot conditions.

LAST PAGE OF ANNEX D

APPENDIX D-1

BUILD A PROTECTIVE POSITION FOR AN ARMORED VEHICLE

APPENDIX D-1

BUILD A PROTECTIVE POSITION FOR AN ARMORED VEHICLE

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The construction of survivability positions is considered an unlikely engineer task in thi environment since the salt marshes will not support vehicular traffic. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX D-1

APPENDIX D-2

BUILD A PROTECTIVE POSITION FOR A 1/4-TON MOUNTED TOW

APPENDIX D-2

BUILD A PROTECTIVE POSITION FOR A 1/4-TON MOUNTED TOW

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The construction of survivability positions is considered an unlikely engineer task in this environment since the salt marshes will not support vehicular traffic. Therefore, this task is not evaluated.

APPENDIX D-3

BUILD A PROTECTIVE POSITION FOR A NON-ARMORED VEHICLE

APPENDIX D-3

BUILD A PROTECTIVE POSITION FOR A NON-ARMORED VEHICLE

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The construction of survivability positions is considered an unlikely engineer task in this environment since the salt marshes will not support vehicular traffic. Therefore, this task is not evaluated.

LAST PAGE OF ANNEX D-3

APPENDIX D-4

BUILD A PROTECTIVE POSITION FOR A FORWARD AREA ALERTING RADAR (FAAR)

APPENDIX D-4

BUILD A PROTECTIVE POSITION FOR A FORWARD AREA ALERTING RADAR (FAAR)

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The construction of survivability positions is considered an unlikely engineer task in this environment since the salt marshes will not support vehicular traffic. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX D-4

APPENDIX D-5

BUILD A PROTECTIVE POSITION FOR A PULSE AQUISITION RADAR (PAR)

APPENDIX D-5

BUILD A PROTECTIVE POSITION FOR A PULSE AQUISITION RADAR (PAR)

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The construction of survivability positions is considered an unlikely engineer task in this environment since the salt marshes will not support vehicular traffic. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX D-5

APPENDIX D-6

BUILD A PROTECTIVE POSITION FOR A SELF-PROPELLED HOWITZER

APPENDIX D-6

BUILD A PROTECTIVE POSITION FOR A SELF-PROPELLED HOWITZER

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The construction of survivability positions is considered an unlikely engineer task in this environment since the salt marshes will not support vehicular traffic. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX D-6

APPENDIX D-7

BUILD A PROTECTIVE POSITION FOR A 105-MM TOWED HOWITZER

APPENDIX D-7

BUILD A PROTECTIVE POSITION FOR A 105-MM TOWED HOWITZER

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The construction of survivability positions is considered an unlikely engineer task in this environment since the salt marshes will not support vehicular traffic. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX D-7

APPENDIX D-8

BUILD A PROTECTIVE POSITION FOR A 155-MM TOWED HOWITZER

APPENDIX D-8

BUILD A PROTECTIVE POSITION FOR A 155-MM TOWED HOWITZER

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The construction of survivability positions is considered an unlikely engineer task in this environment since the salt marshes will not support vehicular traffic. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX D-8

APPENDIX D-9

BUILD A TWO-MAN FIGHTING POSITION

APPENDIX D-9

BUILD A TWO-MAN FIGHTING POSITION

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The construction of survivability positions is considered an unlikely engineer task in this environment due to the high water table in the salt marshes. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX D-9

APPENDIX D-10

BUILD A POSITION FOR A DISMOUNTED TOW

APPENDIX D-10

BUILD A POSITION FOR A DISMOUNTED TOW

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The construction of survivability positions is considered an unlikely engineer task in this environment due to the high water table in the salt marshes. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX D-10

APPENDIX D-11

BUILD A POSITION FOR A MORTAR

APPENDIX D-11

BUILD A POSITION FOR A MORTAR

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The construction of survivability positions is considered an unlikely engineer task in this environment due to the high water table in the salt marshes. Therefore, this task is not evaluated.

APPENDIX D-12

BUILD A TANK DITCH

APPENDIX D-12

BUILD A TANK DITCH

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The construction of tank ditches is not considered a likely engineer task in this environment due to the high water table and limited operating space. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX D-12

APPENDIX D-13

INSTALL A TACTICAL MINEFIELD USING GEMMS

APPENDIX D-13

INSTALL A TACTICAL MINEFIELD USING GEMMS

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The installation of a linear obstacle such as a GEMMS minefield is considered an unlikely engineer task in this environment since the salt marshes already provide a formidable natural obstacle. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX D-13

APPENDIX D-14

INSTALL A TACTICAL MINEFIELD USING VOLCANO

APPENDIX D-14

INSTALL A TACTICAL MINEFIELD USING VOLCANO

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The installation of a linear obstacle such as a VOLCANO minefield is not considered a likely engineer task in this environment since the salt marshes already provide a formidable natural obstacle. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX D-14

APPENDIX D-15

INSTALL A POINT MINEFIELD USING CONVENTIONAL MINES

APPENDIX D-15

INSTALL A POINT MINEFIELD USING CONVENTIONAL MINES

1. Terrain. Desert Salt Marshes.

2. Method of Construction. It is unlikely that a linear obstacle such as a standard pattern minefield would be installed in the salt marshes. However, point minefield will be installed by combat engineers to hinder enemy use of potential ford sites through the marshes.

3. Workload Estimates.

a. Temperate weather.

(1) Figures D-15-1 and D-15-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(2) E-FOSS recommends a point minefield with 30 AT mines and three AP mines.[1] Using laying rates of four AT mines per manhour and eight AP mines per manhour, the time required to emplace a point minefield is calculated as follows:[2]

(a) Emplace 30 AT mines:

30/4 = 7.50 manhours

(b) Emplace 3 AP mines:

3/8 = .38 manhours

(c) Allow 10 percent of total emplacement for recording:

(7.50 + 0.38) (1.10) = 8.67 manhours

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[1]DA, US Army Engineer School, Engineer Family of Systems Study (E-FOSS), Volume VII, Appendix N, Washington, D. C., 1979, p. N-III-a-3.

[2]DA, FM 20-32, Mine/Countermine Operations at the Company Level, Washington, D. C., 1976, p. 204.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures D-15-3 and D-15-4. See Annex A for a discussion of the method used.

(1) Installing land mines is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71.

$$(8.67) / (0.71) = 12.21 \text{ manhours}$$

A team of eight men will complete this activity in 1.53 hours.

(2) The 1.53 hours required exceeds the maximum one-time work of 36 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

INSTALL A POINT MINEFIELD USING CONVENTIONAL MINES
(Desert Salt Marshes + Temperate Weather)

HEAVY EQUIPMENT WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	8
ACTIVITY	Install Point Minefield	8.67
	Elapsed Time Required To Complete Task	1.08

Figure D-15-1

LIGHT EQUIPMENT WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	8
ACTIVITY	Install Point Minefield	8.67
	Elapsed Time Required To Complete Task	1.08

Figure D-15-2

INSTALL A POINT MINEFIELD USING CONVENTIONAL MINES
(Desert Salt Marshes + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		8
ACTIVITY	Install Point Minefield	12.21*
Elapsed Time Required To Complete Task		1.53

Figure D-15-3

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		8
ACTIVITY	Install Point Minefield	12.21*
Elapsed Time Required To Complete Task		1.53

Figure D-15-4

LAST PAGE OF APPENDIX D-15

APPENDIX D-16

DISABLE A BRIDGE

APPENDIX D-16

DISABLE A BRIDGE

1. Terrain. Desert Salt Marshes.

2. Method of Construction. Bridges are not likely to be encountered in the salt marshes. However, should it become necessary to develop an estimate for this task in the salt marshes, then Appendix C-15 may be used.

LAST PAGE OF APPENDIX D-16

APPENDIX D-17

CRATER A ROAD

APPENDIX D-17

CRATER A ROAD

1. Terrain. Desert Salt Marshes.

2. Method of Construction. A team of eight combat engineers is assigned to crater a road and install a point minefield using conventional explosives and mines.

3. Workload Estimates.

a. Temperate weather. Figures D-17-1 and D-17-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) The road crater is installed to block a two-lane, asphalt road with a traveled width of 25 feet. The time required to install the road crater in the salt marshes does not differ substantially from the time estimates in Appendix E-17:

Preparing and firing the shaped charges = 10.00 manhours

Preparing and firing the cratering charges = 2.40 manhours

Total time required to install the crater = 12.40 manhours

An 8-man team will finish this activity in 1.55 hours.

(2) A point minefield is installed in and around the crater. It is assumed that the target is mined with 12 AT mines and 6 AP mines. Effort required is based on an estimated laying rate in sand of four AT mines per manhour and eight AP mines per manhour.

12 / 4 = 3.00 manhours

6 / 8 = 0.75 manhours

TOTAL = 3.75 manhours

AD-A169 799 WORKLOAD ESTIMATES FOR COMBAT ENGINEERS IN THE DESERT (U) ARMY ENGINEER STUDIES CENTER FORT BELVOIR VA T O ATKINSON ET AL. APR 86 USAESC-R-86-2 5/6

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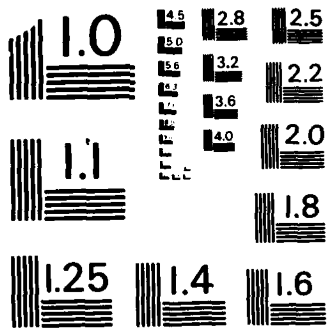

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

An 8-man team will finish this activity in 0.47 hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures D-17-3 and D-17-4. See Annex A for a discussion of the method used.

(1) Preparing and firing the explosives is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$$(12.40) / (0.58) = 21.38 \text{ manhours}$$

An 8-man team will finish this activity in 2.67 hours.

(2) Installing land mines is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71.

$$(3.75) / (0.71) = 5.28 \text{ manhours}$$

An 8-man team will finish this activity in 0.66 hours.

(3) The 2.67 hours required exceeds the maximum one-time work rate of 50 minutes listed in Figure A-2. The 0.66 hours required exceeds the maximum one-time work rate of 36 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

CRATER A ROAD
(Desert Salt Marshes + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	8
ACTIVITY	Prepare and Fire Demolitions	12.40
	Install Point Minefield	3.75
	Elapsed Time Required To Complete Task	2.02

Figure D-17-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	8
ACTIVITY	Prepare and Fire Demolitions	12.40
	Install Point Minefield	3.75
	Elapsed Time Required To Complete Task	2.02

Figure D-17-2

CRATER A ROAD
(Desert Salt Marshes + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	8
ACTIVITY	Prepare and Fire Demolitions	21.38*
	Install Point Minefield	5.28*
	Elapsed Time Required To Complete Task	3.33

Figure D-17-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	8
ACTIVITY	Prepare and Fire Demolitions	21.38*
	Install Point Minefield	5.28*
	Elapsed Time Required To Complete Task	3.33

Figure D-17-4

LAST PAGE OF APPENDIX D-17

APPENDIX D-18

CLEAR A TANK DITCH

APPENDIX D-18

CLEAR A TANK DITCH

1. Terrain. Desert Salt Marshes.

2. Method of Construction. This task is considered an unlikely engineer mission in this environment since the salt marshes are already a formidable natural obstacle for tracked and wheeled vehicles. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX D-18

APPENDIX D-19

REPAIR A ROAD CRATER

APPENDIX D-19

REPAIR A ROAD CRATER

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The engineer resources used in this task consist of one bulldozer or M9 ACE with operator, one 2-1/2-cubic-yard scoop loader with operator, ten combat engineers, and five or ten dump trucks depending on the type of engineer force.

a. The typical road crater is assumed to be a trapezoidal prism with a depth of 2.25 meters, a length of 12.5 meters, a top width of 8.70 meters and a bottom width of 2.25 meters. (See Figure E-19-1.) The volume of the crater is the same as the volume estimated in Appendix E-19 (approximately 200 cubic yards). The area in and around the crater is seeded with mines.

b. *It cannot be assumed that sufficient backfill material is* available at the crater site. Such a road crater would have penetrated the firm upper crust and exposed the saturated soil below. Digging at the site with a bulldozer would likely only further expose this saturated layer. In the salt marsh areas, aggregate must be hauled in to fill the crater. ESC assumes a travel and loading cycle of 30 minutes. Generally speaking, the desert is a good source of aggregate, so a relatively short cycle was assumed.

3. Workload Estimates.

a. Temperate weather. Figures D-19-1 and D-19-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) The heavy engineer force shuttles five 5-ton dump trucks from a stockpile site of suitable fill material to the crater site. A bucket

loader fills the trucks at the stockpile site and a D7 dozer or ACE is used at the crater site to spread and compact the fill material.

(a) Before fill can be brought in, the area must be cleared of mines. As in Appendix E-19, combat engineers accomplish this activity in 30 manhours.

(b) The 5-ton dump truck has a haul capacity of 5 cubic yards.[1] Thus with five trucks, 25 cubic yards can be hauled per cycle, and eight cycles will be required.

(200) / (25) = 8 cycles

(8) (30) = 240 minutes = 4 hours

(5) (4) = 20 truck hours

(c) An additional 15 minutes are allowed after the last truck cycle for the D7 dozer to spread and compact the fill.

4.00 + 0.25 = 4.25 hours

(2) The light engineer force shuttles ten 2-1/2-ton dump trucks from a stockpile site to the crater site. A bucket loader fills the trucks at the stockpile site and a D5 dozer is used at the crater site to spread and compact the fill material.

(a) Before the fill can be brought in the area must be cleared of mines. Combat engineers accomplish this activity in 30 manhours.

(b) The 2-1/2-ton dump truck has a haul capacity of 2-1/2 cubic yards.[2] Thus with 10 trucks, 25 cubic yards can be hauled per cycle and 16 cycles will be required.

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[1] DA, TM 9-500, Data Sheets for Ordnance Type Material, Washington, D. C., 1962, pp. 21-69 through 21-76.

[2] TM 9-500, pp. 21-69 through 21-76.

$(200) / (25) = 8$ cycles

$(8)(30) = 240$ minutes $= 4$ hours

$(10)(4) = 40$ truck hours

(c) An additional 20 minutes are allowed after the last truck cycle for the D5 dozer to spread and compact the fill.

$4.00 + 0.33 = 4.33$ hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures D-19-3 and D-19-4. See Annex A for a discussion of the method used.

(1) Clearing the mines is moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

$(30.0) / (0.58) = 51.72$ manhours

A team of 10 men will complete this activity in 5.17 hours.

(2) Operating engineer equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(a) 2.5-CY loader.

$(4.00) / (0.52) = 7.69$ hours

(b) D7 dozer.

$(4.25) / (0.52) = 8.17$ hours

(c) D5 dozer.

$(4.33) / (0.52) = 8.32$ hours

(d) 5-ton truck.

$(7.69)(5) = 38.45$ truck hours

(e) 2.5-ton truck.

$(7.69)(10) = 76.90$ truck hours

(3) The 5.17 hours required exceeds the maximum one-time work rate of 50 minutes listed in Figure A-2. The 7.69, 8.17, and 8.32 hours

required exceed the maximum one-time work rate of 62 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

REPAIR A ROAD CRATER
(Desert Salt Marshes + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	5-Ton Truck	Combat Engr	2.5-CY Loader
	Number of Items	1	5	10	1
ACTIVITY	Clear Mines			30.00	
	Backfill Crater	4.25	20.00		4.00
	Elapsed Time Required To Complete Task	7.25			

Figure D-19-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-Ton Truck	Combat Engr	2.5-CY Loader
	Number of Items	1	10	10	1
ACTIVITY	Clear Mines			30.0	
	Backfill Crater	4.33	40.00		4.00
	Elapsed Time Required To Complete Task	7.33			

Figure D-19-2

REPAIR A ROAD CRATER
(Desert Salt Marshes + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		D7 Dozer or M9 ACE	5-Ton Truck	Combat Engr	2.5-CY Loader
Number of Items		1	5	10	1
ACTIVITY	Clear Mines			51.72*	
	Backfill Crater	8.17*	38.45*		7.69*
Elapsed Time Required To Complete Task		13.34			

Figure D-19-3

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		D5 Dozer	2.5-Ton Truck	Combat Engr	2.5-CY Loader
Number of Items		1	10	10	1
ACTIVITY	Clear Mines			51.72*	
	Backfill Crater	8.32*	76.90*		7.69*
Elapsed Time Required To Complete Task		13.49			

Figure D-19-4

LAST PAGE OF APPENDIX D-19

APPENDIX D-20

CONSTRUCT 100 METERS OF COMBAT TRAIL

APPENDIX D-20

CONSTRUCT 100 METERS OF COMBAT TRAIL

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The construction of combat trails is considered an unlikely engineer task in this environment since the salt marshes will not support vehicular traffic. New road or trail construction through the salt marshes would require the use of special geotechnical fabrics not available to forward engineer units.[1] Therefore, this task is not evaluated.

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[1]Jack Fowler, "Building on Muck," Civil Engineering/ASCE; May 1985, pp. 67-69.

LAST PAGE OF APPENDIX D-20

APPENDIX D-21

REPLACE COMBAT BRIDGING

APPENDIX D-21

REPLACE COMBAT BRIDGING

1. Terrain. Desert Salt Marshes.

2. Method of Construction. The construction of fixed bridging is not considered a likely engineer task in this environment since the salt marshes are generally flat in relief. However, should it become necessary to develop an estimate for this task in the salt marshes, then Appendix C-21 may be used.

LAST PAGE OF APPENDIX D-21

APPENDIX D-22

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD

APPENDIX D-22

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD

1. Terrain. Desert Salt Marshes.

2. Method of Construction. An engineer team consisting of heavy equipment and combat engineers is assigned to maintain an unpaved but well-built secondary road that has become rutted and worn from heavy traffic. The road to be maintained is a two-lane, graded and drained earth road. Compaction effort is not in included this estimate.

3. Workload Estimates.

a. Temperate weather.

(1) As in Appendix E-22, the estimate is based on the projected maintenance and repair required during a 5-day period for a 10-kilometer section of road. ESC estimates that the roads will deteriorate twice as fast in the desert salt marshes as in Europe. Repair times, however, will remain the same as those for Europe. The engineer road repair team will, therefore, spend twice the amount of time and effort estimated in Appendix E-22. Figure D-22-1 reflects the engineer resources and effort required for a 10-kilometer section using 5-ton dump trucks.

(a) 2.5-CY loader.

(3.11) (2) = 6.22 equipment hours

(b) Four 5-ton dump trucks.

(12.44) (2) = 24.88 equipment hours

(c) 16 combat engineers.

(49.76) (2) = 99.52 manhours

(d) Four graders.

(12.44) (2) = 24.88 equipment hours.

(2) The number of dump trucks shown in Figure D-22-2 is doubled since a 5-ton dump truck is rated at approximately twice the volume and weight capacity of a 2 1/2-ton dump truck. Eight 2.5-ton dump trucks:

(24.88) (2) = 49.76 equipment hours

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures D-22-3 and D-22-4. See Annex A for a discussion of the method used.

(1) Operating engineer equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(a) 2.5-CY loader.

(6.22) / (0.52) = 11.96 equipment hours

(b) 5-ton dump truck.

(24.88) / (0.52) = 47.85 equipment hours

(c) Grader.

(24.88) / (0.52) = 47.85 equipment hours

(d) 2.5-ton dump truck.

(49.76) / (0.52) = 95.69 equipment hours

The engineer equipment will require 11.96 hours to complete their activities.

(2) Manual labor by combat engineers is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71.

(99.52) / (0.71) = 140.17 manhours

A team of 16 men will require 8.76 hours to complete this activity.

(3) The 11.96 hours and the 8.76 hours required both greatly exceed the respective maximum one-time work rates shown in Figure A-2.

However, these times are spread over a five day period. At a given road repair site the maximum one-time work rates are 36 minutes for the combat engineers and 62 minutes for the equipment operators. The asterisk in the figures indicates that, if the work at a repair site exceeds these times, the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD
(Desert Salt Marshes + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-CY Loader	5-Ton Truck	Combat Engr	Grader
	Number of Items	1	4	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	6.22	24.88	99.52	24.88
	Elapsed Time Required To Complete Task	6.22			

Figure D-22-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-CY Loader	2.5-Ton Truck	Combat Engr	Grader
	Number of Items	1	8	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	6.22	49.76	99.52	24.88
	Elapsed Time Required To Complete Task	6.22			

Figure D-22-2

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD
(Desert Salt Marshes + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-CY Loader	5-Ton Truck	Combat Engr	Grader
	Number of Items	1	4	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	11.96*	47.85*	140.17*	47.85*
	Elapsed Time Required To Complete Task	11.96			

Figure D-22-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-CY Loader	2.5-Ton Truck	Combat Engr	Grader
	Number of Items	1	8	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	11.96*	95.69*	140.17*	47.85*
	Elapsed Time Required To Complete Task	11.96			

Figure D-22-4

LAST PAGE OF APPENDIX D-22

APPENDIX D-23

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE

APPENDIX D-23

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE

1. Terrain. Desert Salt Marshes.

2. Method of Construction. An engineer team consisting of graders, trucks, and combat engineers is assigned to maintain a paved MSR. The asphalt section of a combat engineer battalion (heavy) will augment the divisional engineer battalion, however, that section's effort is not included in this estimate.

3. Workload Estimates.

a. Temperate weather. The method used to compute estimates is as follows:

(1) The road to be maintained is a two-lane, bituminous surface road. The estimate is based on the projected maintenance and repair required during a 5-day period for a 10-kilometer section of road. ESC assumes that the road will deteriorate twice as fast in the desert salt marshes as in Europe. Repair times, however, will remain the same as those for Europe. Time estimates for Europe, shown in Appendix E-23, are therefore doubled for the desert salt marshes. Figure D-23-1 reflects the engineer times and resources required using 5-ton dump trucks.

(a) Eight 5-ton dump trucks.

(24.88) (2) = 49.76 equipment hours

(b) 16 combat engineers.

(49.76) (2) = 99.52 manhours

(c) Four graders.

(12.44) (2) = 24.88 equipment hours

(2) The number of dump trucks shown in Figure D-23-2 is doubled since a 5-ton dump truck is rated at approximately twice the volume and weight capacity of a 2 1/2-ton dump truck. Sixteen 2.5-ton dump trucks.

$$(49.76)\ (2) = 99.52 \text{ equipment hours}$$

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures D-23-3 and D-23-4. See Annex A for a discussion of the method used.

(1) Operating engineer equipment is light work according to Figure A-1. At 120° F, Figure A-3 provides a degradation factor of 0.52.

(a) 5-ton dump truck.

$$(49.76) / (0.52) = 95.69 \text{ equipment hours}$$

(b) Grader.

$$(24.88) / (0.52) = 47.85 \text{ equipment hours}$$

(c) 2.5-ton dump truck.

$$(99.52) / (0.52) = 191.38 \text{ equipment hours}$$

The engineer equipment will require 11.96 hours to complete these activities.

(2) Manual labor by combat engineers is heavy work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.71.

$$(99.52) / (0.71) = 140.17 \text{ manhours}$$

A team of 16 men will require 8.76 hours to complete this activity.

(3) The 11.96 hours and the 8.76 hours required both greatly exceed the respective maximum one-time work rates shown in Figure A-2. However, these times are spread over a five day period. At a given road repair site the maximum one-time work rates are 36 minutes for the combat engineers and 62 minutes for the equipment operators. The asterisk in the figures indicates that, if the work at a repair site exceeds these times, the

engineer commander should consider using two or more shifts to decrease the number of heat casualties.

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE (MSR)
(Desert Salt Marshes + Temperate Weather)

HEAVY EQUIPMENT WORKLOAD RATES

	Resource Type	5-Ton Truck	Combat Engr	Grader
	Number of Items	8	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	49.76	99.52	24.88
	Elapsed Time Required To Complete Task	6.22		

Figure D-23-1

LIGHT EQUIPMENT WORKLOAD RATES

	Resource Type	2.5-Ton Truck	Combat Engr	Grader
	Number of Items	16	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	99.52	99.52	24.88
	Elapsed Time Required To Complete Task	6.22		

Figure D-23-2

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE (MSR)
(Desert Salt Marshes + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-Ton Truck	Combat Engr	Grader
	Number of Items	8	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	95.69*	140.17*	47.85*
	Elapsed Time Required To Complete Task	11.96		

Figure D-23-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-Ton Truck	Combat Engr	Grader
	Number of Items	16	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	191.38*	140.17*	47.85*
	Elapsed Time Required To Complete Task	11.96		

Figure D-23-4

LAST PAGE OF APPENDIX D-23

APPENDIX D-24

DELIBERATE MINEFIELD BREACH

APPENDIX D-24

DELIBERATE MINEFIELD BREACH

1. Terrain. Desert Salt Marshes.

2. Method of Construction. As in Appendix E-24, 10 combat engineers are assigned to conduct a deliberate breach through a 100-meter-deep minefield. The salt marshes do not affect the times and resources estimates in Appendix E-24.

3. Workload Estimates.

a. Temperate weather. Figures D-24-1 and D-24-2 present the workload estimates, under temperate conditions, for heavy and light equipment teams, respectively. The method used to compute estimates is as follows:

(1) Breach a 1-meter foot path with bangalore torpedo: 4 manhours.

(2) Widen the breach to 8 meters using mine detectors and explosives: 80 manhours.

(3) Mark the cleared lane using the Hand Emplaced Minefield Marking Set (HEMMS): 10 manhours.

b. Hot weather. Adjustments for work production degradation caused by high temperatures have been applied to the data in Figures D-24-3 and D-24-4. See Annex A for a discussion of the method used.

(1) Breaching, clearing and marking a lane through a minefield are moderate work according to Figure A-1. At 110° F, Figure A-3 provides a degradation factor of 0.58.

(a) Breach.

$$(4.00) / (0.58) = 6.90 \text{ manhours}$$

(b) Clear lane.

(80.00) / (0.58) = 137.93 manhours

(c) Mark lane.

(10.00) / (0.58) = 17.24 manhours

A 10-man team finishes each activity in 0.69 hours, 13.79 hours, and 1.72 hours, respectively.

(2) The latter two times exceed the maximum one-time work rate of 50 minutes listed in Figure A-2. The asterisk in the figures indicates that the engineer commander should consider using two or more shifts to decrease the number of heat casualties.

c. The time and effort required for a hasty breach to get dismounted assault forces through a 100-meter-deep minefield can be estimated using the first activity of Figures D-24-1 through D-24-4.

DELIBERATE MINEFIELD BREACH
(Desert Salt Marshes + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		10
ACTIVITY	Breach 1-Meter Footpath	4.0
	Clear 8-Meter Wide Path	80.0
	Mark the Lane	10.0
Elapsed Time Required To Complete Task		9.4

Figure D-24-1

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		Combat Engr
Number of Items		10
ACTIVITY	Breach 1-Meter Footpath	4.0
	Clear 8-Meter Wide Path	80.0
	Mark the Lane	10.0
Elapsed Time Required To Complete Task		9.4

Figure D-24-2

DELIBERATE MINEFIELD BREACH
(Desert Salt Marshes + Hot Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	10
ACTIVITY	Breach 1-Meter Footpath	6.90
	Clear 8-Meter Wide Path	137.93*
	Mark the Lane	17.24*
	Elapsed Time Required To Complete Task	16.21

Figure D-24-3

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	10
ACTIVITY	Breach 1-Meter Footpath	6.90
	Clear 8-Meter Wide Path	137.93*
	Mark the Lane	17.24*
	Elapsed Time Required To Complete Task	17.07

Figure D-24-4

LAST PAGE OF APPENDIX D-24

APPENDIX D-25

REDUCE A DRY GAP BANK GRADE FOR VEHICLE PASSAGE

APPENDIX D-25

REDUCE A DRY GAP BANK GRADE FOR VEHICLE PASSAGE

1. Terrain. Desert Salt Marshes

2. Method of Construction. This task is considered an unlikely engineer mission in this environment since the salt marshes are generally flat in relief. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX D-25

APPENDIX D-26

PREPARE A SITE FOR A 40,000 GALLON BRIGADE WATER POINT

APPENDIX D-26

PREPARE A SITE FOR A 40,000 GALLON BRIGADE WATER POINT

1. Terrain. SALT MARSHES.

2. Method of Construction: The construction of a brigade water point is not considered a likely engineer task in this environment since the salt marshes will not support vehicular traffic. Therefore, this task is not evaluated.

LAST PAGE OF APPENDIX D-26

ANNEX E

EUROPEAN WORKLOAD FACTORS

ANNEX E

EUROPEAN WORKLOAD FACTORS

1. Purpose. This annex estimates the time and engineer resources required to complete the various combat engineer tasks in the temperate climate and soil conditions of a European environment.

2. Scope. This analysis quantified the effort required to complete the engineer tasks required to support committed maneuver brigades, and established planning factors for each of those tasks. The values for the quantified engineer effort, combined with ESC-developed production planning factors for engineer work conducted under temperate climate conditions, served as a base line from which to derive the production planning factors for engineer work in a desert environment described in Annexes B through D.

3. Method.

a. Most of the engineer tasks considered by this analysis were selected from the following ESC studies:

(1) US Army Engineer Assessment, Europe, June 1981

(2) Analysis of VII Corps Combat Engineer Wartime Requirements, March 1983.

(3) Analysis of V Corps Combat Engineer Wartime Requirements, 1983.

(4) Analysis of III Corps Combat Engineer Wartime Requirements, 1984.

b. The SAG for each of these studies approved the use of the same engineer tasks as a basis from which to estimate engineer requirements in support of maneuver brigades. The USCENTCOM SAG chose those same tasks as representative of engineer support requirements in USCENTCOM's probable area of operations.

c. Having established the various types of engineer tasks, the method used to evaluate each task involved a four step process:

(1) Define the dimensions and configuration for each task.

(2) Select the resources appropriate for each task based on what probably will be available under actual battlefield conditions, and on the characteristics and capabilities of each resource.

(3) Determine the effort required to complete each task, given the resources selected during Step 2.

(4) Determine the time required to complete each task and, if necessary, apply more resources.

4. Discussion.

a. The designs depicted in this annex were selected from a variety of sources:

(1) Engineer Family of Systems Study, Volume VII, Appendix N, published by the US Army Engineer School in February 1979.

(2) FM 5-103, Survivability, draft copy provided by the US Army Engineer School in June 1985.

(3) FM 5-34, Engineer Field Data, published by the US Army Engineer School 24 September 1976.

(4) Interviews with commanders of combat units.

b. In those instances where design configurations differed between sources, the study analysts used their military judgement to select an appropriate design. This selection is subjective and should not be construed as favoring one design over another. Those users who feel strongly that an ESC selection is improper can substitute their dimensions into the algorithms provided with each appendix.

c. A limited range of equipment choices was examined when defining the composition of the engineer work crews. Equipment examined included the D7 and D5 dozers, M9 ACE, 2.5-cubic-yard scoop loader, 5-ton and 2.5-ton dump trucks, and the SEE. Each of these equipment items appears or will appear in the divisional and corps battalion TOEs.

5. Equipment Production Rates.

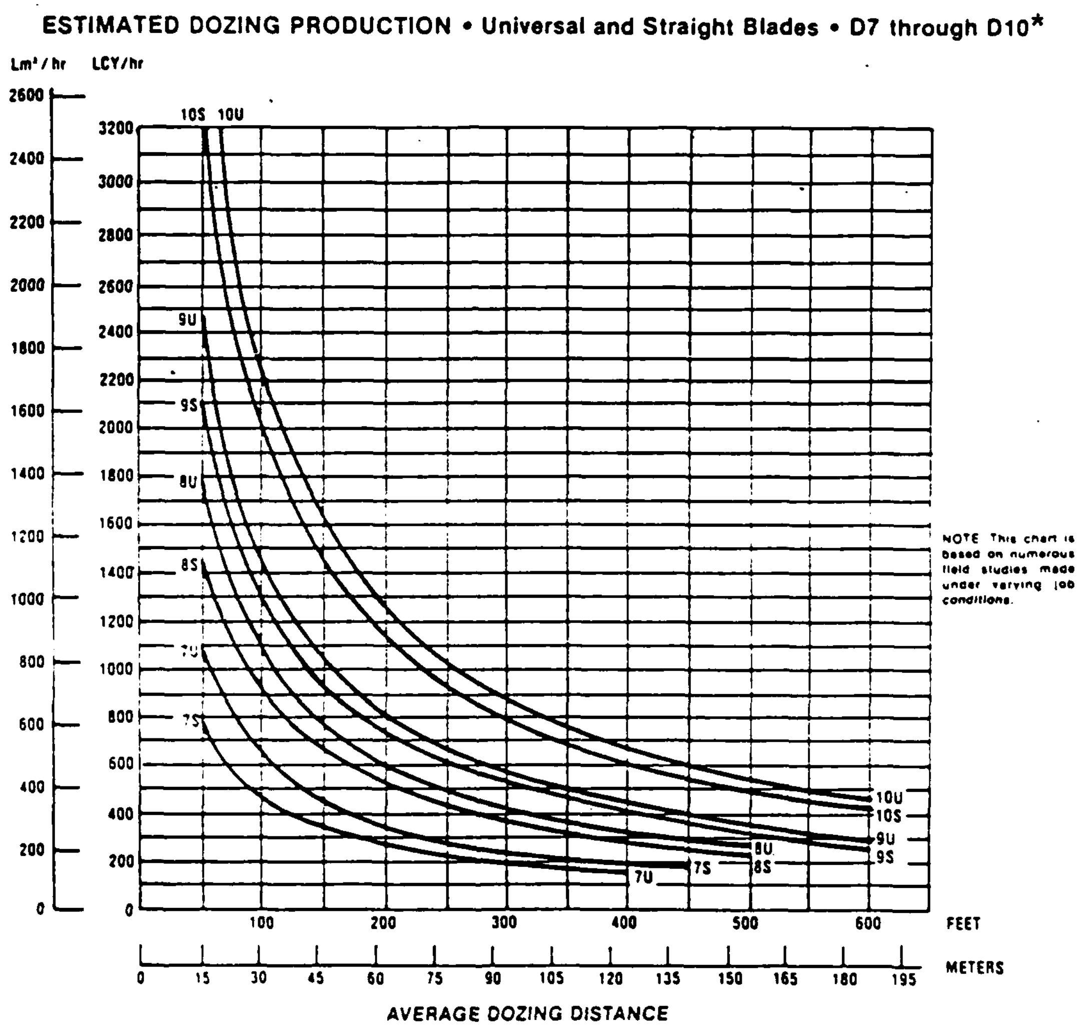
a. Work production rates for bulldozers were estimated using the method described on pages 41 through 45 of the Caterpillar Handbook.[1] Figures E-1 through E-4 are reprinted from pages 42, 43, and 44 of the Handbook.

(1) Figures E-1 and E-2 graphically display the maximum production rates for various dozer/blade combinations. However, because maximum production rates are rarely achieved by dozer operators, these rates are modified by the correction factors specified in Figure E-3. Those factors, described below, were selected as typical of the conditions US combat engineers could expect to encounter at European work sites.

(a) Operator (average) = 0.75. Workrate estimates assume that dozer operators have average abilities.

---

[1]Caterpillar Tractor Company, Caterpillar Performance Handbook, Edition 15, Peoria, Illinois, October 1984.



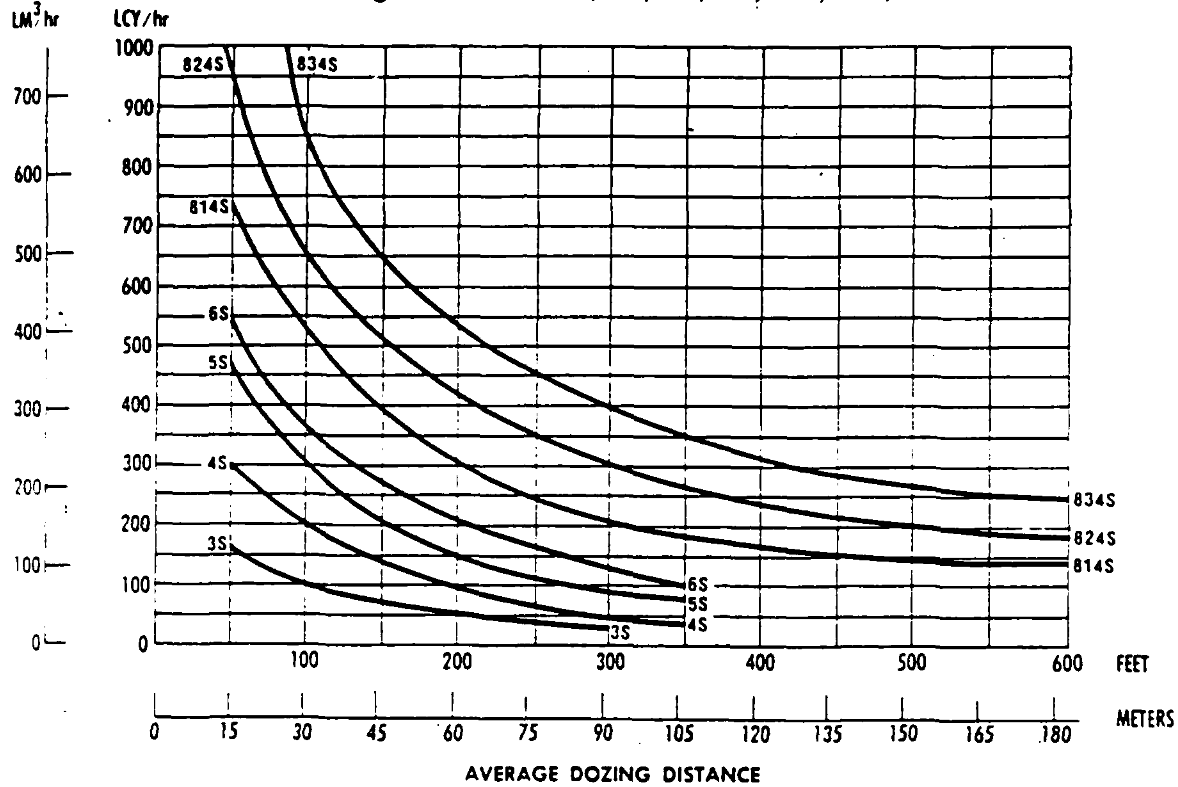
*Reprinted with permission of Caterpillar Tractor Company, Peoria, Illinois.

NOTE: The notations "7S" and "7U" which appear above the 400- and 450-foot marks along the horizontal axis have been mistakenly reversed.

Figure E-1

ESTIMATED DOZING PRODUCTION

Straight Blades • D3, D4, D5, D6, 814, 824, 834



NOTE This chart is based on numerous field studies made under varying job conditions. The 3S represented is for the D3B LGP

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Figure E-2

JOB CONDITION CORRECTION FACTORS

	TRACK-TYPE TRACTOR	WHEEL-TYPE TRACTOR
OPERATOR —		
Excellent	1.00	1.00
Average	0.75	0.60
Poor	0.60	0.50
MATERIAL —		
Loose stockpile	1.20	1.20
Hard to cut; frozen —		
with tilt cylinder	0.80	0.75
without tilt cylinder	0.70	—
cable controlled blade	0.60	—
Hard to drift; "dead" (dry, non-cohesive material) or very sticky material	0.80	0.80
Rock, ripped or blasted	0.60-0.80	—
SLOT DOZING	1.20	1.20
SIDE BY SIDE DOZING	1.15-1.25	1.15-1.25
VISIBILITY —		
Dust, rain, snow, fog or darkness	0.80	0.70
JOB EFFICIENCY —		
50 min/hr	0.84	0.84
40 min/hr	0.67	0.67
DIRECT DRIVE TRANSMISSION		
(0.1 min. fixed time)	0.80	—
BULLDOZER*		
Angling (A) blade	0.50-0.75	—
Cushioned (C) blade	0.50-0.75	0.50-0.75
D5 narrow gauge	0.90	—
Light material U-blade (coal)	1.20	1.20
GRADES — See following graph.		

*Note: Angling blades and cushion blades are not considered production dozing tools. Depending on job conditions, the A-blade and C-blade will average 50-75% of straight blade production.

*Reprinted with permission of Caterpillar Tractor Company, Peoria, Illinois.

Figure E-3

(b) Material = 1.0. No correction factor is applied for working in good, common earth typical of the European terrain.

(c) Slot dozing = 1.2. Whenever possible, engineer dozer operators are assumed to use slot dozing techniques.

(d) Job efficiency (60 minutes per hour) = 1.0. This correction factor is more appropriate for long-term projects, whereas the tasks described in this annex must be completed in a much shorter time. This factor, therefore, is set equal to one for requirements estimates. Analysts who use the workload planning factors presented here to generate long-term engineer capability estimates need to consider degrading the efficiency of the dozer operators over time.

(e) Grade = 1.0. An average grade of 0 percent is assumed for terrain in Europe (see Figure E-4).

(f) Soil density (dry earth) = 0.9. The density of the material in loose cubic yards (LCY) on which the data in the figures are based (2,300 lb per LCY) is divided by the density of dry, packed earth (2,550 lb per LCY).

(g) The total correction factor is 0.81. This factor is applied to the maximum dozer production rates.

$$(0.75)\ (1.0)\ (1.2)\ (1.0)\ (1.0)\ (0.9) = 0.81$$

(2) Figures E-5 and E-6 show the production rates for the D7 and D5 dozer, respectively. The rates are shown for various average dozing distances. The values in the first row are taken from Figures E-1 and E-2. These values represent, in LCY per hour, the maximum production rates of the D7 and D5 dozers with straight dozer blades. The values in the second row resulted when the rates in the first row were converted to bank cubic yards

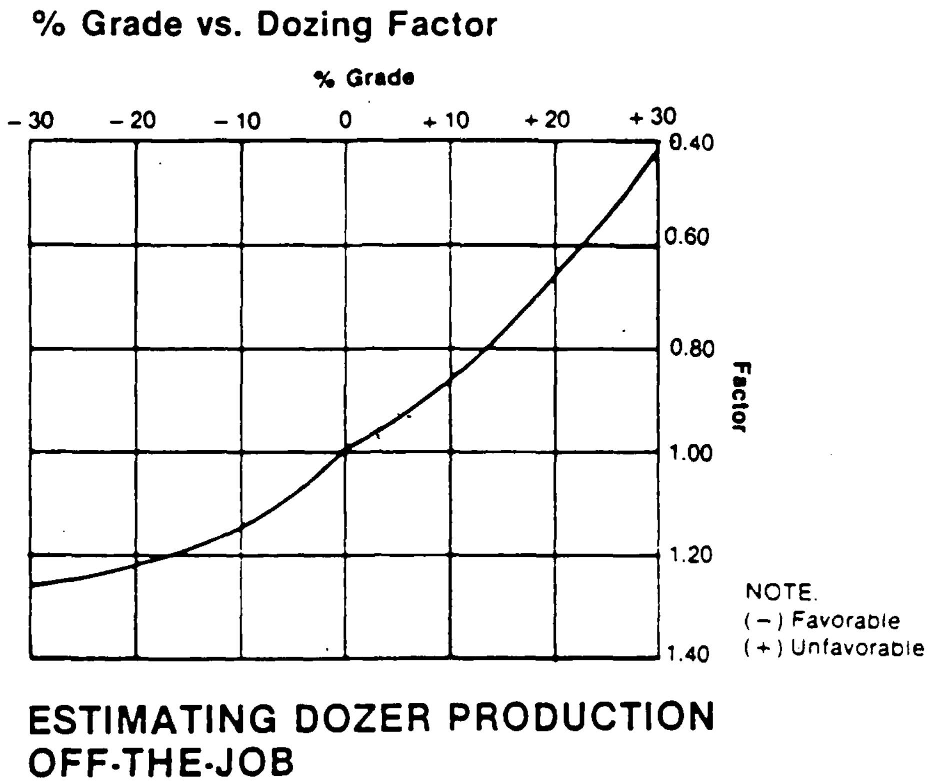

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Figure E-4

PRODUCTION RATES FOR
D7 DOZER

(EUROPEAN TERRAIN)

	PUSH DISTANCE (FEET)					
	50	75	100	125	150	200
LCY/HOUR	760	580	460	400	350	280
BCY/HOUR	608	464	368	320	280	224
CORRECTED RATE	492	376	298	259	227	181

Figure E-5

PRODUCTION RATES FOR
D5 DOZER

(EUROPEAN TERRAIN)

	PUSH DISTANCE (FEET)					
	50	75	100	125	150	200
LCY/HOUR	460	375	300	250	200	150
BCY/HOUR	368	300	240	200	160	120
CORRECTED RATE	298	243	194	162	130	97

Figure E-6

(BCY) per hour by multiplying by 0.80, the load factor for dry packed earth.[2] The third row displays the production rates which result after multiplying the value in the second row by the correction factor of 0.81. These last rates are the dozer production rates for the engineer tasks expected to be performed by combat units in Europe.

b. In this study, the M9 ACE is considered to have earthmoving and bulldozing characteristics comparable to the D7 dozer.[3,4]

c. The analysts estimated the excavation rates for the SEE by using field test data for the JD410 Loader/Backhoe.[5,6] ESC concluded that the backhoe production rate for the JD410 would approximate the rates for the SEE (6.8-cubic foot versus 7-cubic foot bucket capacities).

(1) The field test data suggest that the SEE has two excavation rates. First, an estimated rate of 28 BCY per hour is appropriate when excavating a simple geometric pattern, such as a linear trench or a rectangular pit. Second, a rate of 12 BCY per hour approximates the production rate of the SEE when it is excavating an emplacement with a more complex geometric pattern, such as a circular or U-shaped pit. This slower rate is caused by the need to frequently reposition the SEE between digging cycles.

(2) The field test data also suggest that the approximate backfilling rate for the SEE is 197 LCY per hour.

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[2] Caterpillar Tractor Company, Caterpillar Performance Handbook, Edition 15, Peoria, IL, October 1984, p. 586.

[3] DA, US Army Engineer Center, FM-103, Survivability, 1985 Draft, p. A-2.

[4] DA, US Army Engineer Center and School and Fort Belvoir, Combat Engineer Systems Handbook, Fort Belvoir, Virginia, June 1984, p. 67.

[5] DA, Final Report of Strongpoint Emplacement Excavation for Defensive Operations (SPEEDO), Concept Evaluation, TRADOC Project No. 7-CEP091, 16 February 1978, and raw test data provided by the US Army Mobility Equipment Research and Development Center, Fort Belvoir, Virginia.

[6] ESC used the specifications for the Military SEE Tractor built by the Freightliner Corporation.

d. The Caterpillar Handbook was used to estimate scoop loader rates for both the 2-1/2-cubic-yard scoop loader and the 3/4-cubic-yard SEE.[7]

(1) Caterpillar estimates that the average basic cycle time varies between 0.45 to 0.55 minutes for scoop loaders with bucket capacities less than 3 cubic meters. With an eye towards conservatism, 0.6 minutes was selected as a representative scoop loader rate. Figure E-7 shows steps followed to estimate scoop loader and SEE production rates. The rate for the 2-1/2-cubic-yard scoop loader is 242 LCY or 185 cubic meters per hour.

(2) As stated, Figure E-7 lists the steps used to estimate the SEE production rate. That rate is 72.6 LCY or 55.5 m^3 per hour.

[7]Caterpillar Tractor Company, Caterpillar Performance Handbook, Edition 15, Peoria, Illinois, October 1984, pp. 354-355.

PRODUCTION ESTIMATES FOR THE 2-1/2-CUBIC-YARD SCOOP LOADER AND THE SEE

(EUROPEAN TERRAIN)

FACTOR NAME	BASIC CYCLE TIME	+	MATERIAL TYPE (BROKEN EARTH)	+	DOZER PILED	+	CONSTANT OPERATION	=	TOTAL CYCLE TIME
SCOOP LOADER	0.60		0.05		0.01		-0.04		0.62
SEE	0.60		0.05		0.01		-0.04		0.62

FACTOR NAME	(60)	÷	TOTAL CYCLE TIME	=	CYCLES PER HOUR	×	LCY PER CYCLE	=	LCY PER HOUR
SCOOP LOADER			0.62		96.8		2.5		242.0
SEE			0.62		96.8		0.75		72.6

Figure E-7

LAST PAGE OF ANNEX E

APPENDIX E-1

BUILD A PROTECTIVE POSITION FOR AN ARMORED VEHICLE

APPENDIX E-1

BUILD A PROTECTIVE POSITION FOR AN ARMORED VEHICLE

1. Terrain. European.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator and one engineer to confer with users and to guide the dozer to the position site.

a. The planning factors displayed in this appendix are appropriate for:

(1) Personnel carriers

(2) Infantry TOW carriers

(3) Armored car TOW carriers

(4) Armored car personnel carriers

(5) Infantry fighting vehicles

(6) Cavalry fighting vehicles

(7) Armored tank

(8) Armored car tank

(9) Artillery personnel carrier (fire support team)

(10) Counter battery/counter mortar radar

(11) Self-propelled vulcan

(12) Infantry command post carrier

(13) Armored command post carrier

(14) Towed artillery command post carrier

(15) Infantry mortar carrier

(16) Armored cavalry mortar carrier

(17) Armored mortar carrier

18) Brigade headquarters command post carrier[1]

b. The excavated position is 4.2 meters wide and 1.5 meters deep. It has a 7-meter-long floor and an entrance ramp with a 9-degree slope. To ease earthmover entry into the excavation, a sloped face of 1:1.5 was assumed adequate[2] (see Figure E-1-1.)

(1) The volume of earth that must be excavated is estimated as follows:

$$[(1)\ (w)\ (d)] + [(0.5)\ (\text{ctn } 9^{o})\ (d)\ (w)] + [(0.5)\ (1.5)\ (d)\ (d)\ (w)] =$$

$$[(7)\ (4.2)\ (1.5)] + [(0.5)\ (6.3)\ (1.5)\ (1.5)\ (4.2)] + [(0.5)\ (1.5)\ (1.5)\ (1.5)\ (4.2)] =$$

$$(44.1) + (29.8) + (7.1) = 81.0\ m^3$$

(2) Convert to cubic yards:

$$(81.0)\ (1.308) = 105.9\ \text{BCY}$$

3. Workload Estimates. Figures E-1-2 and E-1-3 present the workload estimates for heavy and light equipment teams, respectively. These estimates were based on the following production rates:

a. D7 and M9 ACE production.

(1) Assume a push distance of 75 feet which, from Figure E-5, gives a production rate of 376 BCY per hour:

$$(105.9\ \text{BCY}) / (376\ \text{BCY per hour}) = 0.28\ \text{hours}$$

---

[1] DA, Engineer Studies Center, Survivability--The Effort and the Payoff, Washington, D.C., June 1981, p. 30.

[2] DA, US Army Engineer School, Engineer Family of Systems Study, Washington, D. C., Volume N, February 1979, p. N-III-q-2 through N-III-q-5.

(2) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer requires an additional 5 minutes to move from position site to position site within the defensive perimeter:

$$(0.28) + (0.08) = 0.36 \text{ hours}$$

b. D5 dozer production.

(1) Assume a push distance of 75 feet which, from Figure E-6, gives a production rate of 243 BCY per hour:

$$(105.9 \text{ BCY}) / (243 \text{ BCY per hour}) = 0.44 \text{ hours}$$

(2) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

$$(0.44) + (0.08) = 0.52 \text{ hours}$$

PROTECTIVE POSITION FOR AN ARMORED VEHICLE

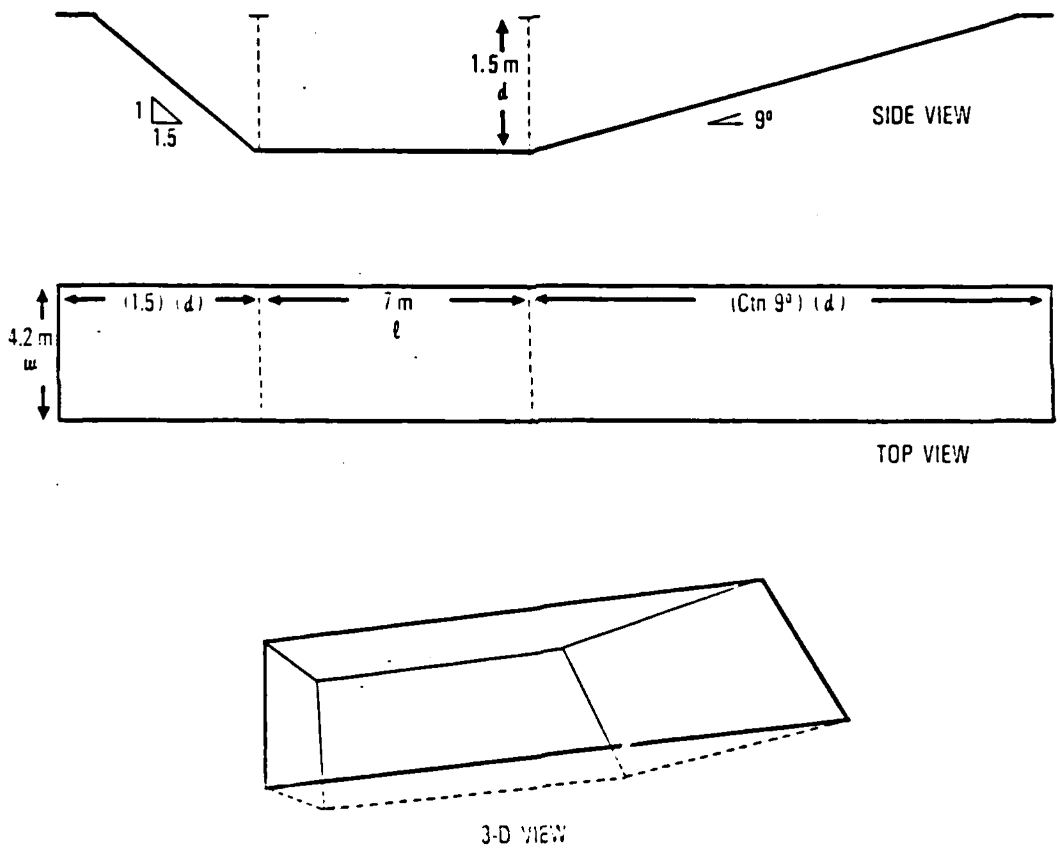


Figure E-1-1

BUILD A PROTECTIVE POSITION
FOR AN ARMORED VEHICLE
(European Terrain + Temperate Weather)

H E A V Y   E Q U I P M E N T
W O R K L O A D   R A T E S

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.36	
	Elapsed Time Required To Complete Task	0.36	

Figure E-1-2

L I G H T   E Q U I P M E N T
W O R K L O A D   R A T E S

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.52	
	Elapsed Time Required To Complete Task	0.52	

Figure E-1-3

LAST PAGE OF APPENDIX E-1

APPENDIX E-2

BUILD A PROTECTIVE POSITION FOR A 1/4-TON MOUNTED TOW

APPENDIX E-2

BUILD A PROTECTIVE POSITION FOR A 1/4-TON MOUNTED TOW

1. Terrain. European.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator and one engineer to confer with users and to guide the dozer to the position site.

a. The excavated position is 5 meters wide and 1 meter deep. It has a 8.5-meter-long floor and an entrance ramp with a 9-degree slope. To ease earthmover entry into the excavation, a sloped face of 1:1.5 was assumed adequate[1] (see Figure E-2-1).

b. The volume of earth that must be excavated is estimated as follows:

$$[(w)\ (l)\ (d)] + [(0.5)\ (\text{ctn } 9^{\circ})\ (d)\ (d)\ (w)] + \left\{(0.5)\ [(1.5)\ (d)]\ (d)\ (w)\right\} =$$

$$[(5)\ (8.5)\ (1)] + [(0.5)\ (6.3)\ (1)\ (1)\ (5)] + [(0.5)\ (1.5)\ (1)\ (1)\ (5)] =$$

$$(42.5) + (15.75) + (3.75) = 62\ m^3 \text{ or } 81.1 \text{ BCY}$$

3. Workload Estimates. Figures E-2-2 and E-2-3 present the workload estimates for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

a. D7 dozer and M9 ACE production.

(1) Assume a push distance of 75 feet which, from Figure E-5, gives a production rate of 376 BCY per hour:

$$(81.1 \text{ BCY}) / (376 \text{ BCY per hour}) = 0.22 \text{ hours}$$

[1]DA, US Army Engineer Studies Center, FM 5-103, Survivability, 1985 Draft, pp. 4-18.

(2) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the user's locating an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer requires an additional 5 minutes to move from position site to position site within the defensive perimeter:

$$(0.22) + (0.08) = 0.30 \text{ hours}$$

b. D5 dozer production.

(1) Assume a push distance of 75 feet which, from Figure E-6, gives a production rate of 376 BCY per hour:

$$(81.1 \text{ BCY}) / (376 \text{ BCY per hour}) = 0.22 \text{ hours}$$

(2) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

$$(0.33) + (0.08) = 0.41 \text{ hours}$$

PROTECTIVE POSITION FOR A 1/4 - TON MOUNTED TOW

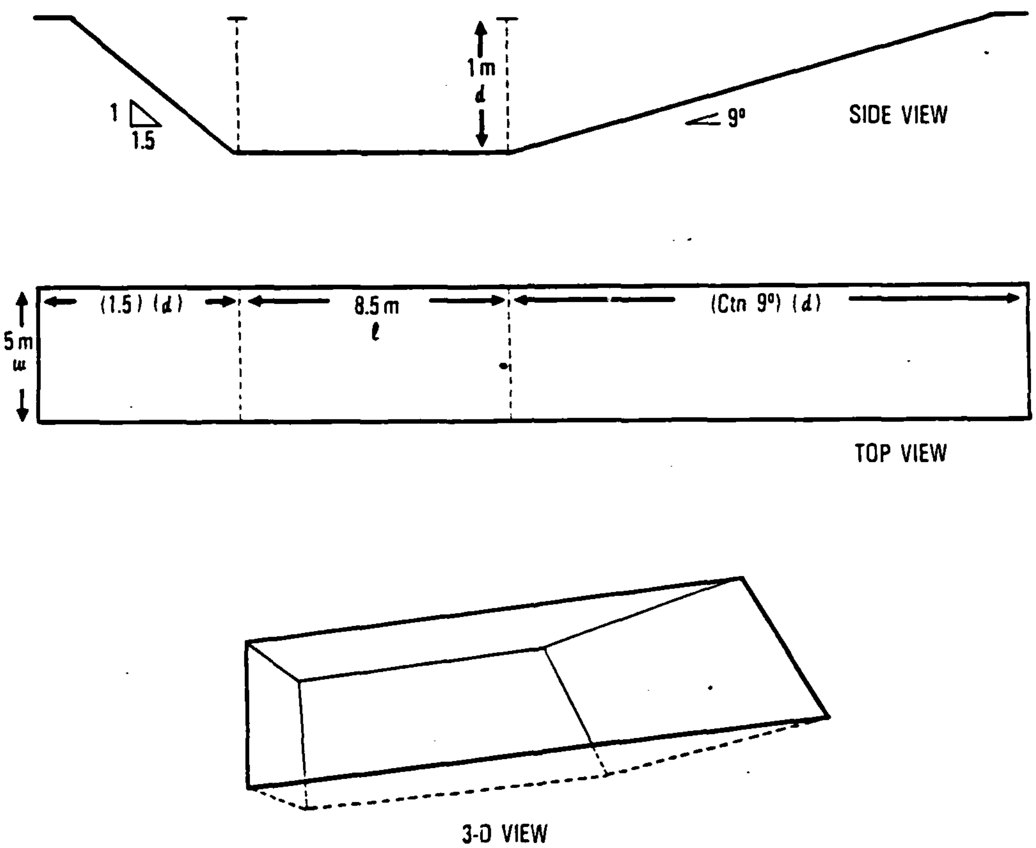


Figure E-2-1

BUILD A PROTECTIVE POSITION FOR A
1/4-TON MOUNTED TOW
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.30	
	Elapsed Time Required To Complete Task	0.30	

Figure E-2-2

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.41	
	Elapsed Time Required To Complete Task	0.41	

Figure E-2-3

LAST PAGE OF APPENDIX E-2

APPENDIX E-3

BUILD A PROTECTIVE POSITION FOR A NON-ARMORED VEHICLE

APPENDIX E-3

BUILD A PROTECTIVE POSITION FOR A NON-ARMORED VEHICLE

1. Terrain. European.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator, one 2-1/2-cubic-yard scoop loader with operator, and one engineer to confer with users and to guide the equipment to the position site.

a. The planning factors displayed in this appendix are appropriate for the 1/4-ton, 3/4-ton, 1-1/4-ton, 2-1/2-ton, and 5-ton cargo trucks with their trailers.[1]

b. The excavated position is 3.5 meters wide and 1.5 meters deep. It has a 10.5-meter-long floor and an entrance ramp with a 9-degree slope. There is a 0.75-meter-high parapet along both sides of the cut. To ease earthmover entry into the excavation, a sloped face of 1:1.5 was assumed adequate[2] (see Figure E-3-1.)

(1) The volume of earth that must be excavated is estimated as follows:

$$[(1)\ (w)\ (d)] + \left\{(0.5)\ [(\text{ctn } 9^{\circ})\ (d)]\ (d)\ (w)\right\} + [(0.5)\ (1.5)\ (d)\ (d)\ (w)] =$$

$$[(10.5)\ (3.5)\ (1.5)] + [(0.5)\ (6.3)\ (1.5)\ (1.5)\ (3.5)] + [(0.5)\ (1.5)\ (1.5)\ (1.5)\ (3.5)] =$$

$$(55.1) + (24.8) + (5.9) = 85.8\ m^3$$

---

[1] DA, US Army Engineer School, Engineer Family of Systems Study, Volume N, Washington, D. C., February 1979, p. N-III-u-1.

[2] Engineer Family of Systems Study, p. N-III-u-1.

(2) Convert to cubic yards:

$$(85.8)\ (1.308) = 112.2 \text{ BCY}$$

3. <u>Workload Estimates</u>. Figures E-3-2 and E-3-3 present the workload estimates for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

a. D7 dozer/scoop loader and M9 ACE/scoop loader production.

(1) Assume a push distance of 75 feet which, from Figure E-5, gives a production rate of 376 BCY per hour:

$$(112.2 \text{ BCY})\ /\ (376 \text{ BCY per hour}) = 0.30 \text{ hours}$$

(2) While the dozer excavates, the scoop loader forms the parapets and removes excess spoil.

(3) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer requires an additional 5 minutes to move from position site to position site within the defensive perimeter:

$$(0.30) + (0.08) = 0.38 \text{ hours}$$

b. D5 dozer/scoop loader production.

(1) Assume a push distance of 75 feet which, from Figure E-6, gives a production rate of 243 BCY per hour:

$$(112.2 \text{ BCY})\ /\ (243 \text{ BCY per hour}) = 0.46 \text{ hours}$$

(2) While the dozer excavates, the scoop loader forms the parapets and removes excess soil.

(3) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

PROTECTIVE POSITION FOR A NON-ARMORED VEHICLE

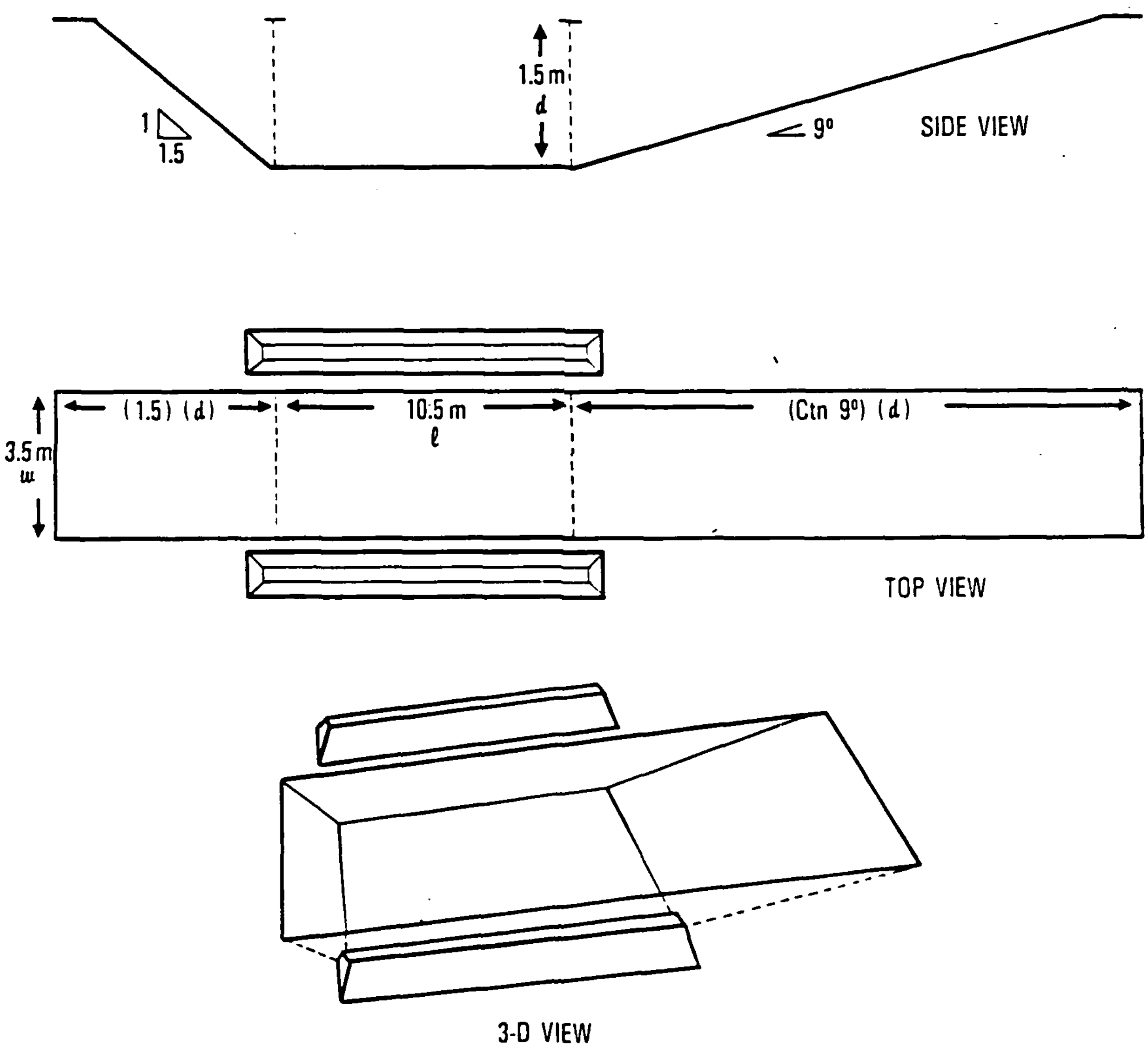


Figure E-3-1

BUILD A PROTECTIVE POSITION FOR A
NON-ARMORED VEHICLE
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	0.38	0.38	
	Elapsed Time Required To Complete Task	0.38		

Figure E-3-2

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	0.54	0.54	
	Elapsed Time Required To Complete Task	0.54		

Figure E-3-3

LAST PAGE OF APPENDIX E-3

APPENDIX E-4

BUILD A PROTECTIVE POSITION FOR A FAAR

APPENDIX E-4

BUILD A PROTECTIVE POSITION FOR A FAAR

1. Terrain. European.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator, one 2-1/2-cubic-yard scoop loader with operator, and one engineer to confer with users and to guide the equipment to the position site. The position has a berm around three sides. The floor of the position is 6.7 meters by 7.6 meters while the berm is 1 meter wide at the top and 2.7 meters high with sloping sides of 1:1[1] (see Figure E-4-1).

a. The volume of earth that must be moved to form the berm is estimated as follows:

$$b = (2.7) + (2.7) + (1) = 6.4 \text{ m}$$

$$[(0.5)\ (a + b)\ (h)]\ [(2)\ (1 + a) + (w)] =$$

$$[(0.5)\ (6.4 + 1)\ (2.7)]\ [(2)\ (7.6 + 6.4) + (6.7)] = 346.65 \text{ m}^3$$

b. Convert to cubic yards:

$$(346.65)\ (1.308) = 453.4 \text{ LCY}$$

c. Convert to BCY:

$$(453.4)\ (0.8) = 362.7 \text{ BCY}$$

3. Workload Estimates. Figures E-4-2 and E-4-3 present the workload estimates for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

---

[1] Taken from notes written by Mr. Eugene Ehrlich during the preparation of the report, Survivability--The Effort and the Payoff, June 1981.

a. D7 dozer/scoop loader and M9 ACE/scoop loader production.

(1) Assume a push distance of 75 feet which, from Figure E-5, gives a production rate of 376 BCY per hour. Because the dozer operator cannot use slot dozing techniques, this rate is reduced by one-sixth (see Annex E, paragraph 5a(1)(c), page E-8).

(362.7 BCY) (1.2) / (376 BCY per hour) = 1.16 hours

(2) As the dozer pushes earth into piles generally conforming to the outline of the position, the scoop loader forms the berm. The scoop loader requires 5 additional minutes after the dozer has finished to complete the shaping of the berm.

(1.16) + (0.08) = 1.24 equipment hours

(3) Assume that the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the dozer to the site. No additional time is added to account for intra-perimeter movement between positions because of the limited number of such positions within a defensive perimeter.

b. D5 dozer/scoop loader production.

(1) Assume a push distance of 75 feet which, from Figure E-6, gives a production rate of 243 BCY per hour. For the same reasons stated above, reduce this rate by one-sixth.

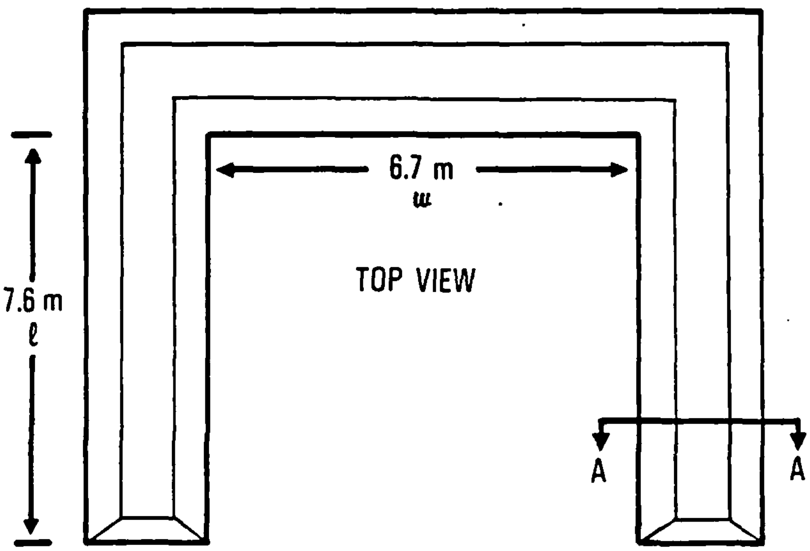
(362.7 BCY) (1.2) / (243 BCY per hour) = 1.79 hours

(2) As above, the scoop loader forms the berm as the D5 dozer excavates.

(1.79) + (0.08) = 1.87 hours

(3) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity and no intra-perimeter movement for the equipment.

PROTECTIVE POSITION FOR A FORWARD AREA ALERTING RADAR



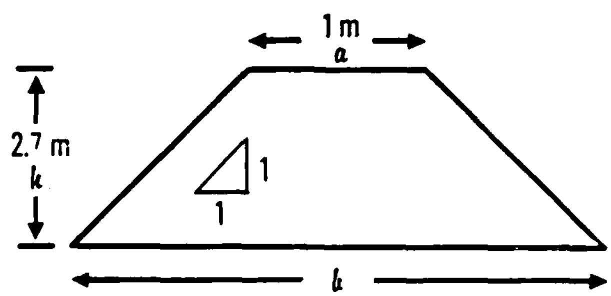


Figure E-4-1

BUILD A PROTECTIVE POSITION FOR A
FORWARD AREA ALERTING RADAR (FAAR)
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	1.16	1.24	
	Elapsed Time Required To Complete Task	1.24		

Figure E-4-2

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	1.79	1.87	
	Elapsed Time Required To Complete Task	1.87		

Figure E-4-3

LAST PAGE OF APPENDIX E-4

APPENDIX E-5

BUILD A PROTECTIVE POSITION FOR A PAR

APPENDIX E-5

BUILD A PROTECTIVE POSITION FOR A PAR

1. Terrain. European.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator, and one engineer to confer with users and to guide the dozer to the position site. This engineer team is supplemented with the 2.5-cubic-yard scoop loader and operator from the Hawk battery.

a. The workload factors shown in this appendix are appropriate for the following components of the Hawk air defense system.

(1) PAR

(2) Range only radar

(3) Constant wave acquisition radar

(4) High power radar

b. The position has a berm around three sides. The floor of the position is 6.7 meters by 7.6 meters, while the berm is 1 meter wide at the top and 1.8 meters high with sloping sides of 1:1[1] (see Figure E-5-1).

(1) The volume of earth that must be moved to form the berm is estimated as follows:

$$b = (1.8) + (1.8) + (1) = 4.6 \text{ m}$$

$$[(0.5)\ (a + b)\ (h)]\ [(2)\ (1 + a) + (w)] =$$

$$[(0.5)\ (1 + 4.6)\ (1.8)][(2)\ (7.6 + 4.6) + (6.7)] = 156.7 \text{ m}^3$$

---

[1]Taken from interview notes written by Mr. Eugene Ehrlich during the preparation of the report, Survivability--The Effort and the Payoff, June 1981.

(2) Convert to cubic yards:

(156.7) (1.308) = 205.0 LCY

(3) Convert to BCY:

(205.0) (0.8) = 164.0 BCY

3. Workload Estimates. Figures E-5-2 and E-5-3 present the workload estimates for heavy and light equipment teams respectively. These estimates were based on the following production rates.

a. D7 dozer/scoop loader and M9 ACE/scoop loader production.

(1) Assume a push distance of 75 feet which, from Figure E-5, gives a production rate of 376 BCY per hour. Because the dozer operator cannot use slot dozing techniques, this rate is reduced by one-sixth (see Annex E, paragraph 5a(1)(c), page E-8).

(164.0 BCY) (1.2) / (376 BCY per hour) = 0.52 hours

(2) As the dozer excavates and piles the earth, the loader from the battery forms the berm. The loader continues to work after the dozer has finished piling earth. However, the estimate of engineer effort ends when the dozer is finished.

(3) Assume that the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the dozer to the site. No additional time is added to account for intra-perimeter movement between positions because of the limited number of such positions within a defensive perimeter.

b. D5 dozer/scoop loader production.

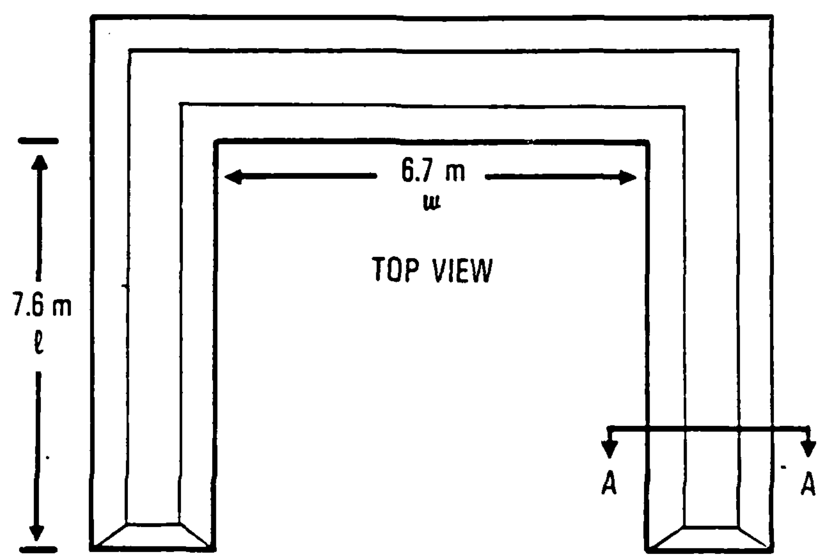
(1) Assume a push distance of 75 feet which, from Figure E-6, gives a production rate of 243 BCY per hour. For the same reasons stated above, reduce this rate by one-sixth.

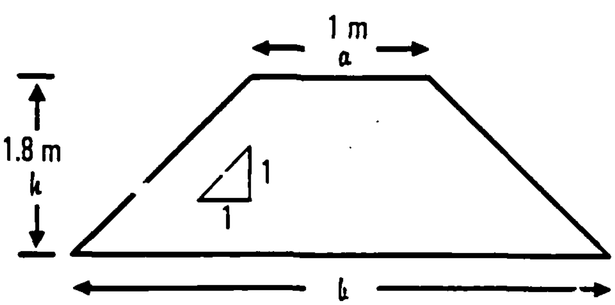
(164.0 BCY) (1.2) / (243 BCY per hour) = 0.81 hours

(2) As above, the additional loader time necessary to complete the position is not included in the time estimate.

(3) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity and no intra-perimeter movement for the equipment.

PROTECTIVE POSITION FOR A PULSE AQUISITION RADAR





CROSS SECTION A - A

Figure E-5-1

BUILD A PROTECTIVE POSITION FOR A
PULSE ACQUISITION RADAR (PAR)
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.52	
	Elapsed Time Required To Complete Task	0.52	

Figure E-5-2

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Excavate	0.81	
	Elapsed Time Required To Complete Task	0.81	

Figure E-5-3

LAST PAGE OF APPENDIX E-5

APPENDIX E-6

BUILD A PROTECTIVE POSITION FOR A SELF-PROPELLED HOWITZER

APPENDIX E-6

BUILD A PROTECTIVE POSITION FOR A SELF-PROPELLED HOWITZER

1. Terrain. European.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator, one 2.5-cubic-yard scoop loader with operator, and one engineer to confer with users and to guide the dozer to the position site.

a. The planning factors displayed in this appendix are appropriate for the following self-propelled artillery pieces. Moreover, the position includes enough room for the M548 6-ton ammunition carrier.

(1) M109 155-mm self-propelled howitzer

(2) M55 8-in self-propelled howitzer

(3) M110 8-in self-propelled howitzer[1]

b. The excavated position is 5.4 meters wide and 1.5 meters deep. It has a 21-meter-long floor and an entrance ramp with a 9-degree slope. To ease earthmover entry into the excavation, a sloped face of 1:1.5 is assumed adequate[2] (see Figure E-6-1).

(1) The volume of earth that must be excavated is estimated as follows:

$$[(1)\ (w)\ (d)] + [(0.5)\ (\text{ctn } 9^{o})\ (d)\ (d)\ (w)] + [(0.5)\ (1.5)\ (d)\ (d)\ (w)] =$$

$$[(21)\ (5.4)\ (1.5)] + [(0.5)\ (6.3)\ (1.5)\ (1.5)\ (5.4)] +$$
$$[(0.5)\ (1.5)\ (1.5)\ (1.5)\ (5.4)] =$$

$$(170.1) + (38.3) + (9.1) = 217.5 \text{ m}^3$$

---

[1]DA, US Army Engineer School, Engineer Family of Systems Study, Volume N, Washington, D. C., February 1979, pp. N-III-v-1 and N-III-v-2.

[2]Engineer Family of Systems Study, p. N-III-v-4.

(2) Convert to cubic yards:

(217.5) (1.308) = 284.5 BCY

3. Workload Estimates. Figures E-6-2 and E-6-3 present the workload estimates for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

a. D7 dozer/scoop loader and M9 ACE/scoop loader production.

(1) Assume a push distance of 75 feet which, from Figure E-5, gives a production rate of 376 BCY per hour:

(284.5 BCY) / (376 BCY per hour) = 0.76 hours

(2) As the dozer excavates, the loader spreads the excavated soil to reduce the possibility of enemy identification. The loader continues to work about 5 minutes after the dozer finishes:

(0.76) + (0.08) = 0.84 hours

(3) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

(0.76) + (0.08) = 0.84 hours

b. D5 dozer/scoop loader production.

(1) Assume a push distance of 75 feet which, from Figure E-6, gives a production rate of 243 BCY per hour:

(284.5 BCY) / (243 BCY per hour) = 1.17 hours

(2) As above, an additional 5 minutes is added to account for the loader's work time:

(1.17) + (0.08) = 1.25 hours

(3) As done above for the D7 and M9, assume the comat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

$$(1.17) + (0.08) = 1.25$$

POSITION FOR A SELF-PROPELLED HOWITZER

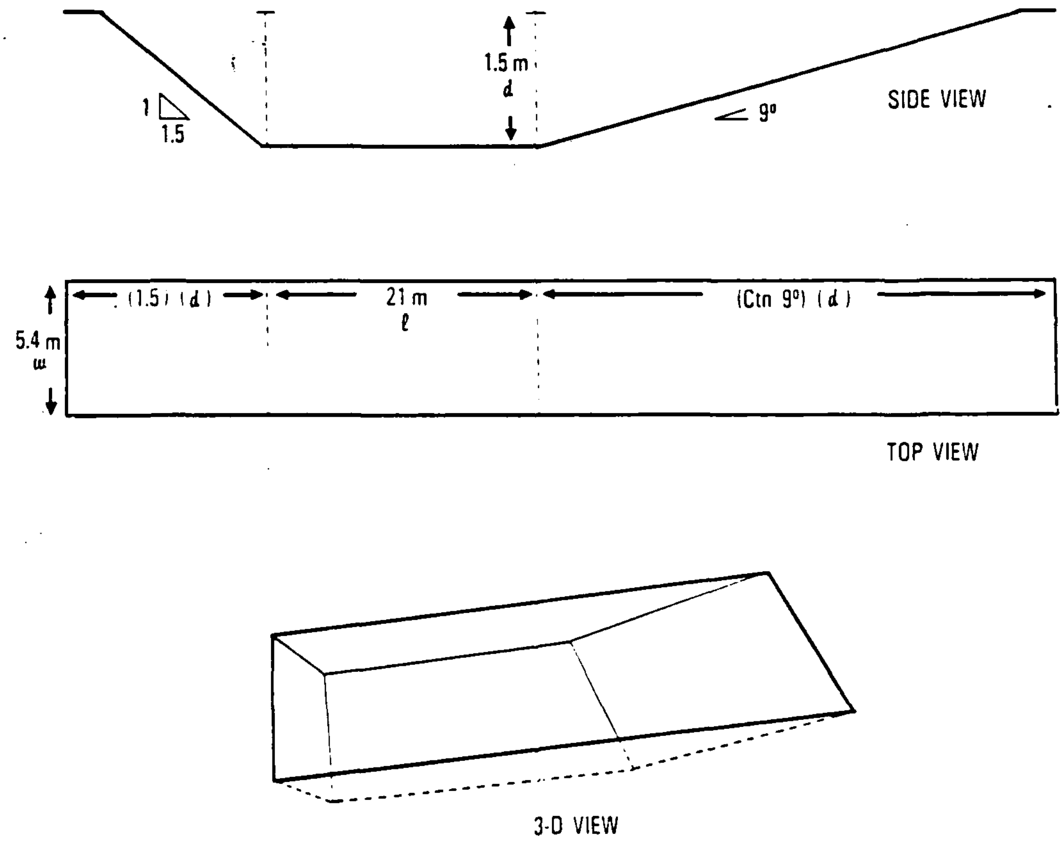


Figure E-6-1

BUILD A PROTECTIVE POSITION FOR A
SELF-PROPELLED HOWITZER
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	0.76	0.84	
	Elapsed Time Required To Complete Task	0.84		

Figure E-6-2

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	1
ACTIVITY	Guide Dozer/Locate Site			0.05
	Excavate	1.17	1.25	
	Elapsed Time Required To Complete Task	1.25		

Figure E-6-3

LAST PAGE OF APPENDIX E-6

APPENDIX E-7

BUILD A PROTECTIVE POSITION FOR A 105-MM TOWED HOWITZER

APPENDIX E-7

BUILD A PROTECTIVE POSITION FOR A 105-MM TOWED HOWITZER

1. Terrain. European.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator and one combat engineer to confer with users and to guide the dozer to the position site. The position is a raised circular earth berm approximately 7 meters in diameter and 0.75-meters high. The berm is 1 meter wide at the top and 3 meters wide at the bottom. There is a 2.5-meter-wide opening in the berm for egress and access[1] (see Figure E-7-1).

a. The volume of earth that forms the berm is estimated as follows:

$$[(0.5)\ (a + b)\ h]\ [(3.1416)\ (D + a) - 2.5] =$$

$$[(0.5)\ (1 + 3)\ (0.75)]\ [(3.1416)\ (7 + 3) - 2.5] = 43.37\ m^3$$

b. Convert to cubic yards:

$$(43.37)\ (1.308) = 56.73\ \text{LCY}$$

c. Convert to BCY:

$$(56.73)\ (0.8) = 45.38\ \text{BCY}$$

3. Workload Estimates. Figures E-7-2 and E-7-3 present the workload estimates for heavy and light equipment teams respectively. These estimates were based on the following production rates.

a. D7 dozer and M9 ACE production.

(1) To account for shaping and packing the berm, assume a push distance of 125 feet which, from Figure E-5, gives a production rate of 259

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[1]Taken from notes written by Mr. Eugene Ehrlich during the preparation of the report, Survivability--The Effort and the Payoff, June 1981.

BCY per hour. Because the dozer operator cannot use slot dozing techniques, this rate is reduced by one-sixth (see Annex E, paragraph 5a(1)(c), page E-8).

(45.38 BCY) (1.2) / (259 BCY per hour) = 0.21 hours

(2) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

(0.21) + (0.08) = 0.29 hours

b. D5 dozer/scoop loader production.

(1) To account for shaping and packing the berm, assume a push distance of 125 feet which, from Figure E-6, gives a production rate of 162 BCY per hour. For the same reasons stated above, reduce this rate by one-sixth.

(45.38) (1.2) / (162 BCY per hour) = 0.33 hours

(2) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

(0.33) + (0.08) = 0.41 hours

PROTECTIVE POSITION FOR A 105-mm TOWED HOWITZER

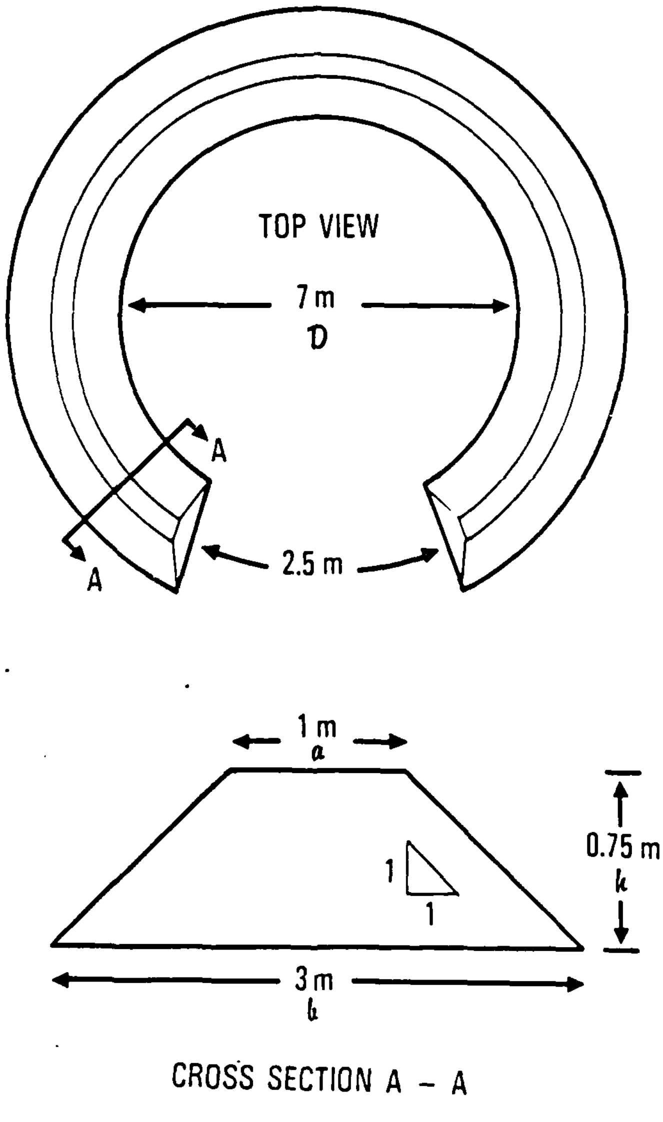

Figure E-7-1

BUILD A PROTECTIVE POSITION FOR A
105-MM TOWED HOWITZER
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Build Berm	0.29	
	Elapsed Time Required To Complete Task	0.29	

Figure E-7-2

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Build Berm	0.41	
	Elapsed Time Required To Complete Task	0.41	

Figure E-7-3

LAST PAGE OF APPENDIX E-7

APPENDIX E-8

BUILD A PROTECTIVE POSITION FOR A 155-MM TOWED HOWITZER

APPENDIX E-8

BUILD A PROTECTIVE POSITION FOR A 155-MM TOWED HOWITZER

1. Terrain. European.

2. Method of Construction. The engineer team assigned to build this position has one bulldozer or M9 ACE with operator and one combat engineer to confer with users and to guide the dozer to the position site. The position is a raised circular earth berm approximately 9 meters in diameter and 1 meter high. The berm is 1 meter wide at the top and 3 meters wide at the bottom. There is a 2.5-meter-wide opening in the berm for egress and access[1] (see Figure E-8-1).

a. The volume of earth that forms the berm is estimated as follows:

$$[(0.5)\ (a + b)\ h]\ [(3.1416)\ (D + a) - 2.5] =$$

$$[(0.5)\ (1 + 3)\ (1)]\ \ [(3.1416)\ (9 + 3) - 2.5] = 70.40\ m^3$$

b. Convert to cubic yards:

$$(70.40)\ (1.308) = 92.08\ \text{LCY}$$

c. Convert to BCY:

$$(92.08)\ (0.8) = 73.66\ \text{BCY}$$

3. Workload Estimates. Figures E-8-2 and E-8-3 present the workload estimates for heavy and light equipment teams respectively. These estimates were based on the following production rates.

a. D7 dozer and M9 ACE production.

(1) To account for shaping and packing the berm, assume a push distance of 125 feet which, from Figure E-5, gives a production rate of 259

[1]Taken from interview notes written by the Mr. Eugene Ehrlich during the preparation of the report Survivability--The Effort and the Payoff, June 1981.

BCY per hour. Because the dozer operator cannot use slot dozing techniques, this rate is reduced by one-sixth (see Annex E, paragraph 5a(1)(c), page E-8).

(73.66 BCY) (1.2) / (259 BCY per hour) = 0.34 hours

(2) Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the dozer to the site. Concurrently, the dozer requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

(0.34) + (0.08) = 0.42 hours

b. D5 dozer production.

(1) To account for shaping and packing the berm, assume a push distance of 125 feet which, from Figure E-6, gives a production rate of 162 BCY per hour. For the same reasons stated above, reduce this rate by one-sixth.

(73.66 BCY) (1.2) / (162 BCY per hour) = 0.55 hours

(2) As done above for the D7 and M9, assume the combat engineer takes 3 minutes to complete his activity while the dozer takes an additional 5 minutes to move to the next position.

(0.55) + (0.08) = 0.63 hours

PROTECTIVE POSITION FOR A 155-mm TOWED HOWITZER

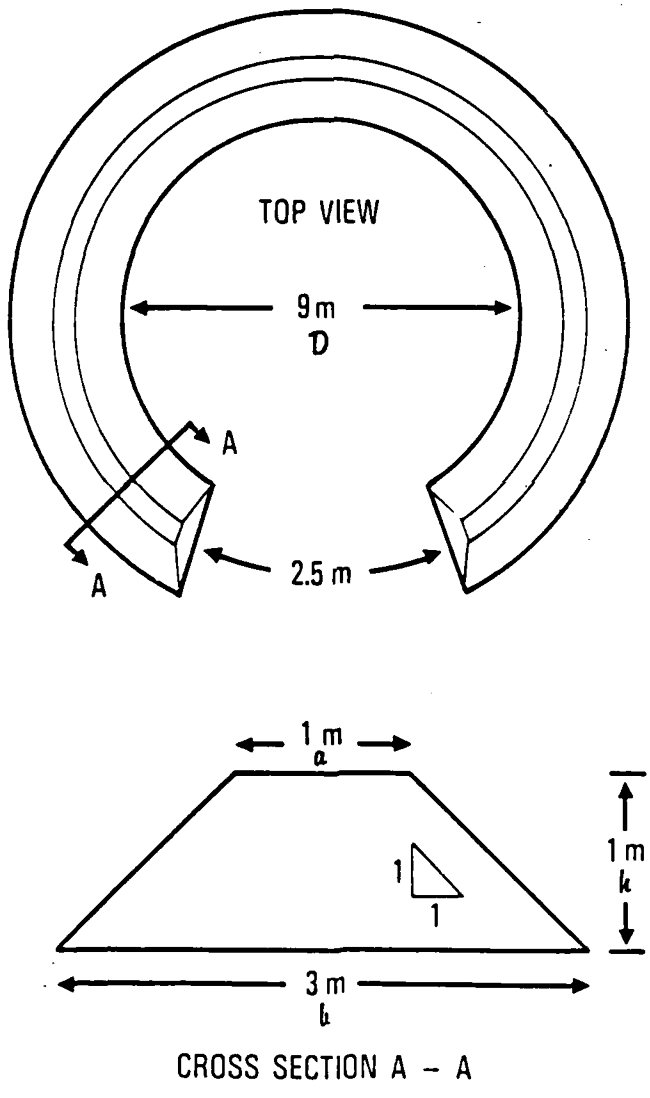

Figure E-8-1

BUILD A PROTECTIVE POSITION FOR A
155-MM TOWED HOWITZER
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Build Berm	0.42	
	Elapsed Time Required To Complete Task	0.42	

Figure E-8-2

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Build Berm	0.63	
	Elapsed Time Required To Complete Task	0.63	

Figure E-8-3

LAST PAGE OF APPENDIX E-8

APPENDIX E-9

BUILD A TWO-MAN FIGHTING POSITION

APPENDIX E-9

BUILD A TWO-MAN FIGHTING POSITION

1. Terrain. European.

2. Method of Construction. The engineer team assigned to build this position has one Small Emplacement Excavator (SEE) with operator and one engineer to confer with users and to guide the SEE to the position site. The position is a linear trench 7 feet long, 2 feet wide, and 5 feet deep. The volume of earth that must be excavated is estimated as follows:

$$(7)\ (2)\ (5)\ /\ 27 = 2.59 \text{ BCY}$$

3. Workload Estimates. Figures E-9-1 and E-9-2 present the workload estimates for heavy and light equipment teams, respectively. These estimates were based on the following production rates:

a. Using the SEE excavation rate for simple geometric patterns shown in paragraph 5c(1), page E-11.

$$(2.59 \text{ BCY})\ /\ (28 \text{ BCY/hour}) = 0.09 \text{ hours}$$

b. Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the SEE to the site. Concurrently, the SEE requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

AD-A169 799 WORKLOAD ESTIMATES FOR COMBAT ENGINEERS IN THE DESERT (U) ARMY ENGINEER STUDIES CENTER FORT BELVOIR VA T O ATKINSON ET AL. APR 86 USAESC-R-86-2 6/6

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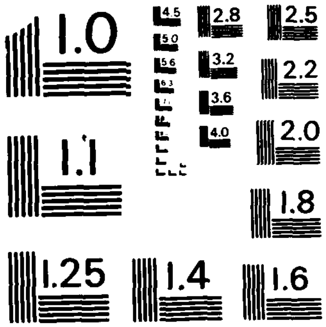

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS - 1963 - A

BUILD A TWO-MAN FIGHTING POSITION
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.05
	Excavate	0.17	
	Elapsed Time Required To Complete Task	0.17	

Figure E-9-1

LIGHT EQUIPMENT WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.05
	Excavate	0.17	
	Elapsed Time Required To Complete Task	0.17	

Figure E-9-2

LAST PAGE OF APPENDIX E-9

APPENDIX E-10

BUILD A POSITION FOR A DISMOUNTED TOW

APPENDIX E-10

BUILD A POSITION FOR A DISMOUNTED TOW

1. Terrain. European.

2. Method of Construction. The engineer team assigned to build this position has one SEE with operator and one engineer to confer with users and to guide the SEE to the position site. The position is a rectangular pit 5 feet long, 5-1/2 feet wide, and 2 feet deep. The volume of earth that must be excavated is estimated as follows:

$$(5)\ (5.5)\ (2)\ /\ 27 = 2.04 \text{ BCY}$$

3. Workload Estimates. Figures E-10-1 and E-10-2 present the workload estimates for heavy and light equipment teams, respectively. These estimates were based on the following production rates:

a. Using the SEE escavation rate for simple geometric patterns shown in paragraph 5c(1), page E-11.

$$(2.04 \text{ BCY})\ /\ (28 \text{ BCY/hour}) = 0.07 \text{ hours}$$

b. Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the SEE to the site. Concurrently, the SEE requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

$$(0.07) + (0.08) = 0.15 \text{ hours}$$

BUILD A POSITION FOR A
DISMOUNTED TOW
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.05
	Excavate	0.15	
	Elapsed Time Required To Complete Task	0.15	

Figure E-10-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.05
	Excavate	0.15	
	Elapsed Time Required To Complete Task	0.15	

Figure E-10-2

LAST PAGE OF APPENDIX E-10

APPENDIX E-11

BUILD A POSITION FOR A MORTAR

APPENDIX E-11

BUILD A POSITION FOR A MORTAR

1. Terrain. European.

2. Method of Construction. The engineer team assigned to build this position has one SEE with operator and one engineer to confer with users and to guide the SEE to the position site. The position is a circular pit 8 feet in diameter and 3 feet deep. The volume of earth that must be excavated is estimated as follows:

$$(4)^2 (3.1416) (3) / 27 = 5.58 \text{ BCY}$$

3. Workload Estimates. Figures E-11-1 and E-11-2 present the workload estimates for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

a. Using the SEE excavation rate for complex geometric patterns shown in paragraph 5c(1), page E-11.

$$(5.58 \text{ BCY}) / (12 \text{ BCY/hour}) = 0.47 \text{ hours}$$

b. Assume that, for each site within the supported unit's perimeter, the combat engineer spends about 3 minutes with the users locating an appropriate site for the position and guiding the SEE to the site. Concurrently, the SEE requires an additional 5 minutes to move from position site to position site within the defensive perimeter.

$$(0.47) + (0.08) = 0.55 \text{ hours}$$

BUILD A POSITION FOR A MORTAR
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.05
	Excavate	0.55	
	Elapsed Time Required To Complete Task	0.55	

Figure E-11-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	SEE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide SEE/Locate Site		0.05
	Excavate	0.55	
	Elapsed Time Required To Complete Task	0.55	

Figure E-11-2

LAST PAGE OF APPENDIX E-11

APPENDIX E-12

BUILD A 100-METER TANK DITCH

APPENDIX E-12

BUILD A 100-METER TANK DITCH

1. Terrain. European.

2. Method of Construction. The engineer team assigned to build this ditch consists of one bulldozer or M9 ACE with operator, one 2-1/2-cubic-yard scoop loader with operator, and 10 combat engineers to install mines. The planning factors are displayed in Figures E-12-1 and E-12-2. The tank ditch is 3.5 meters wide, 1.5 meters deep, and 100 meters long.

(1) The volume of earth to be excavated is determined as follows:

$$(w)\ (d)\ (l) = \text{volume}$$

$$(3.5)\ (1.5)\ (100) = 525\ m^3$$

(2) Convert to cubic yards:

$$(525)\ (1.308) = 686.70\ \text{BCY}$$

3. Workload Estimates.

a. D7 dozer production. Assume a push distance of 50 feet which, from Figure E-5 gives a production rate of 492 BCY per hour:

$$686.70 / 492 = 1.40\ \text{hours}$$

b. D5 dozer production. Assume a push distance of 50 feet which, from Figure E-6, gives a production rate of 298 BCY per hour:

$$686.70 / 298 = 2.30\ \text{hours}$$

c. As in the EA III CORPS, the ditch is mined with 12 AT mines and six AP mines per 100 meters of ditch.[1] Laying rates of four AT mines per

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[1] DA, Engineer Studies Center, Analysis of III Corps Combat Engineer Wartime Requirements (U), Volume 1, Washington, D. C., 1984, p. F-10.

manhour and eight AP mines per manhour are used.[2] Time to install the mines is estimated as follows:

$$12 / 4 = 3.00 \text{ manhours}$$

$$6 / 8 = 0.75 \text{ manhours}$$

$$\text{TOTAL} = 3.75 \text{ manhours}$$

---

[2] DA, FM 20-32 Mine/Countermine Operations at the Company Level, Washington, D. C., 1976, p. 204.

BUILD A 100-METER TANK DITCH
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	2.5-CY Loader	Combat Engr
	Number of Items	1	1	10
ACTIVITY	Excavate	1.40	1.40	
	Install Minefield			3.75
	Elapsed Time Required To Complete Task	1.40		

Figure E-12-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	2.5-CY Loader	Combat Engr
	Number of Items	1	1	10
ACTIVITY	Excavate	2.30	2.30	
	Install Minefield			3.75
	Elapsed Time Required To Complete Task	2.30		

Figure E-12-2

LAST PAGE OF APPENDIX E-12

APPENDIX E-13

INSTALL A 2000-METER TACTICAL MINEFIELD USING GEMMS

APPENDIX E-13

INSTALL A 2000-METER TACTICAL MINEFIELD USING GEMMS

1. Terrain. European.

2. Method of Construction. The minefield is installed using the M128 GEMMS and 20 combat engineers.

3. Workload Estimates.

a. The minefield consists of two belts, each 2000 meters long and 60 meters wide, separated by a distance of 40 meters. A density of 0.005 mines per square meter is used.[1] The effort required to emplace the mines is calculated as follows:[2]

(1) Calculate the area to be mined:

$$(2)\ (2000)\ (60) = 240{,}000\ m^2$$

(2) Estimate the number of mines required:

$$(240{,}000)\ (0.005) = 1200 \text{ mines}$$

(3) Add a 10-percent safety factor to get the total number of mines required:

$$(1200)\ (1.1) = 1320$$

(4) The GEMMS holds a maximum of 800 mines. Therefore, a fully loaded GEMMS can emplace 1212 meters of minefield frontage before reloading:

$$800 \ / \ 1320 = 0.61$$

$$(0.61)\ (2000) = 1212 \text{ meters}$$

---

[1] DA, FM 5-102, Countermobility, Washington, D. C., 1985, p. 186.
[2] DA, Engineer Officers Handbook for Scatterable Mine Systems, undated, pp. 14-15.

(5) The emplacement rate using GEMMS is 1600 meters per hour for a minefield of this configuration.[3] At this rate, the 1212 meters will take 0.76 hours and the remaining 788 meters will take 0.50 hours:

$$1212 / 1600 = 0.76 \text{ hours}$$

$$788 / 1600 = 0.50 \text{ hours}$$

(6) The reload time for GEMMS is 24 minutes (0.4 hours).[4] Thus, the total time required to install the minefield is calculated as follows:

Dispense 800 mines	= 0.76
Reload	= 0.40
Dispense 520 mines	= 0.50
Reload	= 0.40
TOTAL	= 2.06 minutes

b. The rear boundary of the minefield is marked using the M133 HEMMS. E-FOSS recommends a marking rate of 8.4 manhours per 1000 meters using HEMMS.[5] Therefore, marking the minefield will require 16.8 manhours.

c. Figures E-13-1 and E-13-2 reflect a notional 20-man workforce with 10 men assigned to guide, operate, and load the GEMMS and 10 men assigned to mark the rear boundary.

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[3] DA, US Army Engineer School, Engineer Family Of Systems Study (E-FOSS), Washington, D. C., 1979, p. N-III-c-3.

[4] DA, US Army Engineer School, FM 5-102, Countermobility, p. 186.

[5] E-FOSS, p. N-III-c-4.

INSTALL A 2000-METER TACTICAL MINEFIELD USING GEMMS
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-Ton Truck	Combat Engr	GEMMS
	Number of Items	1	20	1
ACTIVITY	Install Minefield	2.06	20.6	2.06
	Mark the Minefield With HEMMS		16.8	
	Elapsed Time Required To Complete Task	2.06		

Figure E-13-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-Ton Truck	Combat Engr	GEMMS
	Number of Items	1	20	1
ACTIVITY	Install Minefield	2.06	20.6	2.06
	Mark the Minefield With HEMMS		16.8	
	Elapsed Time Required To Complete Task	2.06		

Figure E-13-2

LAST PAGE OF APPENDIX E-13

APPENDIX E-14

INSTALL A 2000-METER TACTICAL MINEFIELD USING VOLCANO

APPENDIX E-14

INSTALL A 2000-METER TACTICAL MINEFIELD USING VOLCANO

1. Terrain. European.

2. Method of Construction. The minefield is installed using the XM139 mine dispenser mounted in a dump truck and 20 combat engineers.

3. Workload Estimates.

a. The minefield consists of two rows, each 2000 meters long and 40 meters wide, separated by a distance of 40 meters. A density of 0.012 mines per square meter is used.[1] The effort required to emplace the mines is calculated as follows:

(1) The ground VOLCANO lays its two rows of mines, separated by 40 meters, in one pass. One fully loaded system will contain 960 mines (800 AT and 160 AP). These mines will cover 1000 meters of frontage at the desired density.[2]

$$(1000)\ (40)\ (2) = 8000\ m^2$$

$$(960)\ /\ (8000) = 0.012\ mines/m^2$$

(2) The time to emplace 960 mines is approximately 10 minutes (0.17 hours).[3]

(3) To cover the full 2000 meters of frontage, the VOLCANO system will have to be reloaded. The reload time for VOLCANO is approximately 15 minutes (0.25 hours).[4]

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[1] US Army Engineer Center and School, The Handbook of Employment Concepts for Mine Warfare Systems, Ft. Belvoir, VA, September 1985, p. III-24.

[2] US Army Engineer Center and School, The Handbook of Employment Concepts for Mine Warfare Systems, Ft. Belvoir, VA, September 1985, p. III-24.

[3] US Army Engineer Center and School, The Handbook of Employment Concepts for Mine Warfare Systems, Ft. Belvoir, VA, September 1985, p. III-24.

[4] US Army Engineer Center and School, Combat Engineer Systems Handbook, Ft. Belvoir, VA, June 1984, p. 59.

(4) Thus, the total time to install the minefield using ground VOLCANO is calculated as follows:

Dispense 960 mines	=	0.17
Reload	=	0.25
Dispense 960 mines	=	0.17
Reload	=	0.25
TOTAL	=	0.84

b. The rear boundary of the minefield is marked using the M133 Hand Emplaced Marking Set (HEMMS).[5] E-FOSS recommends a marking rate of 8.4 man-hours per 1000 meters using HEMMS. Therefore, marking the minefield will require 16.8 man-hours.

c. Figures E-14-1 and E-14-2 reflect a notional work force with 10 men initially assigned to guide, operate, and load the VOLCANO system, and 10 men initially assigned to mark the rear boundary. After the installation activity is complete (0.84 hours), then all 20 men complete the marking activity.

[5]DA, Engineer Family of Systems Study (E-FOSS), 1979, p. N-III-c-4.

INSTALL A 2000-METER TACTICAL MINEFIELD USING VOLCANO
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	5-Ton Truck	Combat Engr	VOLCANO
	Number of Items	1	20	1
ACTIVITY	Install Minefield	0.84	8.40	0.84
	Mark the Minefield With HEMMS		16.8	
	Elapsed Time Required To Complete Task	1.26		

Figure E-14-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	2.5-Ton Truck	Combat Engr	VOLCANO
	Number of Items	1	20	1
ACTIVITY	Install Minefield	0.84	8.40	0.84
	Mark the Minefield With HEMMS		16.8	
	Elapsed Time Required To Complete Task	1.26		

Figure E-14-2

LAST PAGE OF APPENDIX E-14

APPENDIX E-15

INSTALL A 2000-METER TACTICAL MINEFIELD USING CONVENTIONAL MINES

APPENDIX E-15

INSTALL A 2000-METER TACTICAL MINEFIELD USING CONVENTIONAL MINES

1. Terrain. European.

2. Method of Construction. A standard pattern minefield is emplaced by 30 combat engineers using conventional mines. All mines are buried.

a. The minefield has a length of 2000 meters. The desired density is 1-0.5-0, and the IOE representative cluster composition is 1-1-0. The minefield is installed in paces. The manhours required to emplace the mines are calculated as follows:[1]

(1) Convert meters of front to paces. (Pace = 0.75 meters):

(2000) (1.33) = 2667 paces

(2) Determine the number of clusters in the IOE:

2667 / 9 = 297

(3) Determine the number of mines required for the IOE:

AT = (297) (1) = 297

AP = (297) (1) = 297

(4) Determine the number of mines in the interior of the minefield:

AT = (2667) (1) = 2667

AP = (2667) (0.5) = 1334

(5) Determine the subtotal of mines required for the entire field:

AT = 297 + 2667 = 2964

AP = 297 + 1334 = 1631

---

[1]DA, FM 20-32 Mine/Countermine Operations at the Company Level, Washington, D. C., 1976, pp. 203-207.

(6) Add a 10-percent safety factor to get the total number of mines required:

$$AT = (2964)\ (1.1) = 3{,}261$$

$$AP = (1631)\ (1.1) = 1795$$

(7) Manhours required are computed using laying rates of four AT mines per manhour and eight AP mines per manhour:

$$3261\ /\ 4 = 815.25$$

$$1795\ /\ 8 = 224.38$$

$$\text{TOTAL} = 1039.63 \text{ manhours}$$

b. The rear boundary of the minefield is marked with a single strand of barbed wire fence. E-FOSS uses a marking rate of approximately 75 manhours per 1000 meters of front.[2] Therefore, 150 manhours are required for minefield marking.

c. The elapsed time to complete this task shown in Figures E-15-1 and E-15-2 reflects a notional 30-man workforce with 26 men assigned to minefield laying and four men assigned to marking. This assignment scheme was chosen to minimize the overall time required.

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[2]DA, US Army Engineer School, Engineer Family of Systems Study (E-FOSS), Volume VII, Appendix N, Washington, D. C., 1979, p. N-III-c-9.

INSTALL A 2000-METER TACTICAL MINEFIELD USING CONVENTIONAL MINES (European Terrain + Temperate Weather)

HEAVY EQUIPMENT WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	30
ACTIVITY	Install Minefield	1039.63
	Mark the Minefield With Wire	150.00
	Elapsed Time Required To Complete Task	39.99

Figure E-15-1

LIGHT EQUIPMENT WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	30
ACTIVITY	Install Minefield	1039.63
	Mark the Minefield With Wire	150.00
	Elapsed Time Required To Complete Task	39.99

Figure E-15-2

LAST PAGE OF APPENDIX E-15

APPENDIX E-16

DISABLE A BRIDGE

APPENDIX E-16

DISABLE A BRIDGE

1. Terrain. European.

2. Method of Construction. Ten combat engineers are assigned to disable the bridge and install a point minefield. Reconnaissance effort is not included in this estimate. The planning factors are displayed in Figures E-16-1 and E-16-2.

3. Workload Estimates.

a. The target is a two-lane, Class 60 highway bridge. Variations in length, design, materials, and type of gap crossed make it impossible to describe a typical bridge or a typical demolition method. A study of 73 bridges from the V Corps automated barrier system resulted in an average time requirement of 18 manhours.[1]

b. The target is mined with 12 AT mines and 6 AP mines. Effort required is based on a laying rate of four AT mines per manhour and eight AP mines per manhour:[2]

$$12 / 4 = 3.00$$

$$6 / 8 = 0.75$$

$$\text{TOTAL} = 3.75 \text{ manhours}$$

---

[1] DA, US Army Engineer School, Engineer Family of Systems Study (E-FOSS), Washington, D. C., 1979, p. N-III-e-1.

[2] DA, FM 20-32 Mine/Countermine Operations at the Company Level, 1976, p. 204.

DISABLE A 2-LANE, CLASS 60 BRIDGE
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	10
ACTIVITY	Prepare and Fire Demolitions	18.0
	Install Point Minefield	3.75
	Elapsed Time Required To Complete Task	2.18

Figure E-16-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	10
ACTIVITY	Prepare and Fire Demolitions	18.0
	Install Point Minefield	3.75
	Elapsed Time Required To Complete Task	2.18

Figure E-16-2

LAST PAGE OF APPENDIX E-16

APPENDIX E-17

CRATER A ROAD

APPENDIX E-17

CRATER A ROAD

1. Terrain. European.

2. Method of Construction. A team of eight combat engineers is assigned to crater a road and install a point minefield using conventional explosives and mines. The planning factors are displayed in Figures E-17-1 and E-17-2.

3. Workload Estimates.

a. The road crater is installed to block a two-lane, asphalt road with a traveled width of 25 feet. Using E-FOSS, the time required to install the road crater is estimated as follows:[1]

Preparing and firing the shaped charges = 10.00 manhours

Preparing and firing the cratering charges = 2.40 manhours

Total Time required to install the crater = 12.40 manhours.

b. A point minefield is installed in and around the crater. It is assumed that the target is mined with 12 AT mines and 6 AP mines. Effort required is based on a laying rate of four AT mines per manhour and eight AP mines per manhour.[2]

12 / 4 = 3.00

6 / 8 = 0.75

TOTAL = 3.75 manhours

---

[1]DA, US Army Engineer School, Engineer Family of Systems Study (E-FOSS), Volume VII, Appendix N, Washington, D. C., 1979, p. N-III-g-6.

[2]DA, FM 20-32 Mine/Countermine Operations at the Company Level, 1976, p. 204.

CRATER A ROAD
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	8
ACTIVITY	Prepare and Fire Demolitions	12.40
	Install Point Minefield	3.75
	Elapsed Time Required To Complete Task	2.02

Figure E-17-1

LIGHT EQUIPMENT WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	8
ACTIVITY	Prepare and Fire Demolitions	12.40
	Install Point Minefield	3.75
	Elapsed Time Required To Complete Task	2.02

Figure E-17-2

LAST PAGE OF APPENDIX E-17

APPENDIX E-18

CLEAR A TANK DITCH

APPENDIX E-18

CLEAR A TANK DITCH

1. Terrain. European.

2. Method of Construction. The team assigned this mission will vary depending on whether the engineer forces involved are heavy or light.

3. Workload Estimates.

a. For heavy engineer forces maximum use is made of the CEV. The effort required for these forces to clear a tank ditch is determined as follows:[1]

(1) The CEV breaches the tank ditch. Main gun rounds are "walked" across the crater to eliminate mines. Then the bullblade is used to make the ditch passable to tracked vehicles. Engineer Assessment III Corps allows 0.25 hours for the initial breach.

(2) Fifty meters on both sides of the ditch are mined. An 8-meter path is completely cleared of mines and marked to accommodate one-way vehicle traffic. Engineer Assessment III Corps allows 80 manhours to widen and clear an 8-meter path and 10 manhours for marking.

(3) Finally, a dozer is used to further improve the ingress and egress for follow-on vehicles. Engineer Assessment III Corps estimates 0.5 hours for this task.

b. Light engineer forces do not have a CEV, and initial emphasis is on getting assault troops across the ditch. The effort required for the forces to clear a tank ditch is determined as follows.

---

[1]DA, Engineer Studies Center, Analysis of III Corps Combat Engineer Wartime Requirements (U), Volume 1, 1984, pp. E-2-4 and E-2-5.

(1) The bangalore torpedo is used to breach an initial 1-meter footpath. The time requir d is 4 manhours.

(2) The time required to widen and clear an 8-meter one-way vehicle path remains 80 manhours. The marking task also requires 10 manhours.

(3) The remaining work involves improving access and egress for follow-on vehicles. Single-lane approaches are cut through the steep banks. The design cut is shown in Figure E-18-1.[2]

(a) The volume of earth to be excavated for one bank is calculated as follows:

$$\text{volume of center wedge} + \text{volume of two tetrahedrons} = \text{total volume}$$

$$[(0.5)\ (d)\ (w)\ (1)] + 2\ [(0.33)\ (0.5)\ (d)\ (b)\ (1)] = \text{total volume}$$

$$[(0.5)\ (1.5)\ (6)\ (20)] + 2\ [(0.33)\ (0.5)\ (1.5)\ (1.5)\ (20)] = 105\ m^3$$

(b) Convert from cubic meters to cubic yards:

$$(105)\ (1.308) = 137.34\ \text{BCY}$$

(c) Assume a push distance of 75 feet which, from Figure E-6, gives a production rate of 243 BCY per hour. The time for cutting one bank is determined:

$$137.34\ /\ 243 = 0.57\ \text{hours}$$

The time required to gain access to the far bank is 5 minutes (0.08 hours). Thus, the time required to improve ingress/egress is:

$$0.57 + 0.08 + 0.57 = 1.22\ \text{hours}$$

c. The elapsed time required shown in Figures E-18-2 and E-18-3 assumes the activites are completed sequentially. First the initial breach is

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[2]DA, US Army Engineer School, Engineer Family of Systems Study (E-FOSS), Volume VII, Appendix N, Washington, D. C., 1979, pp. N-III-hh-1 and N-III-hh-5.

accomplished, then the 8-meter wide path is cleared and marked, and finally ingress and egress is improved.

d. The time and effort required for the initial breach of a tank ditch can be estimated for heavy or light forces by using the first line of Figures E-18-2 or E-18-3, respectively.

DESIGN CUT FOR A TANK DITCH CROSSING

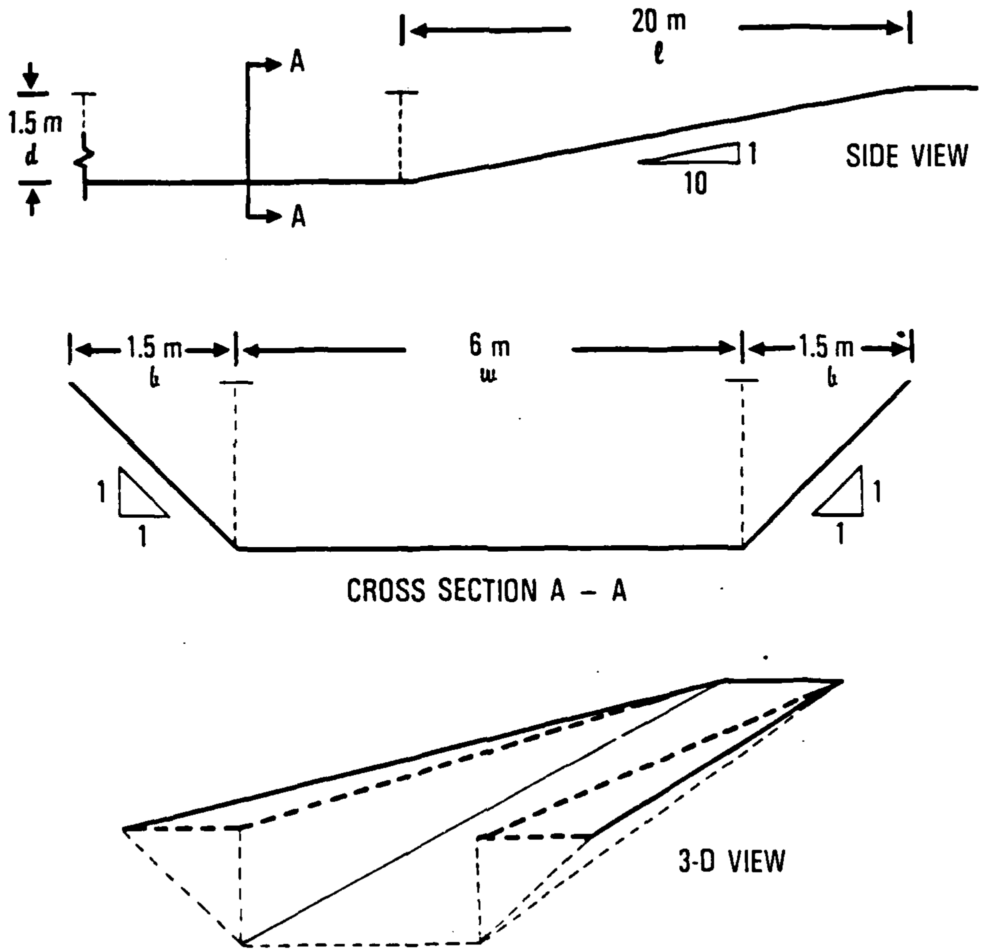

Figure E-18-1

CLEAR A TANK DITCH
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr	CEV
	Number of Items	1	10	1
ACTIVITY	Breach Tank Ditch With CEV			0.25
	Clear 8-Meter-Wide Path		80.0	
	Mark the Lane		10.0	
	Improve Access/Egress	0.5		
	Elapsed Time Required To Complete Task	9.75		

Figure E-18-2

CLEAR A TANK DITCH
(European Terrain + Temperate Weather)

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	10
ACTIVITY	Breach 1-Meter Footpath		4.0
	Clear 8-Meter-Wide Path		80.0
	Mark the Lane		10.0
	Improve Access/Egress	1.22	
	Elapsed Time Required To Complete Task	10.62	

Figure E-18-3

LAST PAGE OF APPENDIX E-18

APPENDIX E-19

REPAIR A ROAD CRATER

APPENDIX E-19

REPAIR A ROAD CRATER

1. Terrain. European.

2. Method of Construction. The engineer resources used in this task consist of one bulldozer or M9 ACE and 10 combat engineers.

a. The typical road crater is assumed to be a trapezoidal prism with a depth of 2.25 meters, a length of 12.5 meters, a top width of 8.70 meters, and a bottom width of 2.25 meters (see Figure E-19-1). The area in and around the crater is seeded with mines.

(1) The volume of earth that must be moved to fill in the crater is estimated as follows:

$$(0.5)\ (d)\quad (b + t)\ (l) = \text{volume}$$

$$(0.5)\ (2.25)\ (2.25 + 8.70)\ (12.5) = 153.98\ m^3$$

(2) Convert to BCY since the dozer will be used to recompact the excavated soil:

$$(153.98)\ (1.308) = 201.41\ \text{BCY}$$

3. Workload Estimates. Figures E-19-2 and E-19-3 present the workload estimates for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

a. D7 dozer and M9 ACE production.

(1) Before the dozer work can begin, the area must be cleared of mines. Combat engineers accomplish this task in 30 manhours.[1]

---

[1]DA, Engineer Studies Center, Analysis of III Corps Combat Engineer Wartime Requirements (U), Volume I, Washington, D. C., 1984, p. E-2-5.

(2) Assuming that sufficient backfill material is available at the site so that the hauling of aggregate is not required, a push distance of 125 feet is used. Figure E-5 gives a production rate of 259 BCY per hour:

$$201.41 / 259 = 0.78 \text{ hours}$$

b. D5 dozer production.

(1) As above, combat engineers clear the area of mines in 30 manhours.

(2) Assume a push distance of 125 feet which, from Figure E-6 gives a production rate of 162 BCY per hour:

$$201.41 / 162 = 1.24 \text{ hours}$$

ROAD CRATER

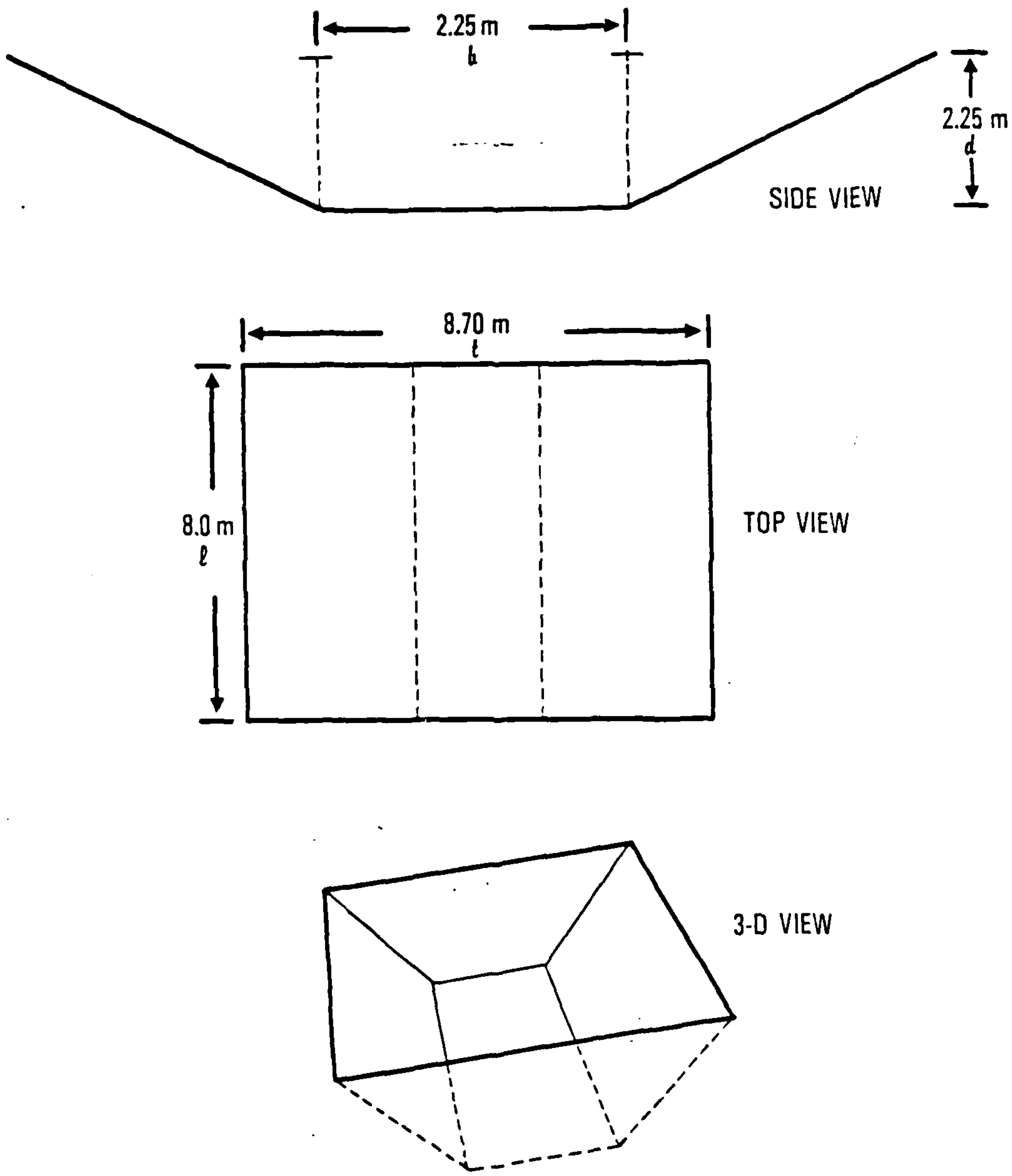

Figure E-19-1

REPAIR A ROAD CRATER
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	10
ACTIVITY	Clear Mines		30.0
	Backfill Crater	0.78	
	Elapsed Time Required To Complete Task	3.78	

Figure E-19-2

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	10
ACTIVITY	Clear Mines		30.0
	Backfill Crater	1.24	
	Elapsed Time Required To Complete Task	4.24	

Figure E-19-3

LAST PAGE OF APPENDIX E-19

APPENDIX E-20

CONSTRUCT 100 METERS OF COMBAT TRAIL

APPENDIX E-20

CONSTRUCT 100 METERS OF COMBAT TRAIL

1. Terrain. European.

2. Method of Construction. The engineer resources assigned this task consist of one bulldozer or M9 ACE with operator and 10 combat engineers organized into two-man chainsaw teams.[1]

3. Workload Estimates.

a. The combat trail is designed to allow passage of all tracked vehicles and most wheeled vehicles. The width required is approximately 4 meters. The natural cover will be disturbed as little as possible and only impassable obstructions such as trees, steep slopes, and large rocks will be removed. The effort required to construct 100 meters is calculated as follows:

b. Assuming that one tree per 3 meters of trail must be removed, then 34 trees must be removed for 100 meters of combat trail. To fell one tree 6 to 8 inches in diameter, cut off the stump, section, and remove it from the trail requires 10 minutes. Thus, the time to clear all trees on the trail is:

34 x 10 = 340 minutes

340 / 60 = 5.67 hours per two-man team

5.67 x 2 = 11.34 manhours

5.67 / 5 = 1.14 hours

[1] DA, US Army Engineer School, Engineer Family of Systems Study (E-FOSS), Volume VII, Appendix N, Washington, D. C., 1979, pp. N-III-gg-1 and N-III-gg-5.

c. Figures E-20-1 and E-20-2 present the workload estimates for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

(1) D7 dozer production. It is assumed that 100 meters of combat trail will result in an average of 20 cubic meters of cut and 20 cubic meters of fill for the dozer. Due to the confined working space, one hour is allowed for this task.

(2) D5 dozer production. The D-5 dozer rate of 1.55 hours shown in Figure E-20-2 is obtained by multiplying the D-7 rate by 1.55, which is the ratio of the D7 dozer production rate to the D5 dozer production rate at a push distance of 75 feet.

CONSTRUCT 100 METERS OF COMBAT TRAILS
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		D7 Dozer or M9 ACE	Combat Engr
Number of Items		1	10
ACTIVITY	Cut Trees		11.34
	Bulldoze Trail	1.00	
Elapsed Time Required To Complete Task		1.14	

Figure E-20-1

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		D5 Dozer	Combat Engr
Number of Items		1	10
ACTIVITY	Cut Trees		11.34
	Bulldoze Trail	1.55	
Elapsed Time Required To Complete Task		1.55	

Figure E-20-2

LAST PAGE OF APPENDIX E-20

APPENDIX E-21

REPLACE COMBAT BRIDGING

APPENDIX E-21

REPLACE COMBAT BRIDGING

1. Terrain. European.

2. Method of Construction. Combat engineers are used to replace combat bridging with fixed bridging. Fixed bridging can be constructed from several types of bridging and in many configurations making it impossible to describe a "typical" mission.

3. Workload Estimates. ESC's research indicates that 5 manhours per meter of bridge constructed is the most reasonable planning factor.[1] This work estimate only considers combat engineers, not members of bridge companies. The planning factors are displayed in Figures E-21-1 and E-21-2.

---

[1] DA, Engineer Studies Center, Analysis of III Corps Combat Engineer Wartime Requirements (U), Volume I, Washington, D. C., 1984, p. E-2-6.

REPLACE COMBAT BRIDGING
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	10
ACTIVITY	Effort for a 10-Meter Section Of Fixed Bridging	50.0
	Elapsed Time Required To Complete Task	5.0

Figure E-21-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	10
ACTIVITY	Effort for a 10-Meter Section Of Fixed Bridging	50.0
	Elapsed Time Required To Complete Task	5.0

Figure E-21-2

LAST PAGE OF APPENDIX E-21

APPENDIX E-22

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD

APPENDIX E-22

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD

1. Terrain. European.

2. Method of Construction. An engineer team consisting of heavy equipment and combat engineers is assigned to maintain an unpaved but well-built secondary road that has become rutted and worn from heavy traffic. Compaction effort is not included in this estimate.

3. Workload Estimates.

a. The road to be maintained is a two-lane, graded and drained earth road over average rolling terrain. The estimate is based on the projected maintenance and repair required during a 5-day period for a 10-kilometer section of road. Figure E-22-1 reflects the engineer resources and effort required for a 10-kilometer section using 5-ton dump trucks.[1]

b. The number of dump trucks shown in Figure E-22-2 is doubled since a 5-ton dump truck is rated at approximately twice the volume and weight capacity of a 2-1/2-ton dump truck.[2]

---

[1] DA, US Army Engineer School, Engineer Family of Systems Study (E-FOSS), Washington, D. C., 1979, Volume VII, Appendix N, pp. N-III-dd-1 and N-III-dd-4.

[2] DA, TM 9-500 Data Sheets for Ordnance Type Material, 1962, pp. 21-69 and 21-76.

MAINTAIN 10 KILOMETERS OF UNPAVED SECONDARY ROAD
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		2.5-CY Loader	5-Ton Truck	Combat Engr	Grader
Number of Items		1	4	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	3.11	12.44	49.76	12.44
Elapsed Time Required To Complete Task		3.11			

Figure E-22-1

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		2.5-CY Loader	2.5-Ton Truck	Combat Engr	Grader
Number of Items		1	8	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	3.11	24.88	49.76	12.44
Elapsed Time Required To Complete Task		3.11			

Figure E-22-2

LAST PAGE OF APPENDIX E-22

APPENDIX E-23

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE

APPENDIX E-23

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE

1. Terrain. European.

2. Method of Construction. An engineer team consisting of graders, trucks, and combat engineers is assigned to maintain a paved MSR. The asphalt section of a combat engineer battalion (heavy) will augment the divisional engineer battalion, however, that section's effort is not included in this estimate.

3. Workload Estimates.

a. The road to be maintained is a two-lane, bituminous surface road. The estimate is based on the projected maintenance and repair required during a 5-day period for a 10-kilometer section of road. Figure E-23-1 reflects the engineer resources and effort required for a 10-kilometer distance using 5-ton dump trucks.[1]

b. The number of dump trucks shown in Figure E-23-2 is doubled since a 5-ton dump truck is rated at approximately twice the volume and weight capacity of a 2-1/2-ton dump truck.[2]

---

[1] DA, US Army Engineer School, Engineer Family of Systems Study (E-FOSS), Volume VII, Appendix N, Washington, D. C., 1979 pp. N-III-cc-1 and N-III-cc-4.

[2] DA, TM 9-500 Data Sheets for Ordnance Type Material, 1962, pp. 21-69 and 21-76.

MAINTAIN 10 KILOMETERS OF A MAIN SUPPLY ROUTE (MSR)
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

Resource Type		5-Ton Truck	Combat Engr	Grader
Number of Items		8	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	24.88	49.76	12.44
	Elapsed Time Required To Complete Task		3.11	

Figure E-23-1

LIGHT EQUIPMENT
WORKLOAD RATES

Resource Type		2.5-Ton Truck	Combat Engr	Grader
Number of Items		16	16	4
ACTIVITY	Effort for a 10-km Section During a 5-Day Period	49.76	49.76	12.44
	Elapsed Time Required To Complete Task		3.11	

Figure E-23-2

LAST PAGE OF APPENDIX E-23

APPENDIX E-24

DELIBERATE MINEFIELD BREACH

APPENDIX E-24

DELIBERATE MINEFIELD BREACH

1. Terrain. European.

2. Method of Construction. Combat engineers are assigned to conduct a deliberate breach through a 100-meter-deep minefield.[1] The planning factors are displayed in Figures E-24-1 and E-24-2.

3. Workload Estimates.

a. The bangalore torpedo is used to get dismounted assault forces through a 100-meter-deep minefield. The time required is 4 manhours.[2]

b. To accommodate vehicles, combat engineers then widen the breach to 8 meters using mine detectors and explosives. Ten manhours are required to clear a 1-meter lane in this manner.[3] Thus, the time required to widen the breach to 8 meters is 80 manhours.

c. The cleared lane is marked using the HEMMS. 10 manhours are allowed for marking.[4]

d. The time and effort required for a hasty breach to get dismounted assault forces through a 100-meter-deep minefield can be estimated by using the first line of Figure E-24-1.

---

[1] DA, Engineer Studies Center, Analysis of III Corps Combat Engineer Wartime Requirements (U), Volume I, Washington, D. C., 1984, pp. E-2-1 and E-2-2.

[2] DA, FM 5-34, Engineer Field Data, Washington D. C., 1976, p. 81.

[3] DA, TC 5-101, Mobility Drills, Coordinating Draft, Washington, D. C., 1983, p. 1-1.

[4] TC 5-101, p. 6-1.

DELIBERATE MINEFIELD BREACH
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	10
ACTIVITY	Breach 1-Meter Footpath	4.0
	Clear 8-Meter-Wide Path	80.0
	Mark the Lane	10.0
	Elapsed Time Required To Complete Task	9.4

Figure E-24-1

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	Combat Engr
	Number of Items	10
ACTIVITY	Breach 1-Meter Footpath	4.0
	Clear 8-Meter-Wide Path	80.0
	Mark the Lane	10.0
	Elapsed Time Required To Complete Task	9.4

Figure E-24-2

LAST PAGE OF APPENDIX E-24

APPENDIX E-25

REDUCE A DRY GAP BANK GRADE FOR VEHICLE PASSAGE

APPENDIX E-25

REDUCE A DRY GAP BANK GRADE FOR VEHICLE PASSAGE

1. Terrain. European.

2. Method of Construction. The engineer team assigned to this task has one bulldozer or M9 ACE with operator and one combat engineer to guide the dozer to the crossing site. The task consists of cutting single-lane approaches through steep banks to provide access and egress from a dry streambed or a streambed containing a shallow, fordable stream. The design cut is shown in Figure E-25-1.[1]

(1) The volume of earth to be excavated for one bank is calculated as follows:

volume of center wedge + volume of two tetrahedrons = total volume

$[(0.5)\ (d)\ (w)\ (1)] + 2\ [(1/3)\ (1/2)\ (d)\ (b)\ (1)]$ = total volume

$[(0.5)\ (2)\ (6)\ (20)] + 2\ [(1/3)\ (1/2)\ (2)\ (2)\ (20)] = 147\ m^3$

(2) Convert cubic meters to cubic yards:

$$(147)\ (1.308) = 193 \text{ BCY}$$

3. Workload Estimates. Figures E-25-2 and E-25-3 present the workload estimates for heavy and light equipment teams, respectively. These estimates were based on the following production rates.

a. D7 dozer production. Assume a push distance of 75 feet, which from Figure E-5 gives a production rate of 376 BCY per hour. Thus, the time for cutting one bank is determined:

$$193 / 376 = 0.51 \text{ hours}$$

---

[1] DA, Engineer Family of Systems Study (E-FOSS), Volume VII, Appendix N, 1979, pp. N-III-hh-1 and N-III-hh-5.

The total time required is equal to the sum of the times to cut the approach passage, to gain access to the far bank, and to cut the exit passage. Assuming the time required to gain access to the far bank is 5 minutes (0.08 hours), then the total time required is:

$$0.51 + 0.08 + 0.51 = 1.10 \text{ hours}$$

b. D5 dozer production. Assume a push distance of 75 feet which, from Figure E-6, gives a production rate of 243 BCY per hour. Thus, the time for cutting one bank is determined:

$$193 / 243 = 0.79 \text{ hours}$$

As estimated above, the total time required is:

$$0.79 + 0.08 + 0.79 = 1.66 \text{ hours}$$

DESIGN CUT FOR A GAP CROSSING APPROACH

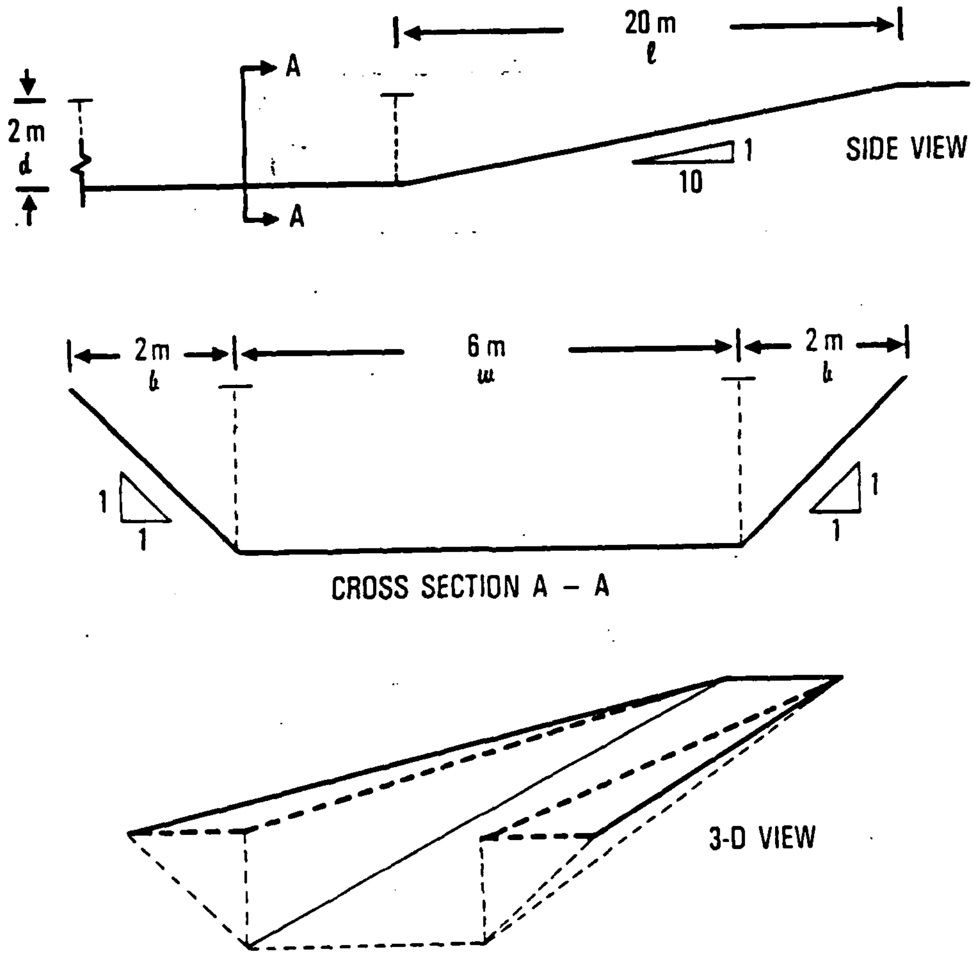

Figure E-25-1

REDUCE A DRY GAP BANK GRADE
FOR VEHICLE PASSAGE
(European Terrain + Temperate Weather)

HEAVY EQUIPMENT
WORKLOAD RATES

	Resource Type	D7 Dozer or M9 ACE	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Reduce Bank Grade	1.10	
	Elapsed Time Required To Complete Task	1.10	

Figure E-25-2

LIGHT EQUIPMENT
WORKLOAD RATES

	Resource Type	D5 Dozer	Combat Engr
	Number of Items	1	1
ACTIVITY	Guide Dozer/Locate Site		0.05
	Reduce Bank Grade	1.66	
	Elapsed Time Required To Complete Task	1.66	

Figure E-25-3

LAST PAGE OF APPENDIX E-25

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