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SOUTHWEST ASIA ENGINEER CAPABILITY OPTIONS FOR HEAVY DIVISIONS (SACAPO)

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This study's aim is to determine the comparative engineer capability of alternate unit structures supporting heavy divisions. The report uses unit, plus equipment and munitions, forecasts as of 15 January 1991. This study assumes all capability unit options have perfect planning and the same command and control. The study also uses a sample task list to represent the total engineer workload. The methodology parallels the 5-heavy-division force sent to operations DESERT SHIELD/DESERT STORM. In this report, the ESC rated the engineer capability of three structures in both 1991 and 1999 (6 cases). The three structures are the Division Engineer, Regimental Engineer, and current structure or base case. ESC expanded the basic 6 cases to 12 by analyzing both a 4-day offense and defense tactical situation. ESC then expanded the cases to 24 by analyzing each division zone with and without a corps support package. Additional excursions changed the size of this corps support package and the use of some key mining and digging equipment. This study's findings determine the capability of 24 engineer alternative structures: constrained by unit personnel and equipment, constrained by available and forecasted engineer munitions, and expressed for a 5-division corps and an average heavy division.

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Prepared by
Engineer Studies Center
U.S. Army Corps of Engineers

September 1991

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This project was only possible because of the discerning interest of the Study Advisory Chairman, COL Thomas Sheehy. COL Sheehy's Force Development Team provided the principal support and subject matter expertise. Special thanks go to the team's MAJ Richard Benton and Ms. Jean Lamrouex for their candid and generous contributions.

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TOTAL	80

CONTENTS

Figure

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EXECUTIVE SUMMARY

Between 1984 and 1990, the U.S. Army Engineer School designed, rated, and field tested a new engineer structure for the maneuver heavy division. The new structure provides an engineer battalion for each divisional maneuver brigade. These three small battalions replaced two larger battalions--the older divisional engineer battalion and a supporting corps combat engineer battalion--with basically no change in total corps engineer strength. The new structure--called the "Division Engineer"--includes a headquarters and staff commanded by a colonel.

The Division Engineer structure had superior command and control over alternative structures. This led to faster planning and responsiveness. The improved execution enabled the unit to change rapidly from offense to defense. Combat simulation showed the Division Engineer provided more force effectiveness than the other rated alternatives. The Engineer School rated the Division Engineer and alternative structures for 1996 conditions.

Between 1989 and 1991, the Division Engineer concept became embodied within the Engineer Restructure Initiative. The revised concept is similar to the Division Engineer except slightly smaller. The new structure is known as the "Regimental Engineer." The Engineer School has not rated the Regimental Engineer, but it continues to have the same superior command and control of the former structure. The Army has approved the Regimental Engineer structure for implementation during the 1990s.

No one has rated the Regimental Engineer structure using task capabilities plus actual and programmed resources. Neither has any former study compared the base case to the Division/Regimental Engineer structures for 1991. The Office of the Chief of Engineers sponsored this study to make these comparisons. This office oversees the optimal design of the engineer force structure for the Army staff. In this report, the Engineer Studies Center (ESC) rated the engineer capability of three structures in both 1991 and 1999 (6 cases). The three structures are the Division Engineer, Regimental Engineer, and current structure or base case.

ESC's methodology parallels the 5-heavy-division force sent to Southwest Asia during operations DESERT SHIELD/DESERT STORM. We expanded the basic 6 cases to 12 by analyzing both a 4-day offense and defense tactical situation. We expanded the cases to 24 by analyzing each division zone with and without a corps support package with more engineer units. Additional excursions changed the size of this corps support package and the use of some key mining and digging equipment. **Figure i** shows the key aspects of this methodology.

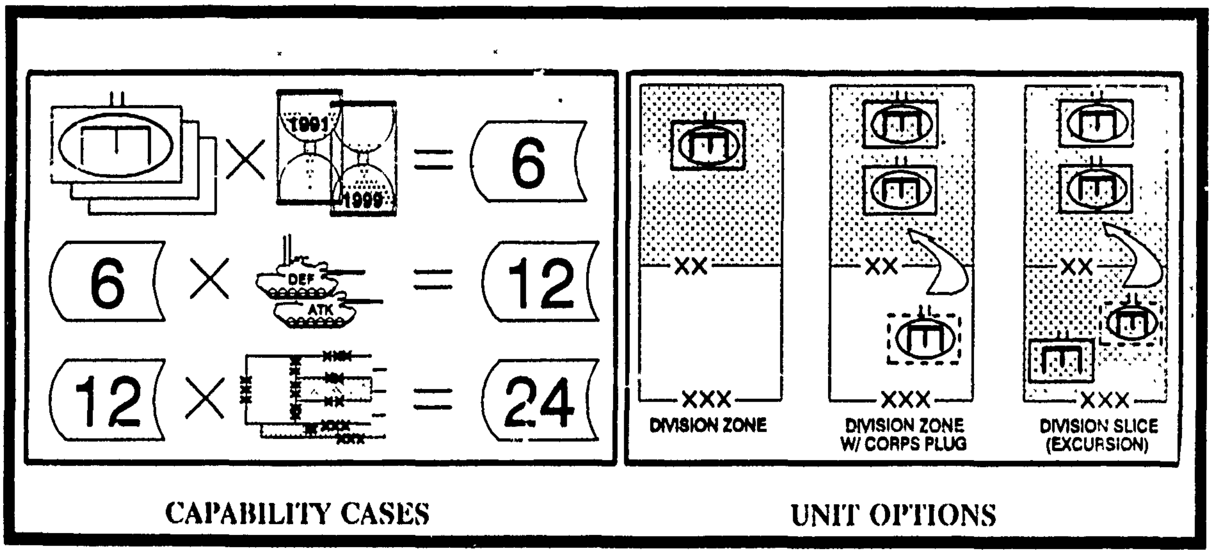

Figure i. METHODOLOGY KEY ASPECTS

Using this methodology, ESC's findings led to four general observations:

- ***Division Engineer and Regimental Engineer Organizations Show Improvements.*** The Division Engineer and Regimental Engineer organizations are equal to the base case and better if the Army buys more scatterable mines in the future. For 1991, both organizations have effective survivability and mobility capability using fewer Sappers than the base case organizations. For 1999, the Army should use the Regimental Engineer organization as it has the highest overall capability of any option. However, the newer Division Engineer units depend on corps for effective main supply route (MSR) maintenance and countermobility capability. To effectively increase the Regimental Engineer organization's capability, the Army should deploy it with the equivalent of a full division slice of corps units.

- ***Base Case Organization Has Several Advantages.*** The 1991 base case organization has the highest capability for the countermobility mission when employed alone. The base case continues as the highest capability option when supplemented by either study corps-support option. Until the Ground VOLCANO is fully available, the engineers need to keep the wheeled corps battalions in the force as 4-company, 36-squad units. Engineers need this manpower to emplace the conventional mines now in stock. This need will fade when scatterable anti-tank mine stocks exceed four million mines. The base case also has the highest capability for MSR maintenance when employed alone or with the corps plug support. This MSR maintenance ranking is sound for 1991 through 1999.

- ***Ground VOLCANO and Flipper Mine Systems Need Watching.*** This study's defensive conflict uses 45 percent of the Army's planned Ground VOLCANO quantities for a 1999 deployed 5-division force. Considering this capability, the Army could reduce authorizations for unit Ground VOLCANO launchers and theater mine stocks by 50 percent. The Flipper is a very potent system with the same mine features as the Ground VOLCANO. The Flipper exceeds its designed emplacement rate. Considering the doctrine of surface laid mines and decreased emphasis on defense, the Flipper is a very cost effective mine system. For example, all the study capability options can almost double 1999 countermobility capability by using available Flipper mines. The Flipper equipment available in the study options can emplace 4.3 times the current mine stockage. If the Army bought more Flipper mines, the total 1991 on-hand equipment could emplace 4.85 times available mine capability. These statistics are for only 4 days of mine laying! The Army can easily justify buying 2 to 5 times or even 10 times more Flipper mines.

- ***Corps Support Units "Make or Break" the Regimental Organizational Concept.*** The new regimental organizational concepts (the Division Engineer and Regimental Engineer options) have permanently altered the separation of missions between division and corps. A deploying force will experience different mobility and MSR maintenance risks depending on the size of the corps support package. This report shows the corps plug package to be inadequate for the MSR maintenance mission and the division slice to be adequate but too costly. ESC would reallocate graders and loaders needed for 1999 MSR maintenance between fewer corps units. ESC would also add graders and loaders to the Division Engineer structure. Planners can accomplish both of these actions by just redistributing 1991 available quantities. All 1991 and 1999 organizational structures studied in this report had an equal balance of mobility and countermobility capabilities. The Engineer School should consciously maintain this equal balance as they revise the engineer force during the rest of the 1990s.

ESC has omitted detailed recommendations from this report. However, as equipment quantities become more focused, engineer planners can adapt our findings in more detail. Such detailed uses include:

- ***Ranking Limited Funds.*** For example, planners can determine if resources should go toward munitions versus new equipment or toward new equipment versus research and development.

- ***Phasing Unit Reorganizations.*** Planners can incrementally phase in new regimental organizations to match limited resources of equipment and munitions.

- ***Changing Force Allocation Rules.*** Once unit designs and resources are known, planners can efficiently adjust forces to meet working needs.

- ***Providing Theater Deployment Guidance.*** Working with known capabilities, planners can ensure a balanced and capable deploying force.

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ABBREVIATIONS AND ACRONYMS

AAO	authorized acquisition objective
ACE	armored combat earthmover or Assistant Chief of Engineers
ACR	armored cavalry regiment
ALB-F	AirLand Battle--Future
AP	anti-personnel
AT	anti-tank
ARCENT	U.S. Army Central Command
AVLB	armored vehicle launched bridge
CEV	combat engineer vehicle
CENTCOM	U.S. Central Command
CONLIB	*Corps Engineer Operations Supporting Non-Linear Battle*
COL	colonel
Conv	conventional
CSE	combat support equipment
CY	cubic yard
div	division
Eq	equipment
Equip	equipment
ERI	Engineer Restructure Initiative
ESC	Engineer Studies Center
ESS	*Engineer Structure Study*
GEMSS	ground-emplaced mine scattering system
HEMMS	hand-emplaced mine marking system
IBM	International Business Machines
KKMC	King Khalid Military City
Km	kilometer

m	meter
MAJ	major
MICLIC	mine clearing line charge
MOPMS	modular pack mine system
MSR	main supply route
Mun	munitions
Obs	obstacle
OCE	Office of the Chief of Engineers
PC	personal computer
POM	Program Objective Memorandum
Regmt	regiment
SACAPO	*Southwest Asia Engineer Capability Options for Heavy Divisions*
SAG	Study Advisory Group
SWA	Southwest Asia
TOE	table of organization and equipment
TRAC-FLVN	TRADOC Analysis Command—Fort Leavenworth
TRADOC	U.S. Army Training and Doctrine Command
USAES	U.S. Army Engineer School

I. INTRODUCTION

1. **PURPOSE.** This study determines the comparative engineer capability of alternate unit structures. These structures support heavy divisions in a Southwest Asia (SWA) theater.

2. **SCOPE.** This study determines the engineer capability of 24 engineer alternative structures. Capability results include both personnel and equipment systems. Equipment systems include the availability of engineer munitions. The following elements make up the 24 alternatives:

a. **Unit Design.** The study rates three unit designs: the current FY 91 force is the **Base Case**; the 1987 E-force--**Division Engineer**--is the second design; and the 1990 E-force--**Regimental Engineer**--is the last design. For clarity, this report will no longer use the E-force terminology.

b. **Tactical Phase.** This report rates each unit alternative under two combat tactical phases. The first phase is a ***counterattack*** as part of an offensive. The second phase is a ***defend mission*** as part of a defense.

c. **Time Frame.** This report rates each alternative for both the present (1991) and future (1999). The 1999 period anticipates new equipment and capability using the Program Objective Memorandum (POM).

d. **Corps Plug.** The Engineer Studies Center (ESC) rates the first 12 alternatives for the division zone using organic or equivalent divisional units. ESC then rated 12 more alternatives using all corps units working forward of the division rear boundary. The divisional and corps units together make up the corps plug.

e. **Divisions.** ESC shows results for the 5 heavy divisions deployed to Saudi Arabia as of 15 January 1991. Each of the 24 alternatives shows results for 5 divisions as well as an average single division.

3. **BACKGROUND.**

a. The Military Engineering and Topographic Division of OCE requested this study on 17 October 1990. This office oversees the optimal design of the engineer force structure for the Chief of Engineers on the Army staff. OCE and ESC refined the study's scope during a coordination conference on 14 November 1990. ESC started the analysis on 7 January 1991.

b. In 1987, the U.S. Army Engineer School (USAES) finished the design of a new engineer organizational concept. This concept increased engineer resources organic to heavy divisions concurrent with reduced resources at corps. The USAES called this concept the "E-force" and later "Division Engineer" force[1]. The original E-force analysis began in 1984.

c. In 1990, the USAES developed a smaller organization called the "Regimental Engineer" force[2]. Except size, the Regimental Engineer force is similar to the Division Engineer force organization.

d. No one has rated these two force options using task capabilities plus actual and programmed resources. The office of the COE would like a detailed capability analysis to determine what aspects of the new organizations are significant. ESC considered actual resources and current units for this analysis.

e. ESC improved this written report with the help of the Study Advisory Group (SAG). The SAG reviewed the final draft and provided guidance during the analysis. The sponsor held SAG meetings on 2 April 1991 and 14 August 1991. The SAG approved the draft report on 16 September 1991.

4. ASSUMPTIONS AND THEIR SIGNIFICANCE.

a. **Assumption.** This report uses data available as of January 1991. **Significance:** ESC bases the equipment and munitions available in 1999 on the buying strategy approved in 1990. Usually, the Army changes these resource decisions with each planning cycle. TRADOC may also change the unit designs of the Regimental Engineer force. The alternatives using the 1999 period are only as accurate as the future actual 1999 force matches our estimates. Some of the 1990 alternatives will change if the USAES revises Regimental Engineer unit designs.

b. **Assumption.** ESC uses the initial experiences from operations DESERT SHIELD/DESERT STORM in the Base Case alternatives. ESC also uses the Army DESERT SHIELD/DESERT STORM priority system for all alternatives. **Significance:** As operations DESERT SHIELD/DESERT STORM deviate from doctrine, so will our results. The Army makes available all engineer equipment and munitions (of any theater) needed for the study's 5-division force.

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[1] On 7 November 1987, the Combined Arms Center approved the USAES E-force Staff Study. On 15 June 1989, the TRADOC Analysis Command--Fort Leavenworth (TRAC-FLVN) approved the study plan for the *Engineer Structure Study (ESS)*. TRAC-FLVN published the final ESS report in May 1990. The ESS tested the Division Engineer and current force capabilities. However, TRAC-FLVN did not constrain this analysis to actual and programmed assets. Further, the ESS results did not state findings by task accomplishment. The ESS findings focused on the combat effectiveness of the maneuver force and factored Command and Control (C2) into the analysis.

[2] TRADOC directed the *Engineer Restructure Initiative (ERI)* in May 1989. This TRADOC effort reduced the size of the Division Engineer force using emerging AirLand Battle--Future doctrine. In July 1990, TRADOC approved the ERI concept and directed USAES to design the Regimental Engineer force units. TRADOC approved the unit designs in September 1990. Neither TRADOC nor the USAES rated the capability of the new units.

c. **Assumption.** All capability options assume perfect planning plus equal command and control. **Significance.** This study only measures quantitative differences derived from unit strengths and equipment levels. ESC assumes all units can plan and execute calculated tasks within the same time. We assign no advantage or disadvantage for different types of radios or command structure.

5. **METHODOLOGY.** The basic methodology uses a 4-day SWA theater conflict. ESC rates unit daily effectiveness as 12 hours for squads and 8 hours for equipment[3]. All calculations use the existing equipment now available or planned for 1999. When available munitions are less than equipment capability, ESC recalculates the unit alternative again constrained by the actual available munitions.

a. **Cases. Figure 1** shows the origin of this study's 24 capability option cases. The variables producing the 24 cases consist of 3 unit options, 2 periods, 2 tactical phases, and 2 sets of corps units.

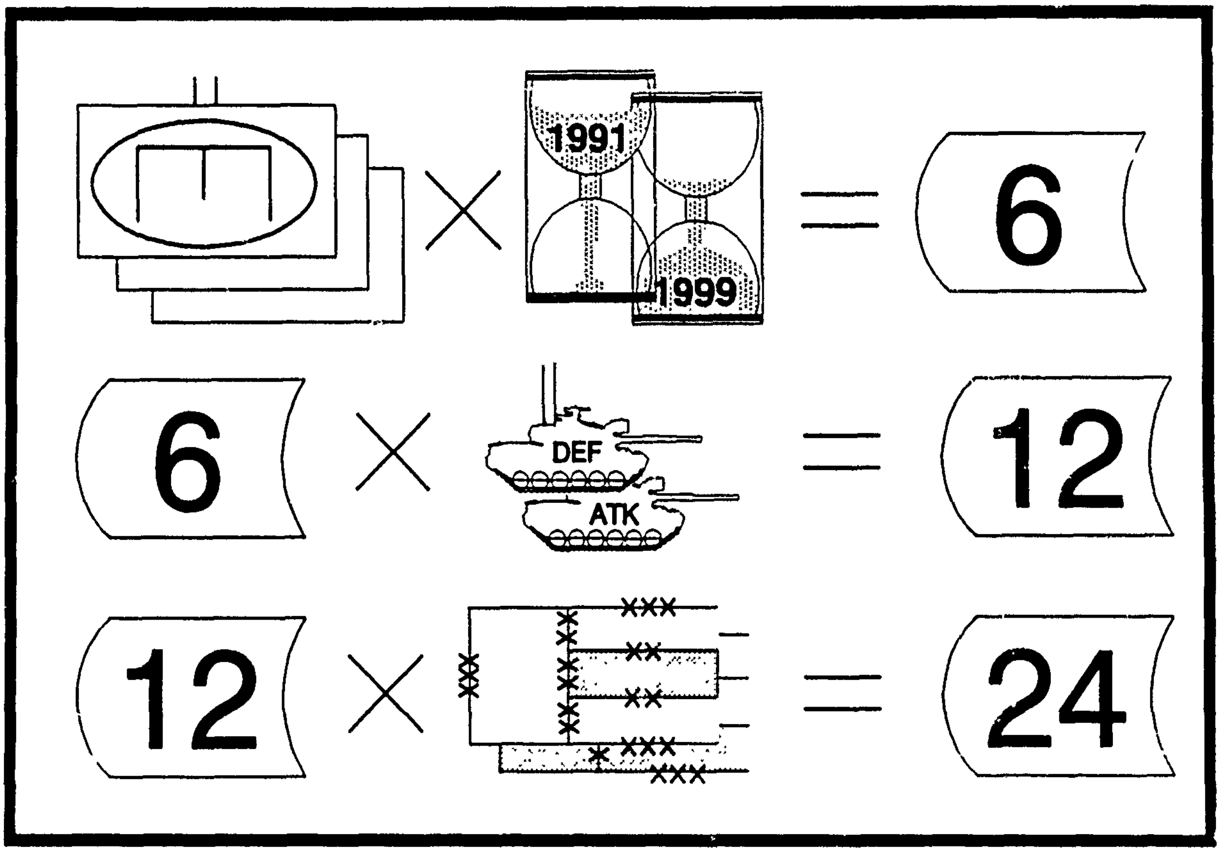

Figure 1. CAPABILITY CASES (12 CASES PER UNIT OPTION)

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[3] This is the standard used by USAES for all TRADOC studies.

b. **Representative Tasks.** **Figure 2** shows the major tasks used for this study. ESC picked six tasks—three offensive and three defensive. These six tasks also portray two mobility, one countermobility, one survivability, and two sustainment engineering tasks. We picked a similar sustainment engineer task (main supply route (MSR) maintenance) for each tactical phase.

- OFFENSE

  Breach MSR Minefield Lane*
  Breach Complex Obstacle Lane (Minefield/Wire/Ditch/Berm)*
  Develop and Maintain MSRs

- DEFENSE

  Emplace Minefield and Road Craters in a Blocking Obstacle**
  Dig Tank/Infantry Fighting Vehicle Position
  Maintain MSRs

---

* *Includes marking lane.*
** *Includes marking lanes that are later closed.*

Figure 2. REPRESENTATIVE TASKS

c. **Capability.** ESC set the percentage of unit daily effectiveness at 50 percent (12 hours) for personnel and 33.3 percent (8 hours) for equipment. The unused hours depict a variety of activities such as movement, security, sleep, maintenance, messing, night operations, material delays, and changes of mission. For the wheeled corps battalion, effectiveness was 1 hour less per day. The wheeled battalion has limited mobility in a SWA region where movement is frequent and over extended distances. ESC also subtracted 1 hour for both corps battalions during day 1. This 1-hour subtraction allows the units to move from assembly areas to locations within the zone of their assigned division. **Figure 3** shows the hours per day for all units used in this study. ESC tracked capability for the following eight pieces of equipment: Combat Engineer Vehicle (CEV); 5-ton dump truck; Ground VOLCANO; Flipper; Armored Combat Earthmover (ACE)/D-7 Bulldozer; Road Grader; Armored Vehicle Launched Bridge (AVLB); and 2½-CY Loader.

d. **Planning Factors.** ESC calculated task planning factors for hot weather in the rocky plateau terrain of a desert[4]. These factors are about double the time it takes to do the same task in the temperate weather of Europe. The tasks that involve emplacing or breaching minefields use alternate methods. ESC used the preferred method until the units depleted those specified

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[4] *Workload Estimates for Combat Engineers in the Desert*, (ESC, April 1986).

resources. An alternate method was used when additional resources were still available. For planning factors that use future equipment, ESC used factors from an AirLand Battle Study sponsored by the USAES[5].

ENGINEER UNIT	DAY 1*		DAYS 2-4	
	SQUADS	EQUIPMENT	SQUADS	EQUIPMENT
DIVISIONAL BATTALIONS	12	8	12	8
**WHEELED CORPS BATTALIONS AND CSE COMPANIES	10	6	11	7
MECHANIZED CORPS BATTALIONS	11	7	12	8

** Corps units degraded 1 hour per day for movement into division area of operation on day 1 only.*
*** Degraded 1 hour per day for slower movement than units with tracked vehicles.*

Figure 3. CAPABILITY (HOURS PER DAY)

e. **Units.** ESC selected Tables of Organization and Equipment (TOE) proper for each unit capability option. **Figure 4** shows the TOEs used and the quantities for the division zone and the corps plug.

f. **Excursions.** ESC conducted three excursions:

(1) The first excursion added the Flipper. The Flipper is a hand-operated mine scattering system. The Army started fielding the Flipper during the study's base case period. For this report, ESC assumed that the Flipper is a future system designed for the defense. ESC estimated this excursion in the division zone for three 199? defensive cases.

(2) The second excursion calculated a full division slice. This excursion includes all the corps units of the corp plug plus more. A division slice has the additional corps units behind the division rear boundary equally divided between the maneuver divisions. **Figure 5** is a schematic diagram showing these units compared to the corps plug and division zone capability options. This excursion includes the full 12 cases and the Flipper capability.

(3) The last excursion examines the sensitivity of dividing blade capability (bull-dozer or ACE) between digging vehicle positions or helping with MSR maintenance. These two tasks are part of the defense and are examined using the 6 division slice cases.

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[5] *Corps Engineer Operations Supporting Non-Linear Battle (CONLIB)*, (ESC, June 1991).

DATE	ENGINEER UNIT ( ) = Strength	BASE CASE		DIVISION ENGINEER		REGIMENTAL ENGINEER	
		Div. Zone	Corps Plug	Div. Zone	Corps Plug	Div. Zone	Corps Plug
1990	Divisional Battalion:						
	TOE 5-145J/K	5	5	-	-	-	-
	TOE 5-335L –1987 (493)	-	-	15	15	-	-
	TOE 5-335L –1991 (433)	-	-	-	-	15	15
	Corps Wheeled Battalion:						
	TOE 5-35H	1	1.5	-	-	-	-
	Corps Mechanized Battalion:						
	TOE 5-45H	4	7.5	-	-	-	-
	TOE 5-335L	-	-	-	5	-	-
	TOE 5-325L	-	-	-	-	-	5
	Combat Support Equipment Company:						
	5-58H	-	-	-	5	-	-
	5-423L	-	-	-	-	-	5
1999 (With Equipment Revisions)	Divisional Battalion:						
	TOE 5-145L	5	5	-	-	-	-
	TOE 5-335L –1987 (493)	-	-	15	15	-	-
	TOE 5-335L –1991 (433)	-	-	-	-	15	15
	Corps Wheeled Battalion:						
	TOE 5-425L	1	1.5	-	-	-	-
	Corps Mechanized Battalion:						
	TOE 5-435L	4	7.5	-	-	-	-
	TOE 5-335L*	-	-	-	5	-	-
	TOE 5-325L	-	-	-	-	-	5
	Combat Support Equipment Company:						
	5-58H	-	-	-	5	-	-
	5-423L	-	-	-	-	-	5

** Same TOE as 1987 divisional battalion.*

Figure 4. TABLES OF ORGANIZATION AND EQUIPMENT (TOE) OPTIONS

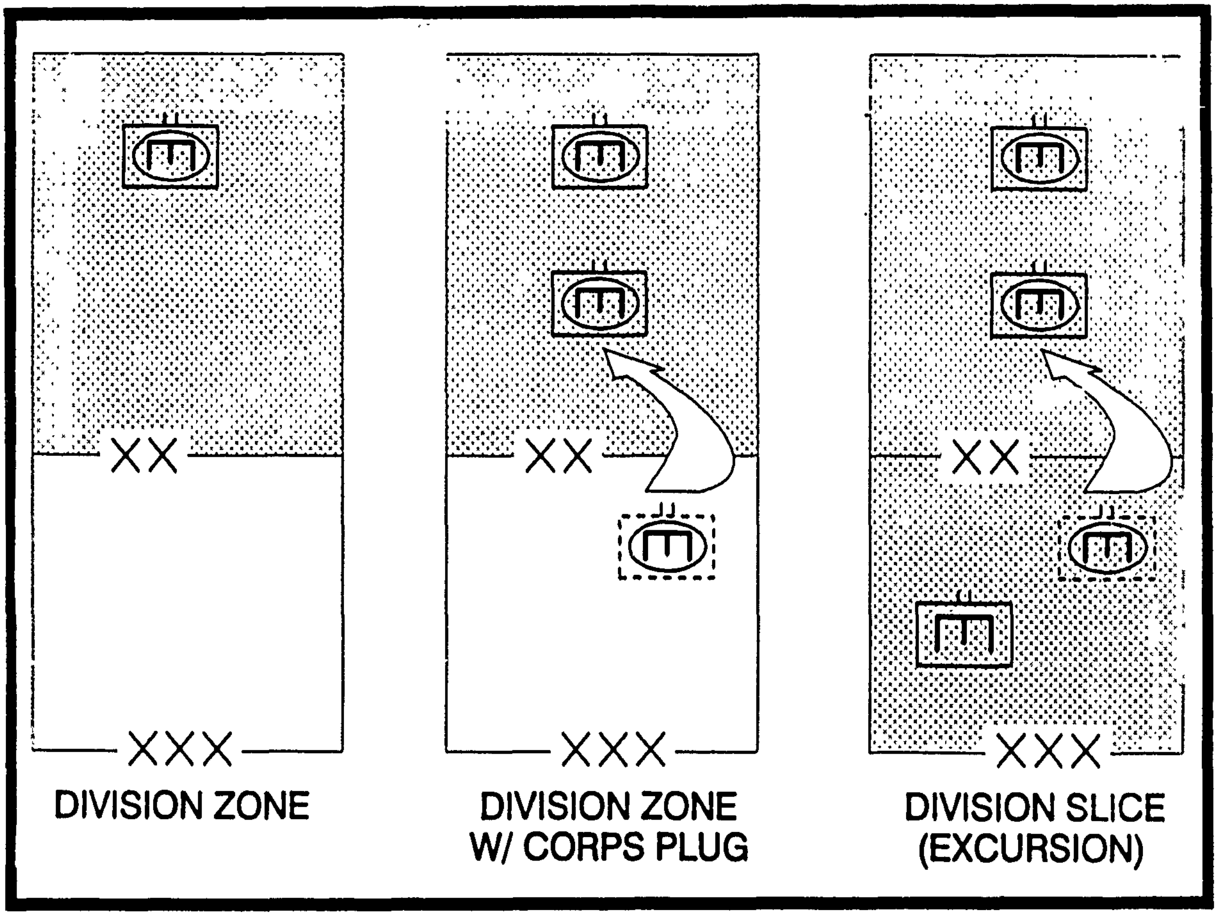

Figure 5. UNIT OPTIONS

g. **Spreadsheets.** ESC calculated study results using a series of LOTUS 123 spreadsheets (release 3.0). This report provides an audit trail without reference to these spreadsheets. However, ESC can provide these spreadsheets upon request[6]. (ESC can copy these spreadsheets onto a MS-DOS formatted 5¼ inch 360b or 1.2mb floppy disk or 3½ inch 7.2kb or 1.4mb disk.) The spreadsheet files are without self-contained menus or instructions.

h. **Calculations.** ESC's spreadsheets used a sequential process to calculate capability. The first step divided capability by the three tasks in a 30-30-40 percent proportion. The 40 percent part is the task associated with complex obstacles. The three offense or defense tasks do not share the same equipment more than twice. So, the second step divided remaining capability equally according to shared equipment. The third step used any remaining equipment capability. ESC took additional steps to use remaining capability when alternate planning factors allowed. During this process, the methodology completely used the available squad hours.

[6] ESC keeps this documentation for five years from date of study.

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II. INPUT DATA

6. **GENERAL.** In this section, ESC shows the data used to calculate capability. This data shows extracts from engineer TOEs, plus Army equipment and munition stocks to include planned acquisition goals. The last paragraph shows the task planning factors.

7. **SQUADS. Figure 6** shows the squad size and number of squads per battalion for all unit options. The squad size and number does not change between the Division Engineer and Regimental Engineer options. Neither does the size and number change between 1990 and 1999 for any unit option except one. That exception is squad size for the corps mechanized battalion in the base case. The four mechanized battalions deployed in DESERT SHIELD/DESERT STORM averaged 8.4 men per squad. This same squad has 10 men in the 1999 TOE. All unit options have three squads per platoon. However, the number of platoons per company and number of companies per battalion vary per option.

	SQUAD SIZE 1990/1999	NUMBER OF SQUADS 1990/1999
DIVISIONAL UNITS: BASE CASE	8	36
DIVISION/REGIMENTAL ENGINEER	8	18
CORPS WHEELED BATTALION: BASE CASE	9	36
DIVISION/REGIMENTAL ENGINEER	8	27
CORPS MECHANIZED BATTALION BASE CASE	8.4/10	36
DIVISION/REGIMENTAL ENGINEER	8	18

Figure 6. BATTALION SQUADS

8. **EQUIPMENT.**

a. **TOE Quantities. Figure 7** lists the eight pieces of equipment calculated for all unit options. ESC listed construction equipment using a single standard. The blade standard is the D7 or medium bulldozer. Using the CONLIB study, we used the ACE equal to 0.85 D7s and the D8 as 1.8 D7s. The dump truck standard is the 5-ton. Based on volume, the 20-ton dump truck represents three 5-ton trucks. Lastly, the 2½-cubic-yard loader is the ESC standard. This makes each 5-cubic-yard loader the same as two 2½-cubic-yard loaders.

b. **Army Availability. Figures 8 and 9** show the availability of engineer equipment in the Army for 1990 and 1999. In Figure 8, ESC assumed that the Flipper is available for all 1999 excursion options. The Army actually started fielding the Flipper during operation DESERT

SHIELD. ESC also assumed that the GEMSS is not available due to maintenance problems experienced in the desert. For the ACE in 1990 and the Ground VOLCANO in 1999, we filled individual units at 100 percent fill until remaining resources were less than a full unit. At that point, we left the remaining units at zero fill. Figure 9 shows that the engineers do not have enough ACEs for 1990 unit options. This figure also shows the engineers do not have enough ground VOLCANOs for all 1999 division slice units.

	D7 DOZER	5-T DUMP TRUCK	GRADER	2½-CY LOADER	CEV	FLIPPER	GROUND VOLCANO	AVLB
DIVISIONAL UNITS								
Base Case 1990 TOE 5-145J/L	* 16.63	33.8	0	1.4	8.2	0	0	12
1999 TOE 5-145L	# 25.00	32.0	0	0.0	8.0	6	4	12
Division Engr 1990 TOE 5-335L	# 18.00	12.0	0	0.0	6.0	0	0	12
1999 TOE 5-335L	# 18.00	12.0	0	0.0	6.0	6	6	12
Regimental Engineer 1990 TOE 5-335L	# 21.00	0.0	0	0.0	6.0	0	0	12
1999 TOE 5-335L	# 21.00	0.0	0	0.0	6.0	6	6	12
CORPS WHEELED BATTALION								
Base Case 1990 TOE 5-35H	13.00	56.0	4	10.0	0.0	0	0	0
1999 TOE 5-425L	18.00	60.0	6	10.0	0.0	6	0	0
Division Engr 1990 TOE 5-335L	28.00	52.0	8	16.0	0.0	0	0	0
1999 TOE 5-335L	28.00	52.0	8	16.0	0.0	6	4	0
Regimental Engineer 1990 TOE 5-315E	12.00	42.0	9	6.0	0.0	0	0	0
1999 TOE 5-315E	12.00	42.0	9	6.0	0.0	6	6	0

Figure 7. ENGINEER UNIT EQUIPMENT

	D7 DOZER	5-T DUMP TRUCK	GRADER	2½-CY LOADER	CEV	FLIPPER	GROUND VOLCANO	AVLB
CORPS MECHANIZED BATTALION								
Base Case								
1990 TOE 5-45L	12.00	39.0	4	8.0	0.0	0	0	0
1999 TOE 5-435L	16.00	72.0	0	4.0	0.0	6	0	0
Division Engr								
1990 TOE 5-335L	# 18.00	12.0	0	0.0	6.0	0	0	12
1999 TOE 5-335L	# 18.00	12.0	0	0.0	6.0	6	6	12
Regimental Engineer								
1990 TOE 5-325',	# 18.00	12.0	0	0.0	6.0	0	0	12
1999 TOE 5-325L	# 18.00	12.0	0	0.0	6.0	6	6	12
COMBAT SUPPORT EQUIPMENT COMPANY								
Base Case								
1990 TOE 5-58H	10.80	73.5	9	8.0	0.0	0	0	0
1999 TOE 5-58H	10.80	84.0	9	8.0	0.0	0	0	0
Division Engr								
1990 TOE 5-58H	6.00	45.0	6	6.0	0.0	0	0	0
1999 TOE 5-58H	6.00	45.0	6	6.0	0.0	0	0	0
Regimental Engineer								
1990 TOE 5-325L	6.0	45.0	6	6.0	0.0	0	0	0
1999 TOE 5-325L	6.0	45.0	6	6.0	0.0	0	0	0

** 4 of 5 units are ACE*
 # = ACE

Figure 7. ENGINEER UNIT EQUIPMENT continued

EQUIPMENT	1990	1999
ACE	PARTLY	YES
GROUND VOLCANO	NO	PARTLY
FLIPPER	NO*	YES
MICLIC CEV AVLB HEMMS CONSTRUCTION (DOZERS, GRADERS, LOADERS, AND DUMPS)	YES	YES
GEMSS	NO*	NO

* *Study Assumption*

Figure 8. EQUIPMENT AVAILABILITY

ITEM	WORLDWIDE QUANTITY (1990/1999)	5-DIVISION PEAK USE*		
		DIVISION ZONE	CORPS PLUG	DIVISION SLICE
CEV	279	90	120	128
MICLIC	678	180	240	232
AVLB	646	180	240	257
ACE	168/434	315	430	430
FLIPPER	0**/174	90	120	154
VOLCANO	0/135	90	120	154
HEMMS	500	125	159	185

* *Largest of Base Case, Division Engineer, or Regimental Engineer unit options.*
** *Study assumption.*

Figure 9. ENGINEER EQUIPMENT INVENTORY

9. **MUNITIONS. Figure 10** shows the Army's worldwide munitions stockage. These munitions are engineer items calculated as part of this study. **The shaded boxes show items that constrained the study (Section III).** ESC did not reduce mining tasks for low stocks of MOPMS. When MOPMS was inadequate, ESC assumed artillery units would use scatterable mines to close gaps and lanes. We also reduced the 1999 MICLIC quantities shown by 10 percent. This percentage allows for those MICLICs used up during DESERT SHIELD/DESERT STORM and for future training.

	JANUARY 1991	PLANNED 91-99 BUYS	ESTIMATED 1999
M139 MINE CANISTER*	0	**456	456
MOPMS	0	**803	803
M180 DEMOLITIONS KIT	12,800	2,000	14,800
M74 ANTI-TANK MINE (FLIPPER)	317,340	0	317,400
M75 ANTI-PERSONNEL MINE (FLIPPER)	76,000	0	76,000
MICLIC:			
MK22 MOD 4 ROCKET	2,700	1,121	***3,821
M58A3 LINE CHARGE	7,300	0	***7,300
M15/19/21 ANTI-TANK MINES	2,160,200	0	2,160,200
M16 ANTI-PERSONNEL MINE	2,593,000	0	2,593,000
40# SHAPED CHARGE	32,900	0	32,900
40# CRATERING CHARGE	42,000	23,000	65,000
BANGALORE TORPEDO	28,800	0	28,800

** 160 M87 mine units (5 ATs & 1 AP).*
*** Estimated 7% of AAO.*
**** Reduced 10% for DESERT SHIELD/DESERT STORM expenditures and future training.*

Figure 10. WORLDWIDE ENGINEER MUNITIONS STOCKAGE

10. **PLANNING FACTORS.** For this report, ESC used SWA planning factors from two recent studies[7]. All planning factor figures show a desert factor. To reach the SWA work rates used in this study, this factor is multiplied by the hours it takes to perform this task in Europe.

a. **Offense. Figures 11 through 13** show the planning factors for the offense. In **Figure 11**, this planning factor sweeps and later detonates scatterable mines from MSRs. Army planners expect this MSR task to dominate mobility operations in the future. However, in operation DESERT STORM, the task was absent except for the related task of removing U.S. mines from airfields.

[7] See footnotes 4 and 5 on pages 4 and 5 respectively.

	SQUAD HOURS	DESERT FACTOR	CEV HOURS	DESERT FACTOR
Breach 1250 Meters	2.05	1.62	1.00	2.00

Figure 11. BREACH MSR MINEFIELD LANE

In **Figure 12**, ESC doubles the dozer hours to reflect the emphasis on mobility.

	DOZER HOURS	LOADER HOURS	DUMP TRUCK HOURS	GRADER HOURS	DESERT FACTOR
Maintain 100 Kilometers of Loose Surface 2-Lane Road	76.9	23.9	95.7	95.7	3.85

Figure 12. DEVELOP AND MAINTAIN MSR

In **Figure 13**, ESC had no previous planning factor for breaching a berm or ditch. The shown breaching times were furnished by USAES and came from actual engineer tests in California.

SUB-TASK	SQUAD HOURS	CEV HOURS	DOZER HOURS	AVLB	MICLIC	BANGALORE TORPEDO	HEMMS	DESERT FACTOR
METHOD 1 - MICLIC AND CEV								
Breach 200m Minefield	0.30	0.80			2			1.62/ 1.92*
Breach 100m Wire	0.15	0.40			1			1.62/ 1.92
Breach Berm		0.30						1.92
Breach Ditch		0.15		1				1.92
Widen and Mark Lane	6.15	4.80					1	1.72/ 1.92
TOTAL	6.60	6.45		1	3		1	

Figure 13. BREACH COMPLEX OBSTACLE LANE

SUB-TASK	SQUAD HOURS	CEV HOURS	DOZER HOURS	AVLB	MICLIC	BANGALORE TORPEDO	HEMMS	DESERT FACTOR
METHOD 2 - BANGALORE TORPEDO AND DOZER/ACE								
Breach 200m Minefield	36.20		0.80			14		1.62/ 1.92
Breach 100m Wire	0.90		0.40			7		1.62/ 1.92
Breach Berm			0.30					1.92
Breach Ditch			0.15	1				1.92
Widen and Mark Lane	6.15		4.80				1	1.72/ 1.92
TOTAL	43.25		6.45	1		21	1	

** Squad Factor/Equipment Factor*

Figure 13. BREACH COMPLEX OBSTACLE LANE continued

b. **Defense. Figures 14 through 16** show the defensive planning factors. The MSR maintenance task in **Figure 15** is similar to the offense (Figure 12) but with less dozer hours. As the availability of engineer equipment went to zero, the maintenance task was adjusted to reflect less than optimal equipment configurations. ESC made this adjustment by continuing MSR maintenance when only one to three of the four items of equipment remained. However, we doubled the hours shown for this inefficient method (2*[38.45+23.9+95.7+95.7]).

	DOZER HOURS	DESERT FACTOR
Dig 1 Position	1.33	3.69

Figure 14. DIG TANK/INFANTRY FIGHTING VEHICLE POSITION

	DOZER HOURS	LOADER HOURS	DUMP TRUCK HOURS	GRADER HOURS	DESERT FACTOR
Maintain 100 Kilometers of Loose Surface 2-Lane Road	38.45	23.9	95.7	95.7	3.85

Figure 15. MAINTAIN MSR

METHOD 1 - GROUND VOLCANO								
SUB-TASK	**SQUAD HOURS**	**DUMP TRUCK HOURS**	**GROUND VOLCANO HOURS**	**DESERT FACTOR**	**M139* CAN-ISTER**	**MOPMS**	**M133 HEMMS**	**M180 DEMO KIT**
Lay 2000m Minefield	1.15	2.85	2.85	1.62	1.75			
Mark 125m Lane	1.40			1.72			0.25	
Blow 2 Road Craters	3.45			1.72		4		10
Close 125m Lane	1.55			1.62		7		
TOTAL	7.55	2.85	2.85		1.75	11	0.25	10

METHOD 2 - FLIPPER (EXCURSION ONLY)								
SUB-TASK	**SQUAD HOURS**	**DUMP/ FLIPPER HOURS**	**DESERT FACTOR**	**M74 AT MINE**	**M75 AP MINE**	**MOPMS**	**M133 HEMMS**	**M180 DEMO KIT**
Lay** 2000m Minefield	3.20	3.2	1.72	1,115	225			
Mark 125m Lane	1.40		1.72				0.25	
Blow 2 Road Craters	3.45		1.72			4		10
Close 125m Lane	1.55		1.62			7		
TOTAL	9.60	3.2		1,115	225	11	0.25	10

Figure 16. MINEFIELD OBSTACLE WITH ROAD CRATERS

METHOD 3 - CONVENTIONAL MINES AND EXPLOSIVES								
SUB-TASK	SQUAD HOURS	DUMP TRUCK HOURS	DESERT FACTOR	M15/19/21 AT MINE	M16 AP MINE	40# SHAPE CHARGE	40# CRATER CHARGE	(NOT USED)
Lay 2000m Minefield	150.75	52.44	1.41	3,261	1,795			
Mark w/ Barbed Wire	39.60		1.41					
Blow 2 Road Craters	8.00		1.72/ 1.41	24	12	12	20	
TOTAL	198.35	52.44		3,285	1,807	12	20	

* *125m x 1150m per M139 canister.*
** *1 mine every 10 seconds.*

Figure 16. MINEFIELD OBSTACLE WITH ROAD CRATERS continued

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III. FINDINGS

11. **GENERAL.** In this section, ESC presents its findings primarily by unit options. The first three unit-option sets each have 12 cases. Additional paragraphs explain two excursions. The excursions explore the use of older equipment and the different uses of existing equipment.

12. **DIVISION ZONE.** This option looks at the minimum level of engineer units for a 5-division force. Both the Division Engineer and Regimental Engineer organizations have the same three battalions per division. For the base case, ESC looked at two different engineer organizations. The first battalion is the expected organic divisional battalion. For the second unit, ESC added one corps battalion. ESC used the corps unit to maintain a uniform comparison. (The engineers designed the three new battalions from the total personnel spaces of the two base case battalions.) Figure 4 lists the TOE designations and quantities of all units. **Figure 17** shows the equipment inventory of each option case as used in the offense and defense calculations.

TYPE	1990			1999		
	BASE CASE	DIV ENGR	REGMT ENGR	BASE CASE	DIV ENGR	REGMT ENGR
ACE	67	162	168	125	270	315
D7 Bulldozer	77	108	147	82	0	0
Total Blades	144	270	315	207	270	315
CEV	41	90	90	40	90	90
AVLB	110	180	180	120	180	180
Ground VOLCANO	0	0	0	20	90	90
MICLIC	0	180	180	100	180	180
Loaders	49	0	0	26	0	0
Graders	20	0	0	6	0	0
Dump Trucks	381	180	0	508	180	0

Figure 17. DIVISION ZONE EQUIPMENT PER 5-DIVISION FORCE

a. **5-Division Force.** These comparisons look at the full force for the complete four-day conflict. ESC shows comparisons for each of the six tasks. Each task comparison shows the three unit organizations for both 1990 and 1999. This type of display allows direct comparison with worldwide engineer equipment and munition levels (Figures 9 and 10). The three offense tasks are shown first, followed by the remaining three defensive tasks.

(1) **Offense.** **Figure 18** shows the capability for breaching MSR minefield lanes. The Division Engineer and Regimental Engineer capabilities are equal for this task. The number of CEVs make these two cases over twice as capable as the base case.

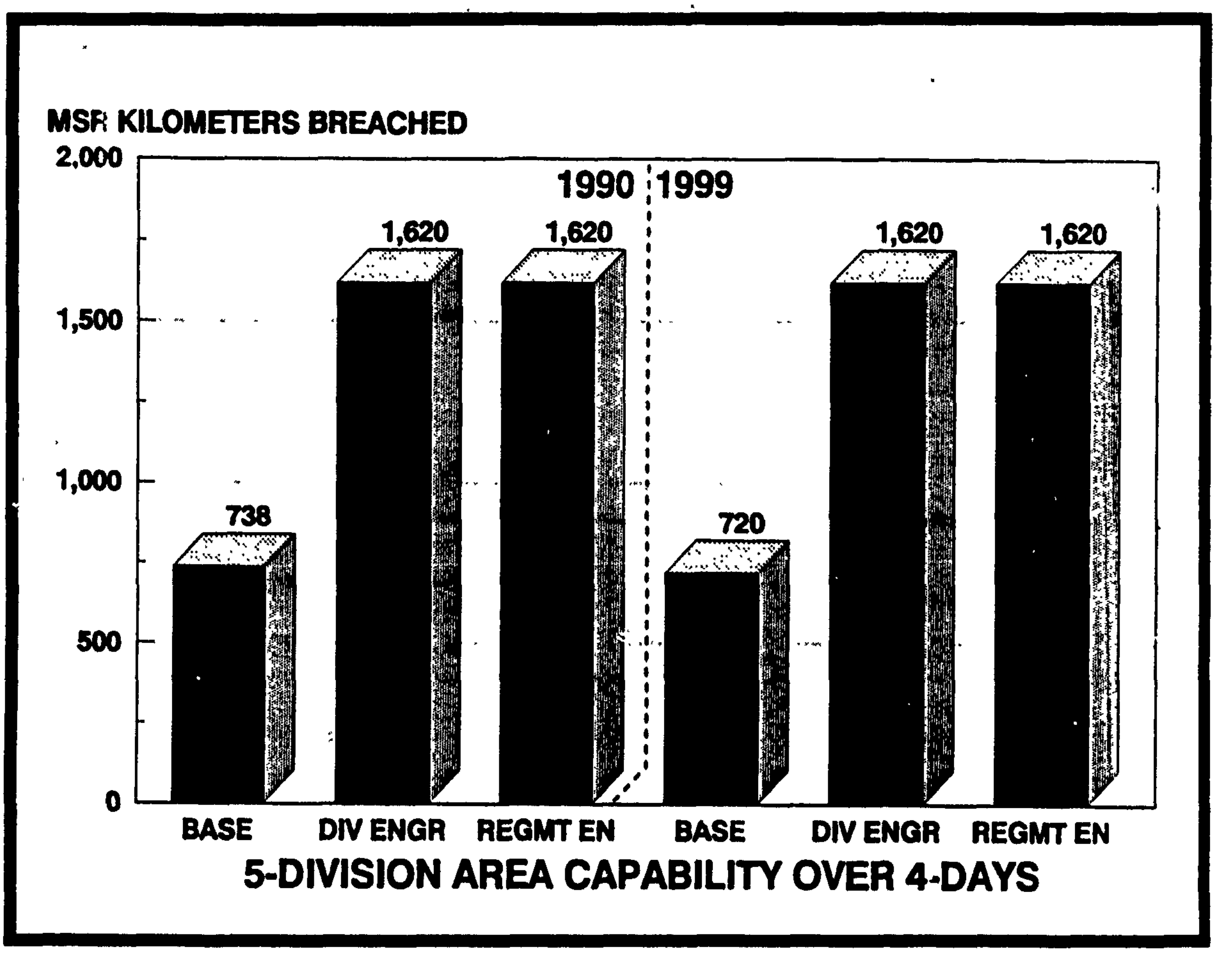


Figure 18. MSR MINEFIELD LANE BREACHING CAPABILITY (DIVISION ZONE)

Figure 19 shows the capability for developing and maintaining MSRs. For this task, the availability of four construction items of equipment determines rankings. The base case has the most capability, followed by the Division Engineer case and the Regimental Engineer case. The lack of dump trucks in the regimental organization causes the difference between the Division Engineer and Regimental Engineer cases. NOTE: Figure 19 shows total kilometers spread over four days. If engineers maintain the *same* MSR network daily, the total extent of MSRs is one-fourth that shown.

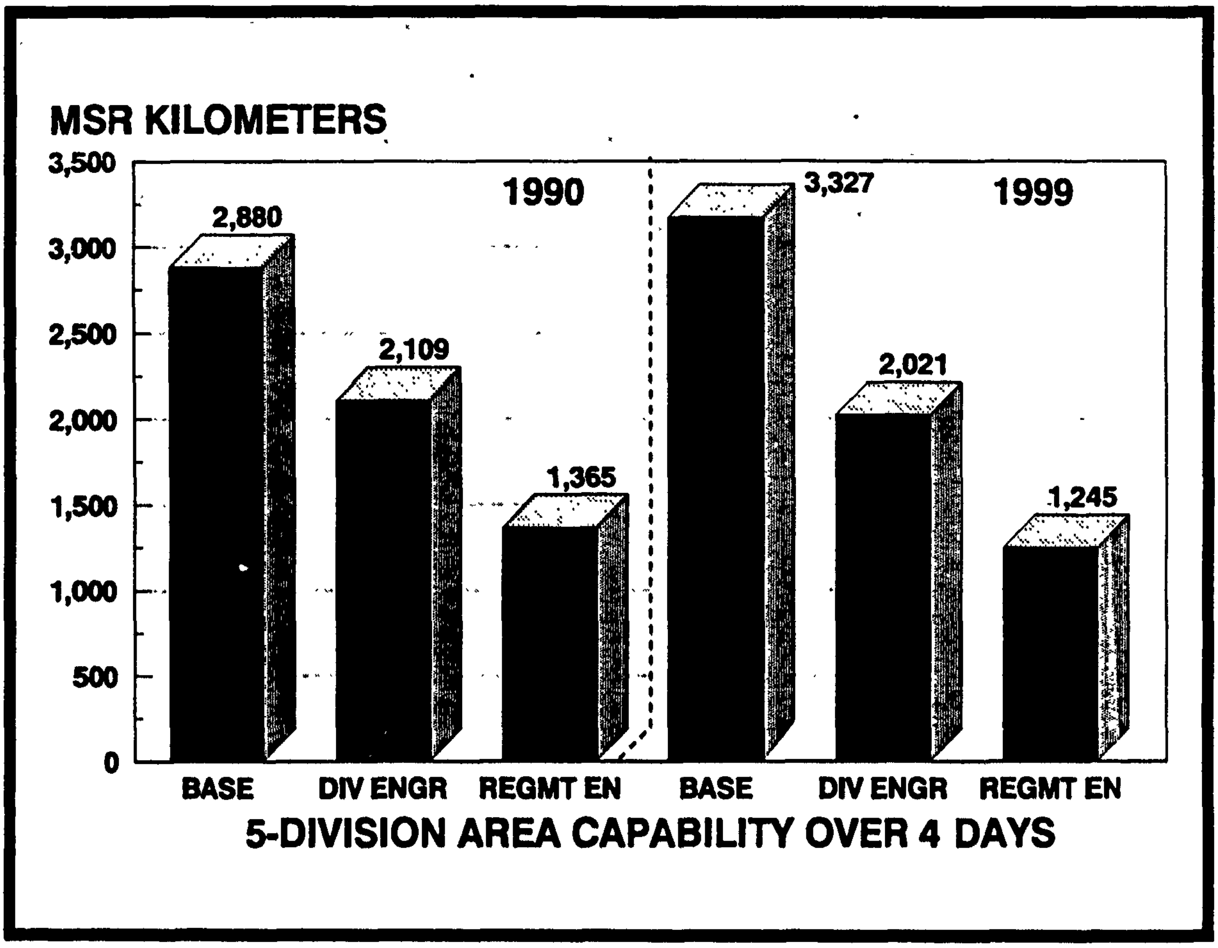
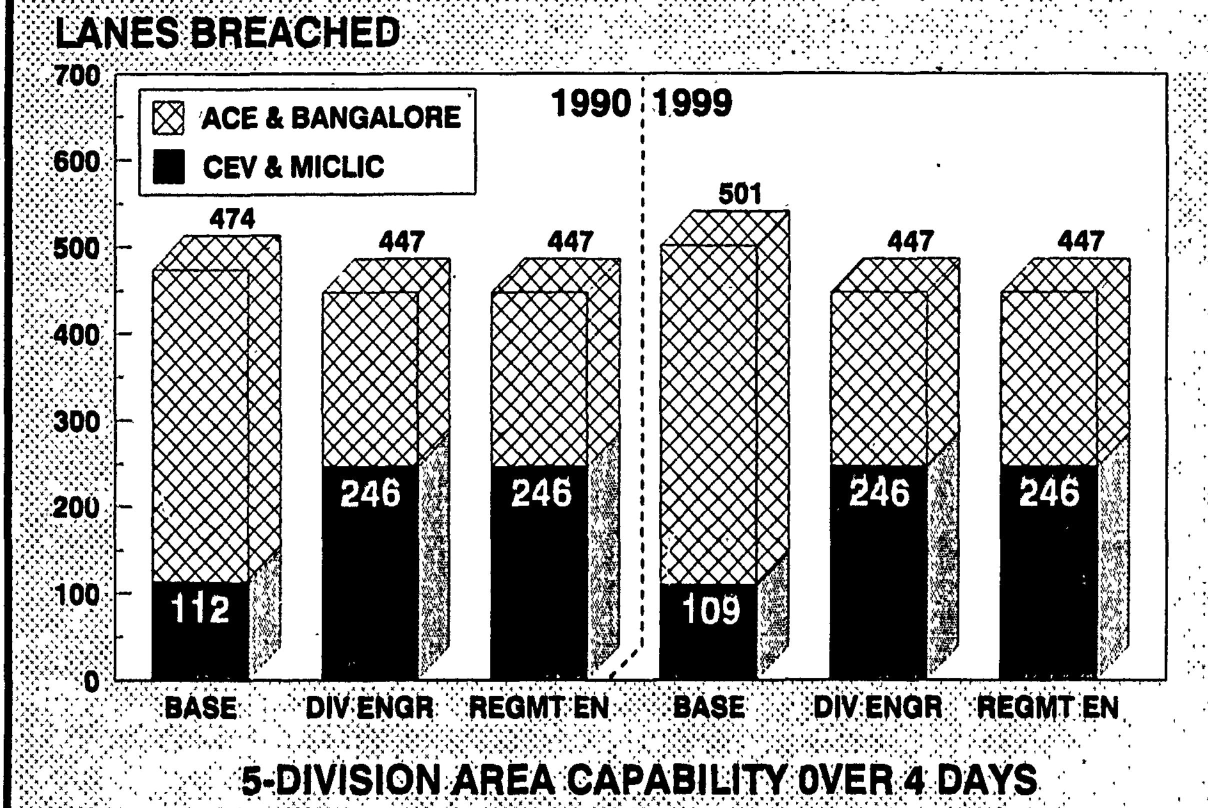


Figure 19. MSR DEVELOPMENT AND MAINTENANCE CAPABILITY (DIVISION ZONE)

Figure 20 shows the last offensive task of breaching complex obstacle lanes. The top part of this figure shows that the three cases are fairly equal. The base case is slightly better, but this is only significant for 1999. The engineer force uses two methods to do this task. After units use all their CEV capability, additional breaching uses the blade of the ACE or bulldozer. The latter method uses more squad power but the base case has this capability to spare. The bottom part of Figure 20 shows the equipment hours used and the munitions depleted. All quantities shown here are less than the worldwide inventory (Figures 9 and 10). So for this task, equipment and manpower are the factors limiting capability.



EQUIPMENT AND MUNITIONS USED AND EXPENDED	1990			1999		
	BASE CASE	DIV ENGR	REGMT EN	BASE CASE	DIV ENGR	REGMT EN
AVLB USES PER DAY	119	112	112	125	112	112
MICLIC USES PER DAY	84	184	184	82	184	184
HEMMS USES PER DAY	119	112	112	125	112	112
BANGALORE TORPEDO (4-DAY TOTAL)	7,609	4,216	4,216	8,225	4,216	4,216

Figure 20. COMPLEX OBSTACLE LANE BREACHING CAPABILITY (DIVISION ZONE)

(2) **Defense. Figure 21** shows the first defense task for the capability of digging vehicle fighting positions. The Regimental Engineer case has the highest capability followed by the Division Engineer case. The base case has the lowest capability. The Regimental Engineer has three more ACEs per battalion than the Division Engineer. This small difference is significant for 15 battalions working 4 days. **Figure 22** shows the capability for maintaining MSRs. As for the offense, the base case has the highest capability. The Division Engineer is a distant second and the Regimental Engineer has no capability. The latter zero capability happens since this organization has no dump trucks. Both the Division Engineer and Regimental Engineer cases use their ACEs for digging positions. This limits their MSR capability because no spare capacity is available.

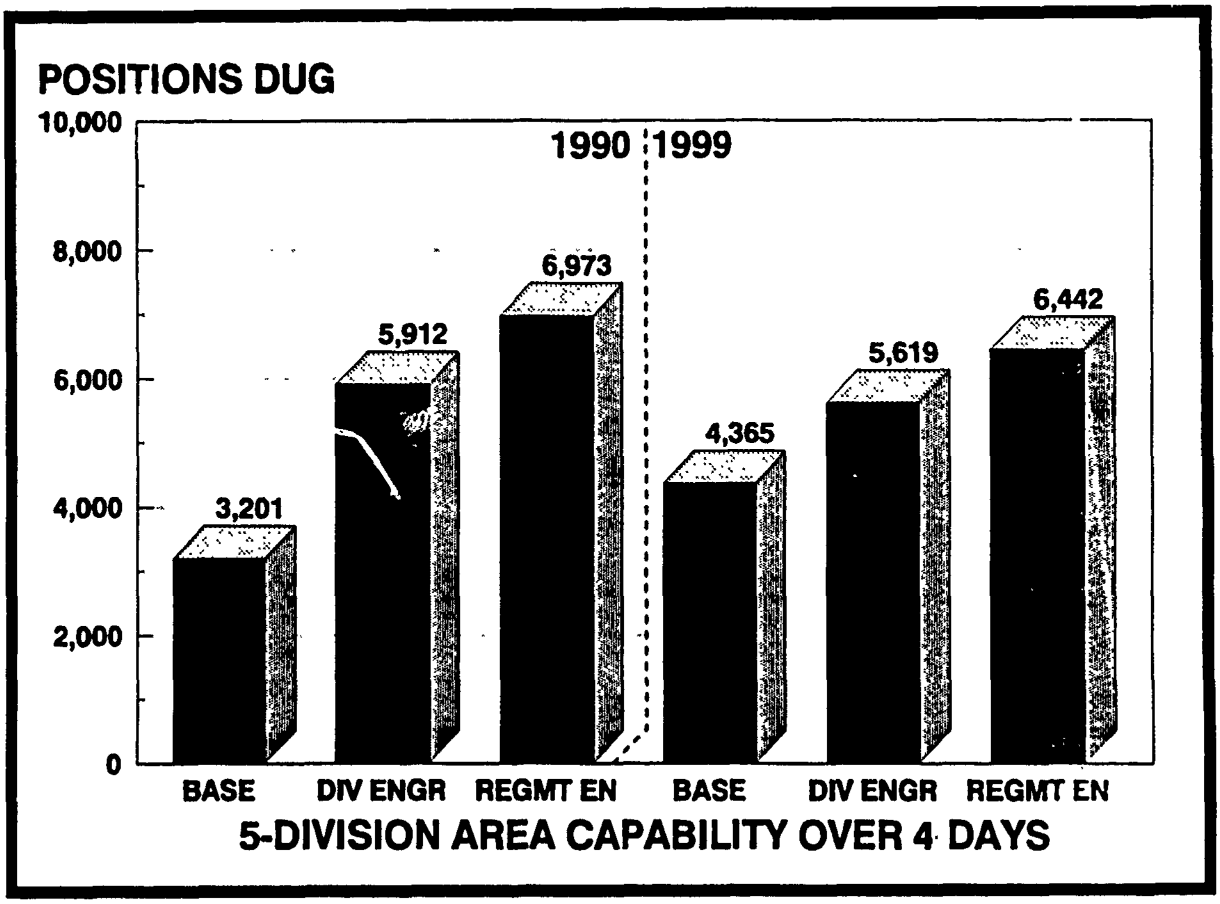


Figure 21. TANK/INFANTRY FIGHTING VEHICLE POSITION DIGGING CAPABILITY (DIVISION ZONE)

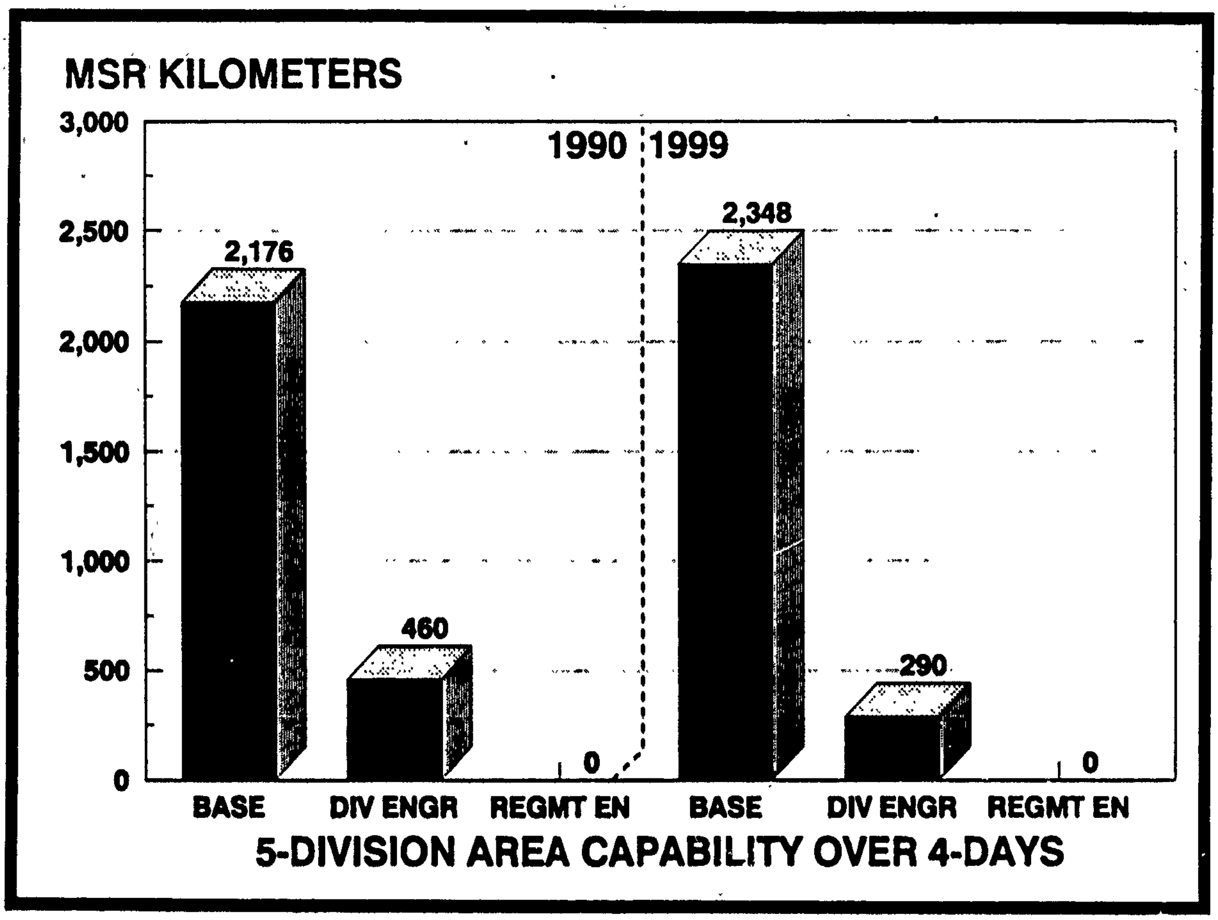
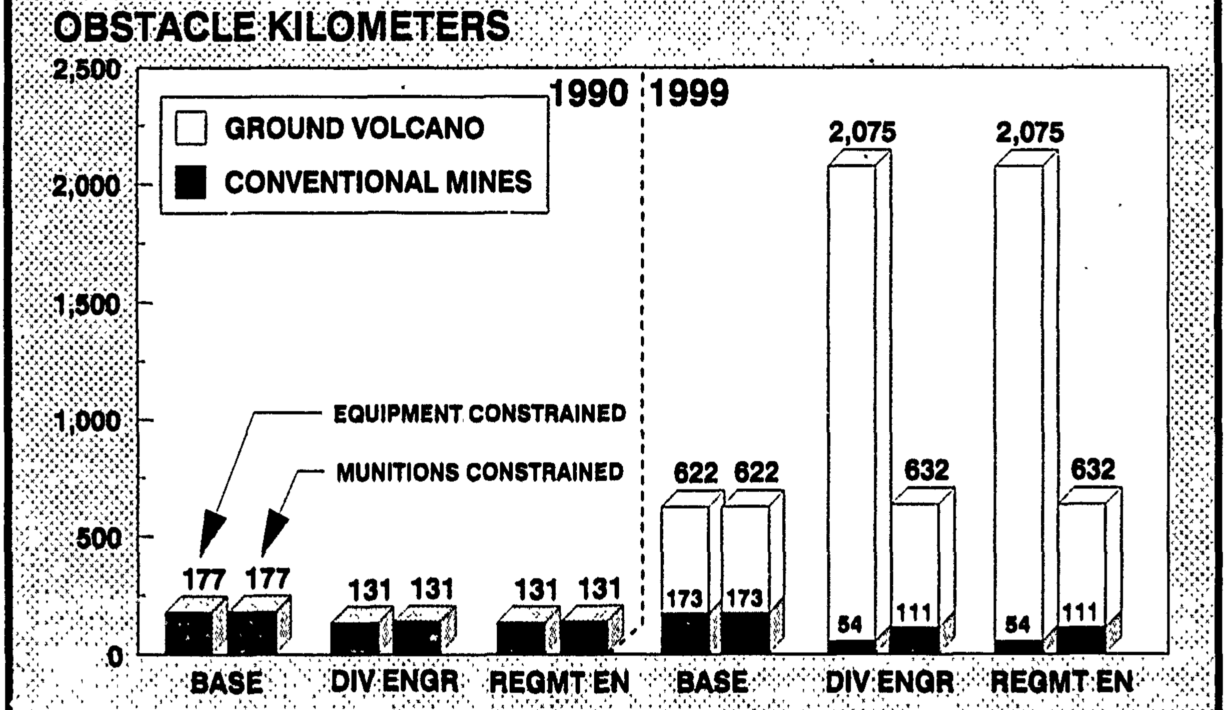


Figure 22. MSR MAINTENANCE CAPABILITY (DIVISION ZONE)

Figure 23 is the final defensive task of obstacle emplacement capability. This analysis shows 12 cases for the first time. ESC expresses each organization period for equipment plus a munitions-constrained case. The 1990 cases have no munitions constraints but are shown for consistency. For 1999, the Division and Regimental cases are equal and more than three times the equipment-constrained base case. However, when we constrain capability by the worldwide availability of munitions, all three options are about equal. The lack of ground VOLCANO mines causes this imbalance. The bottom of Figure 23 clearly shows us this munitions constraint--the 456 canisters of M139 mines are the constraint. The MOPMS, HEMMS, and M-180 demolition kit requirements are smaller because of reduced ground VOLCANO minefield frontage. The Division Engineer and Regimental Engineer cases can emplace more conventional minefields with the reduced ground VOLCANO minefield totals. However, the lack of more available manpower in these two organizations prevents them from overtaking the base case.

b. **1-Division Average.** These comparisons look at one-fifth of the full force, or a 1-division average. The comparisons are for the complete 4-day conflict. ESC shows comparisons for each of the three organizations. Each organization comparison shows three tasks for 1990 and 1999. This type display gives an overall glimpse at what engineers are doing for one division. The three offense tasks are shown first, followed by the remaining three defensive tasks.



5-DIVISION AREA CAPABILITY OVER 4 DAYS

EQ=EQUIPMENT LIMITED	1990			1999		
MUN=MUNITION LIMITED	BASE CASE	DIV ENGR	REGMT EN	BASE CASE	DIV ENGR	REGMT EN
CONV AT MINES - EQ	291,029	214,639	214,639	283,967	88,282	88,282
- MUN					182,039	182,039
CONV AP MINES - EQ	160,088	118,068	118,068	156,203	48,562	48,562
- MUN					100,135	100,135
M139 MINES(960)- EQ	0	0	0	393	1,768	1,768
- MUN					456	456
40# SHAPED CHG- EQ	1,063	784	784	1,037	322	322
- MUN					665	665
40# CRATER CHG- EQ	1,772	1,307	1,307	1,729	537	537
- MUN					1,108	1,108
MOPMS - EQ	0	0	0	2,470	11,116	11,116
- MUN					2,868	2,868
HEMMS PER DAY - EQ	0	0	0	14	63	63
- MUN					16	16
M180 DEMO KIT - EQ	0	0	0	2,246	10,105	10,105
- MUN					2,607	2,607

Figure 23. MINEFIELD OBSTACLE AND ROAD CRATER EMPLACEMENT CAPABILITY (DIVISION ZONE)

(1) **Offense. Figure 24** shows the capability for the three offensive tasks. The comparative results are the same as for the 5-division comparisons. However, the quantities show how much is done for each division. For example, the Division Engineer and Regimental Engineer organizations breach 89 obstacle lanes during four days. This is about 30 lanes per battalion and 7 to 8 lanes per day per battalion. The base case has two larger battalions that breach 95 to 100 obstacle lanes in four days. This equals 24 to 25 lanes per battalion day. The Division Engineer and Regimental Engineer organizations have decreased MSR capability in 1999. This decrease from 1990 is due to the conversion of all dozers to ACEs. The study assumes that the ACE has only 85 percent of the dozer's digging capability at the obstacle site. From these offense task comparisons, it is difficult to determine the best overall organizational structure.

(2) **Defense. Figure 25** shows the capability for the three defensive tasks. From this figure the base case has the highest overall capability. However, the Division Engineer and Regimental Engineer organizations have superior position digging capability. These fighting positions use most of the ACE or D7 dozer capability. The defense also needs this blade capability for the second task of MSR maintenance. The question arises--what happens if we transfer blade capability to MSR maintenance? ESC will answer this question later in an excursion (paragraph 16). For the division zone analysis, the number of dug positions are reasonable estimates. For example, a heavy division has about 400 fighting vehicles. Engineers can dig in these vehicles 1 to 3 times daily. This equals 1600 to 4800 positions. The analysis shows that the Division Engineer organization digs about 1100 positions and the Regimental Engineer between 1300 to 1400.

c. **Observations. Figure 26** shows case rankings after calculating 12 division zone cases. For this observation, ESC arranged the results by the four engineer missions. Mobility represents the two offensive breaching tasks. The one defensive obstacle task represents countermobility while the digging defensive task represents survivability. The two MSR maintenance tasks, one in both offense and defense, represent sustainment engineering. The last column of Figure 26 shows all four missions equally averaged. ESC also gave mobility and countermobility double weight, but the all-task average did not change. Overall, there is no distinction between organizational concepts. However, the base case is the best in 1990. The Division Engineer and Regimental Engineer concepts are best in 1999 with no munitions constraints. With munitions constraints, all three options are equal in 1999. Note that mobility rankings are equal with all options ranked at 2. Of the two mobility tasks, the base case was highest in one and the Division Engineer and Regimental Engineer better in the other. Because of this divergence, we gave the overall mobility average rating a 2 for all concepts rather than a 1. A deeper look at mobility shows that no new major mobility system is available to enhance capability by 1999. So the Division Engineer and Regimental Engineer organizations are no better off than today's base case. This could change between 2000 and 2010 when new developments may be fielded. Such developments include laser mine neutralizers and vehicle magnetic signature duplicators. Significant observations also include:

(1) The base case is superior at MSR maintenance, especially during the defense. This does not imply a flaw to the Division Engineer and Regimental Engineer organizations. Planners intentionally moved this capability in the latter organizations to Corps units. The next paragraph will test this doctrine as the analysis adds 12 more cases using corps units.

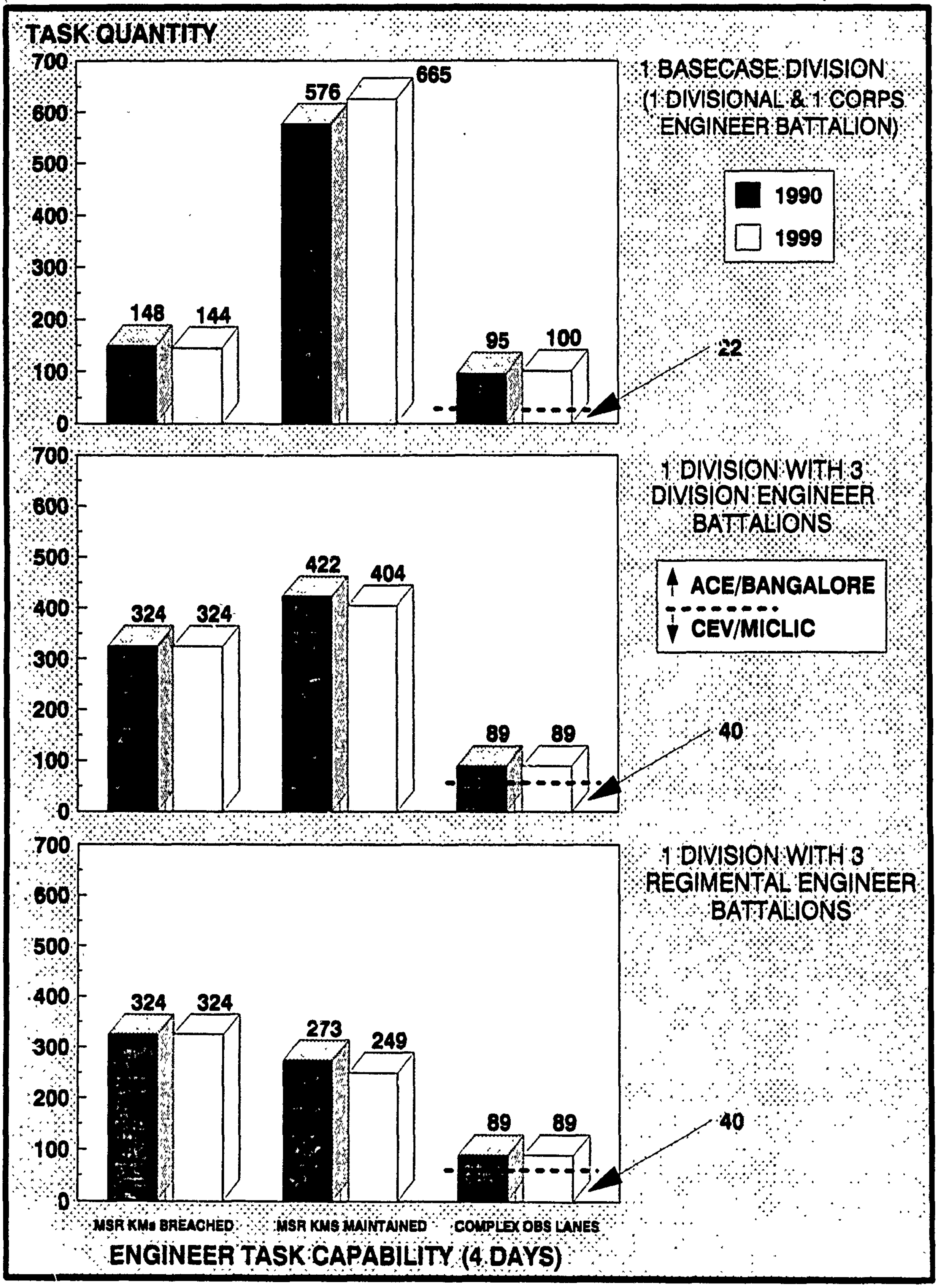


Figure 24. OFFENSE TASK CAPABILITY (DIVISION ZONE)

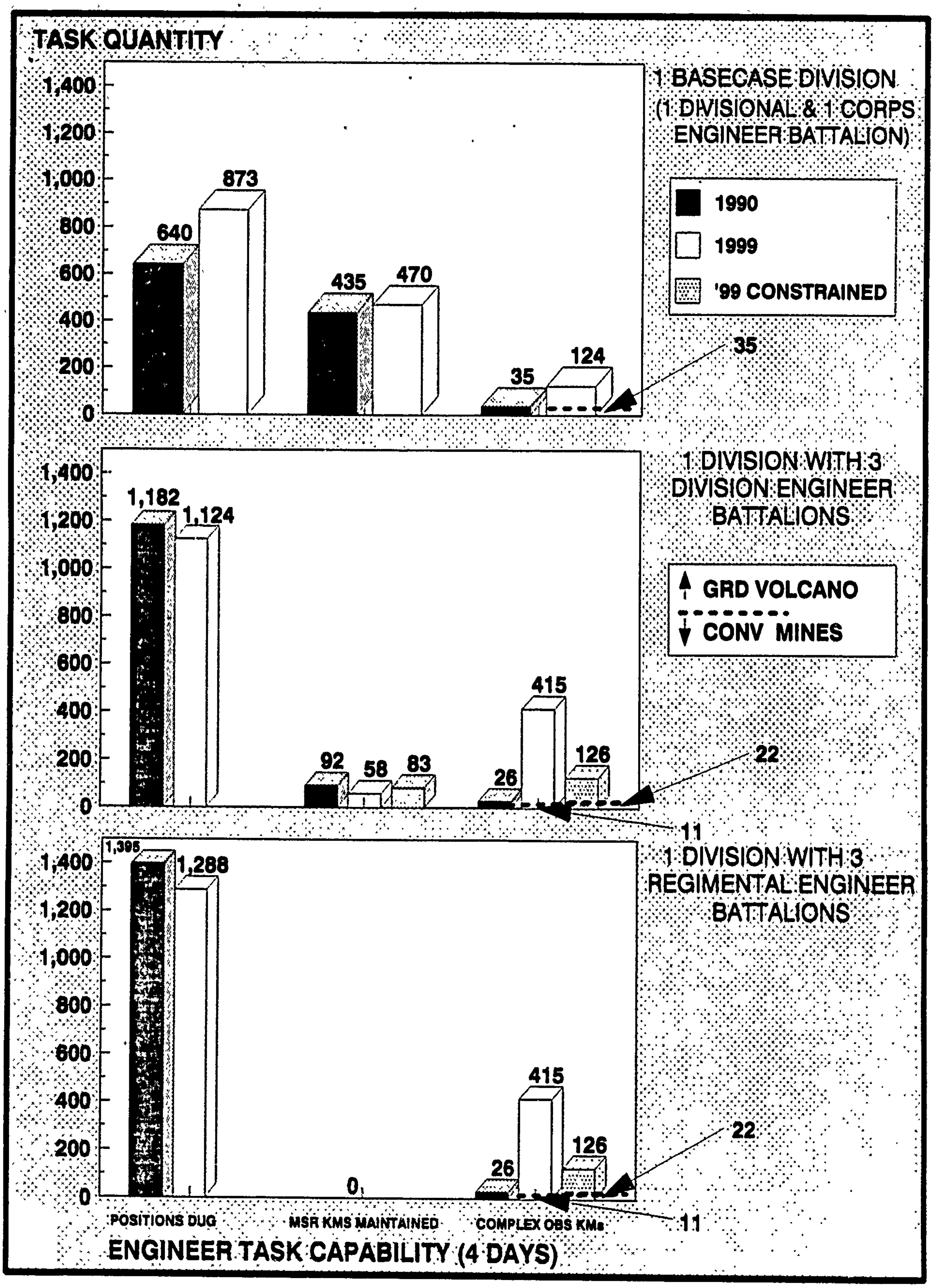


Figure 25. DEFENSE TASK CAPABILITY (DIVISION ZONE)

CASES	RANKINGS				
	MOBILITY	COUNTER-MOBILITY	SURVIVABILITY	SUSTAINMENT ENGINEERING	ALL-TASK AVERAGE
1990:					
Base Case	2	1	3	1	1
Division Engineer	2	2	2	2	2
Regimental Engineer	2	2	1	3	2
1999 -- Only Equipment:					
Base Case	2	3	3	1	3
Division Engineer	2	1	2	2	1
Regimental Engineer	2	1	1	3	1
1999 -- Munitions & Equipment:					
Base Case	2	1	3	1	1
Division Engineer	2	1	2	2	1
Regimental Engineer	2	1	1	3	1

Figure 26. DIVISION ZONE MISSION OBSERVATIONS

(2) The Division Engineer and Regimental Engineer organizations have less squad Sappers than the base case. Since rankings are equal, ESC concluded that new equipment is less man intensive. This is especially true if scatterable minefield munitions are available.

(3) Munitions limit the mine-laying task, not equipment or squad capability. This indicates the Army needs conventional mines and additional manpower (of base case units) for an interim period. This period ends when the Army manufactures more scatterable mines.

13. **CORPS PLUG.** This option set adds the corps units working forward of the division rear boundary. Earlier, Figure 4 listed the TOE quantities of the corps plug units. **Figure 27** shows the total equipment inventory in the 5-division area of each option case as used in the calculations. This inventory includes the equipment of the division-zone units plus the units that make up the corps plug.

TYPE	1990			1999		
	BASE CASE	DIV ENGR	REGMT ENGR	BASE CASE	DIV ENGR	REGMT ENGR
ACE	67	162	168	125	347	430
D7 Bulldozer	126	228	267	206	43	5
Total Blades	193	390	435	331	390	435
CEV	41	120	120	40	120	120
AVLB	110	240	180	120	240	240
Ground VOLCANO	0	0	0	20	120	120
MICLIC	0	240	180	166	240	180
Loaders	82	30	30	84	30	30
Graders	36	30	30	45	30	30
Dump Trucks	546	465	285	1132	465	285

Figure 27. CORPS PLUG EQUIPMENT PER 5-DIVISION FORCE

a. **Unit Allocations.** For this option set, ESC used two methods to determine corps units working in the division zone. For the base case, ESC used the actual operation DESERT STORM laydown of VII Corps units. **Figure 28** shows this laydown converted to this report's 5-division force. Note that this method calculates a single-division slice and multiplies this by 5 to get the study's allocation. For the Division Engineer and Regimental Engineer allocation, ESC used a second method that applies to both. This method is an allocation rule that appeared in the *Engineer Structure Study* and was part of emerging doctrine[8]. **Figure 29** shows this method and the division allocations that resulted. These allocations are for study purposes only as the Army has not published the final doctrine.

[8] See footnote 1 on page 2 of this study.

	CORPS LAYDOWN*	DIVISION SLICE	SACAPO STUDY
MANEUVER UNITS:			
ACR	1.00	-	-
Armor Division	2.00	-	-
Mechanized Division	1.00	-	-
Total Divisions	3.33	1.00	5.00
CORPS ENGINEER UNITS:			
Mechanized Battalions	5.00**	1.50	7.50
Wheeled Battalion	1.00	0.30	1.50
Combat Heavy Battalion	3.00	0.90	NA

* 14 February 1991.
** Includes extra divisional battalion.

Figure 28. CORPS PLUG ALLOCATION RULES (BASE CASE)

	DIVISION ALLOCATION	SACAPO STUDY
HEAVY DIVISIONS	1	5
CORPS ENGINEER UNITS:		
Mechanized Battalion	1	5
Wheeled Battalion	0	0
CSE Company	1	5

Figure 29. CORPS PLUG ALLOCATION RULES (DIVISION ENGINEER AND REGIMENTAL ENGINEER CASES)

b. **5-Division Force.** These comparisons are the same type as presented before for the division zone.

(1) **Offense. Figure 30** shows the capability for breaching MSR minefield lanes. The Division Engineer and Regimental Engineer organizations provide more CEVs to the force. Relative rankings remain the same, but now the base case has just one-third versus one-half the capability of the other cases. **Figure 31** shows the capability for developing and maintaining MSRs. Here the doctrine impact of more construction equipment in corps units is clear. The capability added to the Division Engineer and Regimental Engineer organizational cases is the same. However, the Division Engineer is slightly higher because its division-zone contribution is larger. All cases are within 10 percent of each other and are not significantly different in rank.

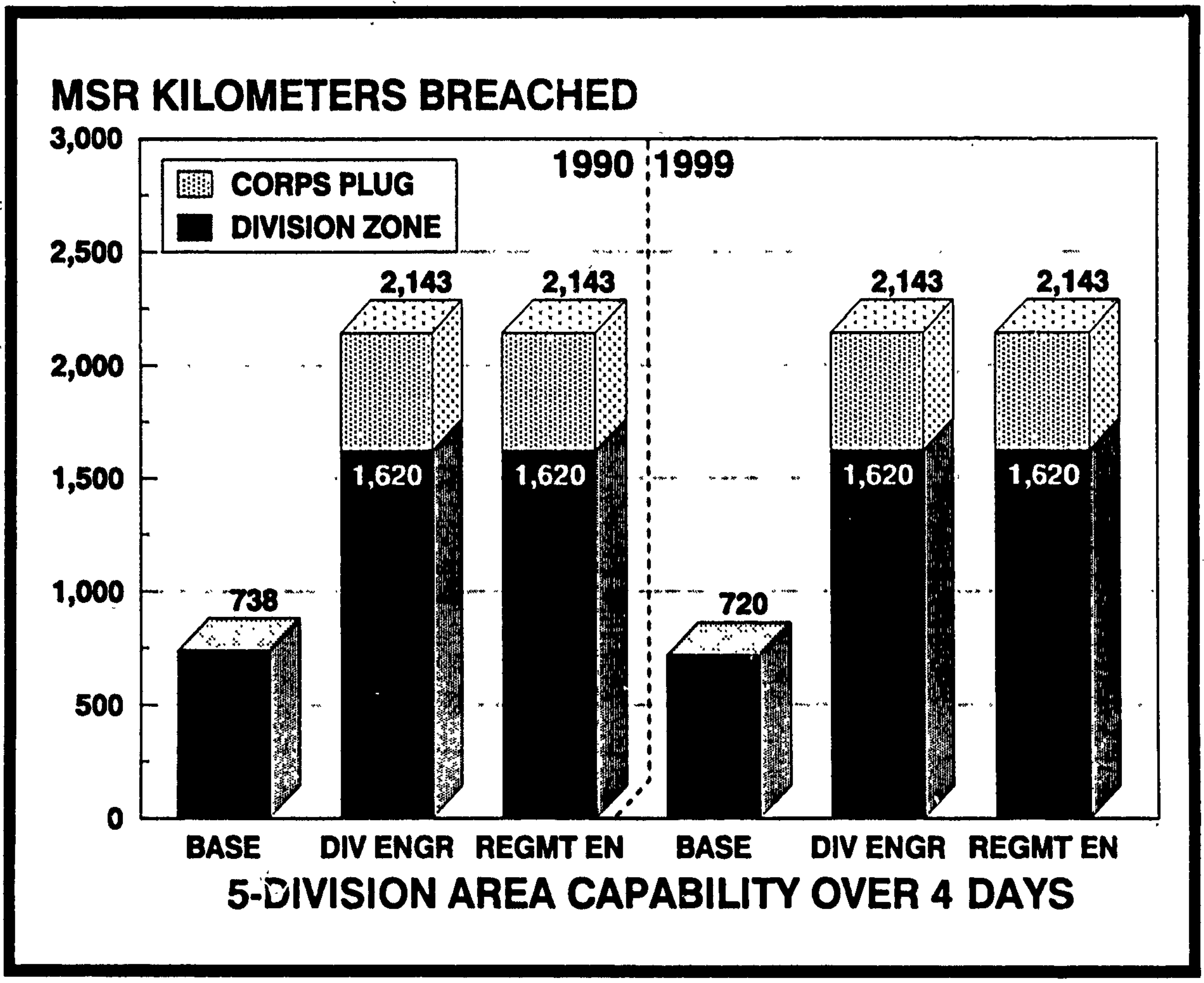


Figure 30. MSR MINEFIELD LANE BREACHING CAPABILITY (CORPS PLUG)

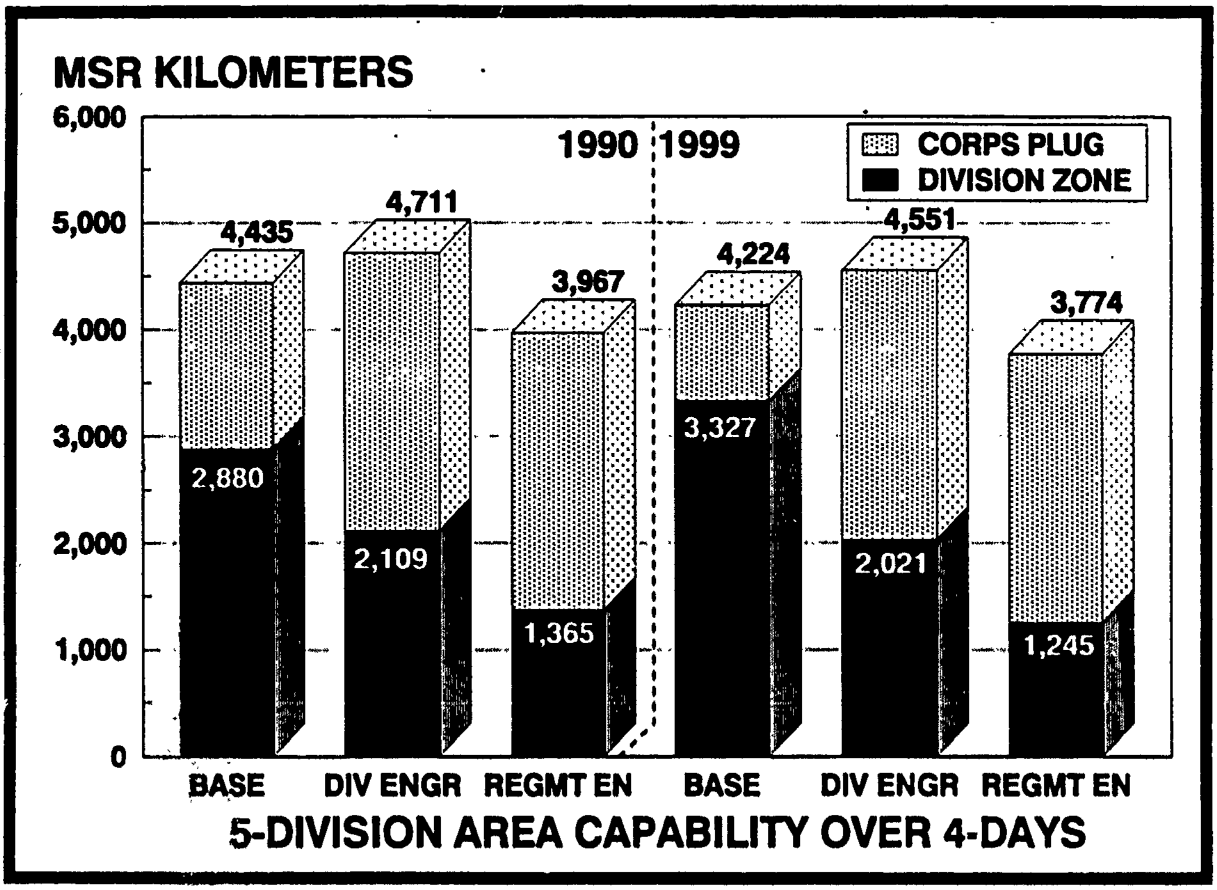
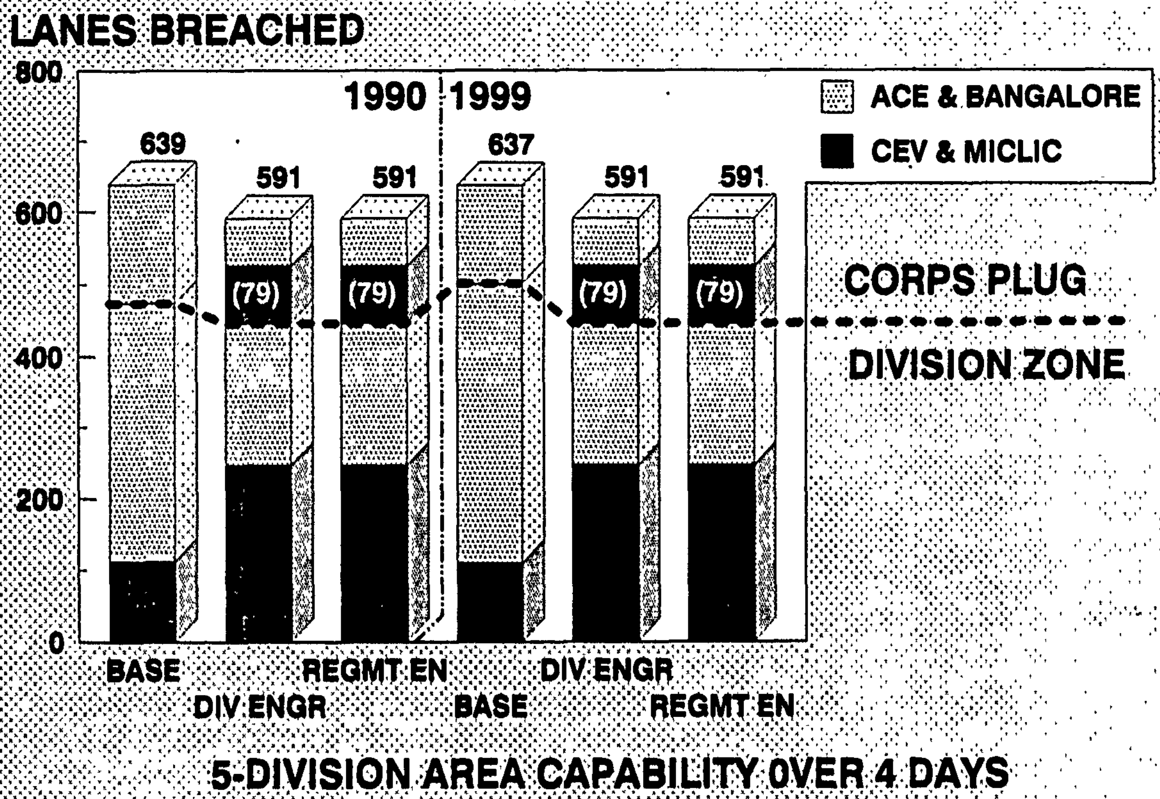


Figure 31. MSR DEVELOPMENT AND MAINTENANCE CAPABILITY (CORPS PLUG)

Figure 32 shows the final offensive task of breaching complex obstacle lanes. This time, the base cases still have the most capability. However, the difference is not significant for either 1990 or 1999. The Division Engineer and Regimental Engineer organizations add CEV as well as ACE/dozer capability. The base case has only ACE/dozer-added capability, with extra manpower to equal the gains in the other cases. The bottom part of Figure 32 again shows that no bridging, munitions, or marking system quantities limit the offensive tasks.



EQUIPMENT AND MUNITIONS USED AND EXPENDED	1990			1999		
	BASE CASE	DIV ENGR	REGMT EN	BASE CASE	DIV ENGR	REGMT EN
AVLB USES PER DAY	160	148	148	159	148	148
MICLIC USES PER DAY	84	244	244	82	244	244
HEMMS USES PER DAY	160	148	148	159	148	148
BANGALORE TORPEDO (4-DAY TOTAL)	11,064	5,599	5,599	11,087	5,599	5,599

Figure 32. COMPLEX OBSTACLE LANE BREACHING CAPABILITY (CORPS PLUG)

(2) **Defense.** **Figure 33** shows the first defense task for the capability of digging vehicle fighting positions. The rankings again place the Regimental Engineer case first, followed by the Division Engineer case. The base case still has the lowest capability. **Figure 34** shows the capability for maintaining MSRs. Like the division zone, the base case has the highest capability. The Division Engineer is second and the Regimental Engineer is last. For the similar offensive task, the rankings were equal.

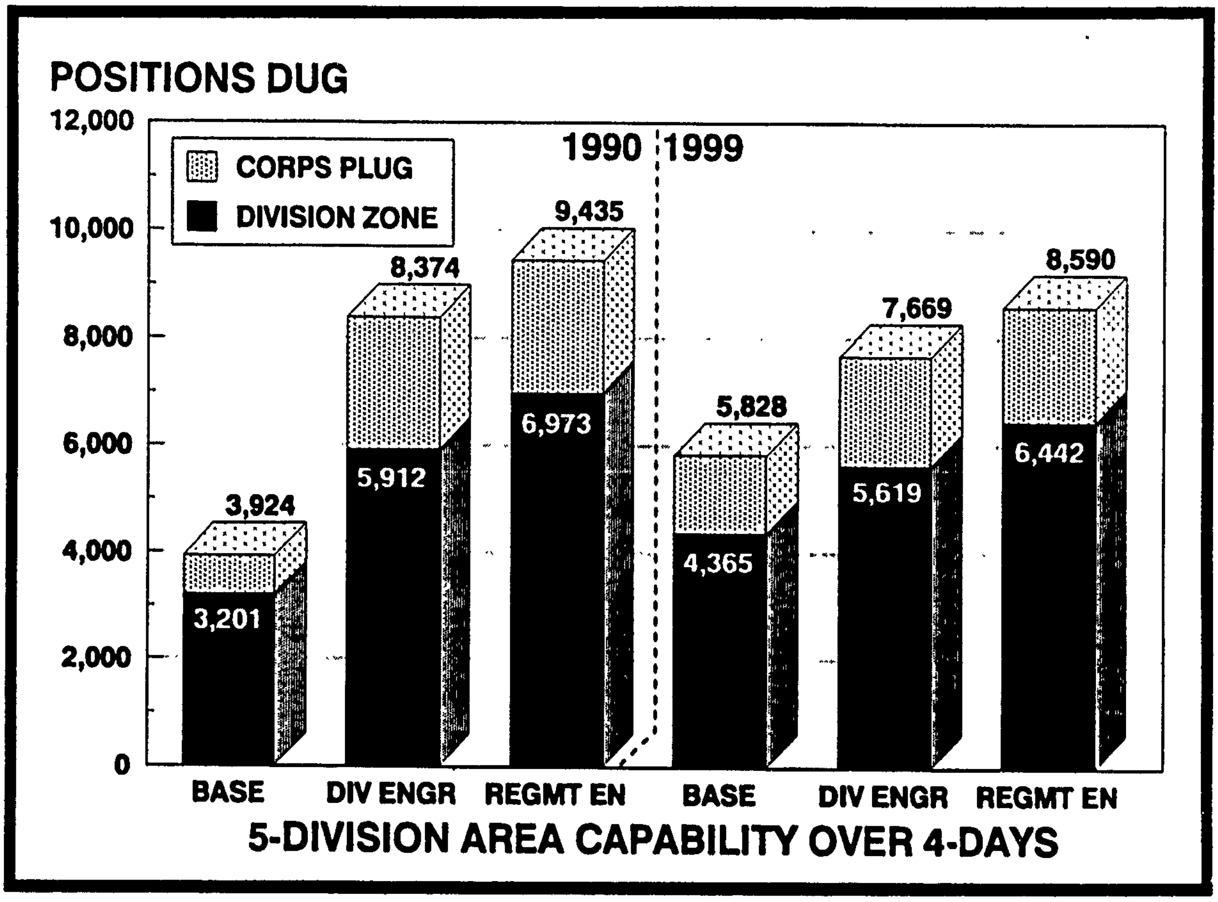


Figure 33. TANK/INFANTRY FIGHTING VEHICLE POSITION DIGGING CAPABILITY (CORPS PLUG)

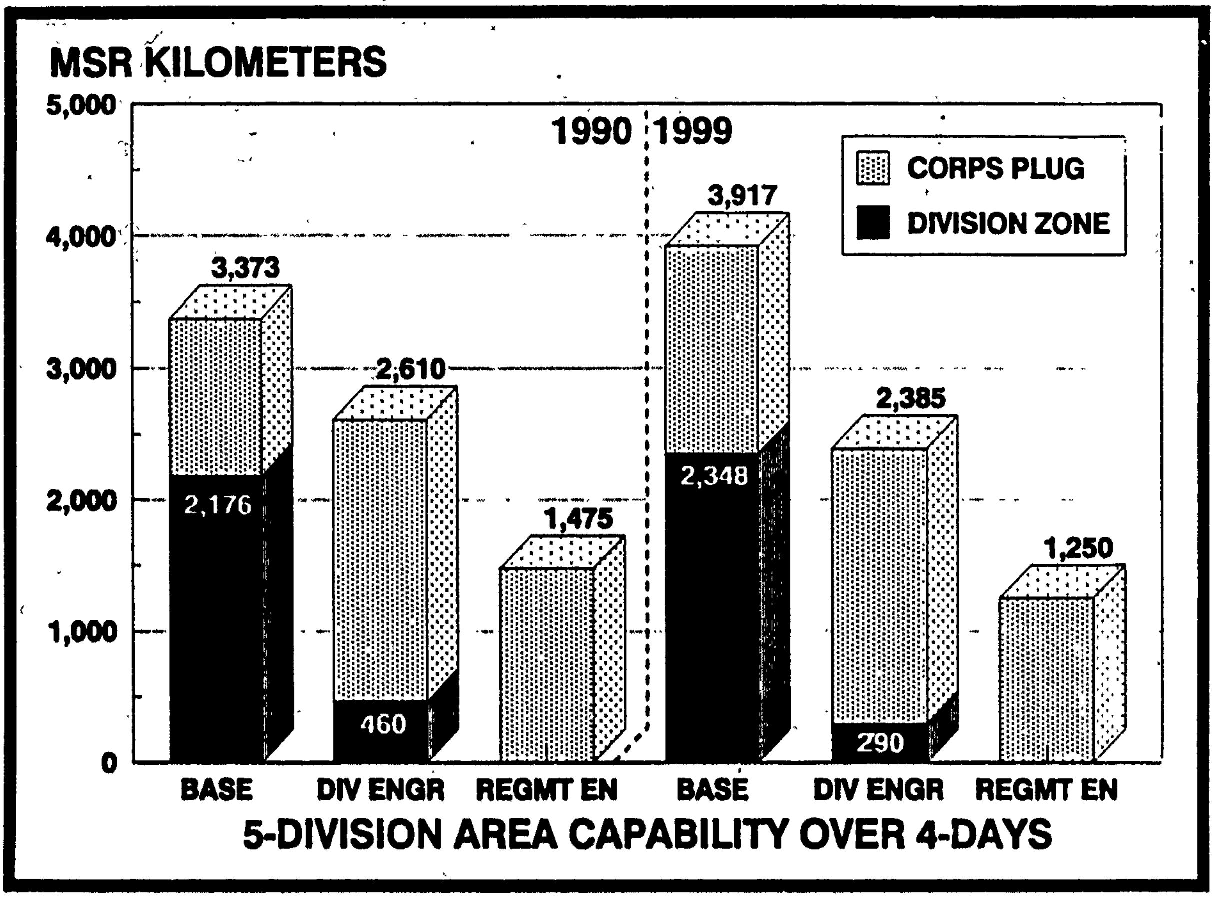
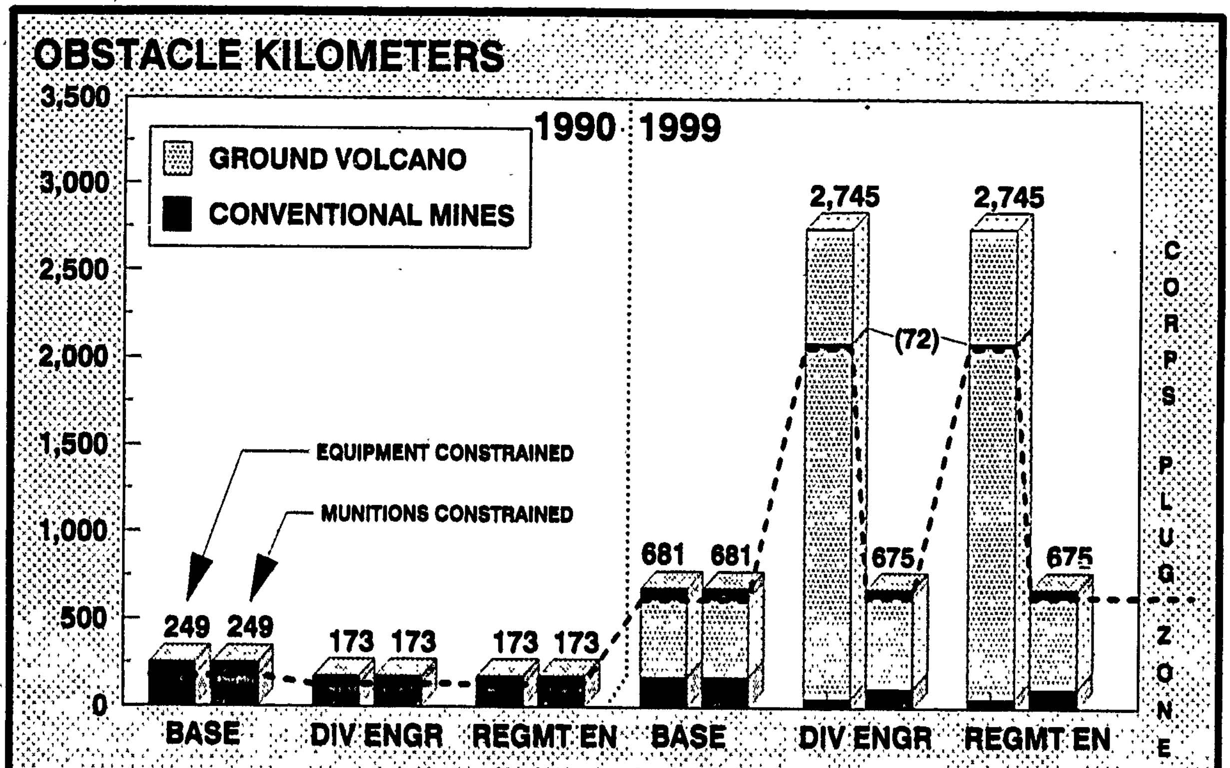


Figure 34. MSR MAINTENANCE CAPABILITY (CORPS PLUG)

Figure 35 is the final defensive task of obstacle emplacement capability. ESC's analysis again shows 12 cases. Although the 1990 cases have no munitions constrains, they are shown for consistency. For 1999, the Division and Regimental cases are equal and are more than four times greater than the equipment-constrained base case. However, when we constrain capability by the worldwide availability of munitions, all three options are again about equal. The lack of ground VOLCANO mines causes this imbalance. The bottom of Figure 35 more clearly shows us this munitions constraint. The 456 canisters of M139 mines are again the constraint. The MOPMS, HEMMS, and M-180 demolition kits are smaller because of reduced ground VOLCANO minefield frontage. The Division Engineer and Regimental Engineer cases are unable to emplace many more conventional minefields because of reduced available manpower.



5-DIVISION AREA CAPABILITY OVER 4 DAYS

EQ=EQUIPMENT LIMITED	1990			1999		
MUN=MUNITION LIMITED	BASE CASE	DIV ENGR	REGMT EN	BASE CASE	DIV ENGR	REGMT EN
CONV AT MINES - EQ	409,658	284,694	284,694	381,579	117,535	117,535
- MUN					252,095	252,095
CONV AP MINES - EQ	225,343	156,604	156,604	209,897	64,653	64,653
- MUN					138,671	138,671
M139 MINES(960)- EQ	0	0	0	393	2,339	2,339
- MUN					456	456
40# SHAPED CHG- EQ	1,496	1,040	1,040	1,394	429	429
- MUN					921	921
40# CRATER CHG- EQ	2,494	1,733	1,733	2,323	716	716
- MUN					1,535	1,535
MOPMS - EQ	0	0	0	2,470	14,705	14,705
- MUN					2,868	2,868
HEMMS PER DAY - EQ	0	0	0	14	84	84
- MUN					16	16
M180 DEMO KIT - EQ	0	0	0	2,246	13,368	13,368
- MUN					2,607	2,607

Figure 35. MINEFIELD OBSTACLE AND ROAD CRATER EMPLACEMENT CAPABILITY (CORPS PLUG)

c. **1-Division Average.** These comparisons again look at one-fifth of the full force, or a 1-division average. The comparisons are for the complete 4-day conflict. ESC shows comparisons for each of the three organizations. Each organizational comparison shows three tasks for both 1990 and 1999. The three offense tasks are shown first, followed by the remaining three defensive tasks.

(1) **Offense. Figure 36** shows the capability for the three offensive tasks. This figure also shows the ACE method percentage for the capability added to the third task. The third task breaches lanes using either the CEV and MICLIC or the ACE/dozer with the Bangalore torpedo. The results are similar for two of the three tasks. This display clearly shows the Division Engineer and Regimental Engineer organizations better than the base case. The Division Engineer has a slight edge over the Regimental Engineer organization. We can explain the latter edge by noting that the Division Engineer option has the highest MSR maintenance capability.

(2) **Defense. Figure** 37 shows the capability for the three defensive tasks. The method used for the third task is also shown on this figure. The added capability to emplace complex obstacles for 1990 always uses conventional explosives. The figure shows the 1999 added capability taken up by the ground VOLCANO system. The overall highest performing option is hard to determine. Again, the results show that a blade excursion would help clarify the results.

d. **Observations. Figure 38** shows case rankings after calculating 12 corps plug cases. ESC again arranged the results by engineer missions. The last column of Figure 38 now shows the Division Engineer and Regimental Engineer concepts best in 1990. The same two concepts also have the highest capability in 1999, to include with munitions constraints. If ESC gives double weight to mobility and countermobility, the rankings do not change. Overall, the Division Engineer and Regimental Engineer concepts have the highest capability. However, no distinction can be made between these two concepts. Significant observations also include:

(1) The base case continues to be superior at MSR maintenance, but only because of this case's advantage during the defense. Engineer planners' intention to switch this capability to Corps units is now apparent in the offense.

(2) The Division Engineer and Regimental Engineer organizations have gained an edge in mobility. This observation supports the thrust of new and emerging doctrine that emphasizes the offense. However, no edge is discernable to the Division Engineer organization over the Regimental Engineer organization.

(3) Munitions still severely limit mine-laying, not equipment or squad, capability.

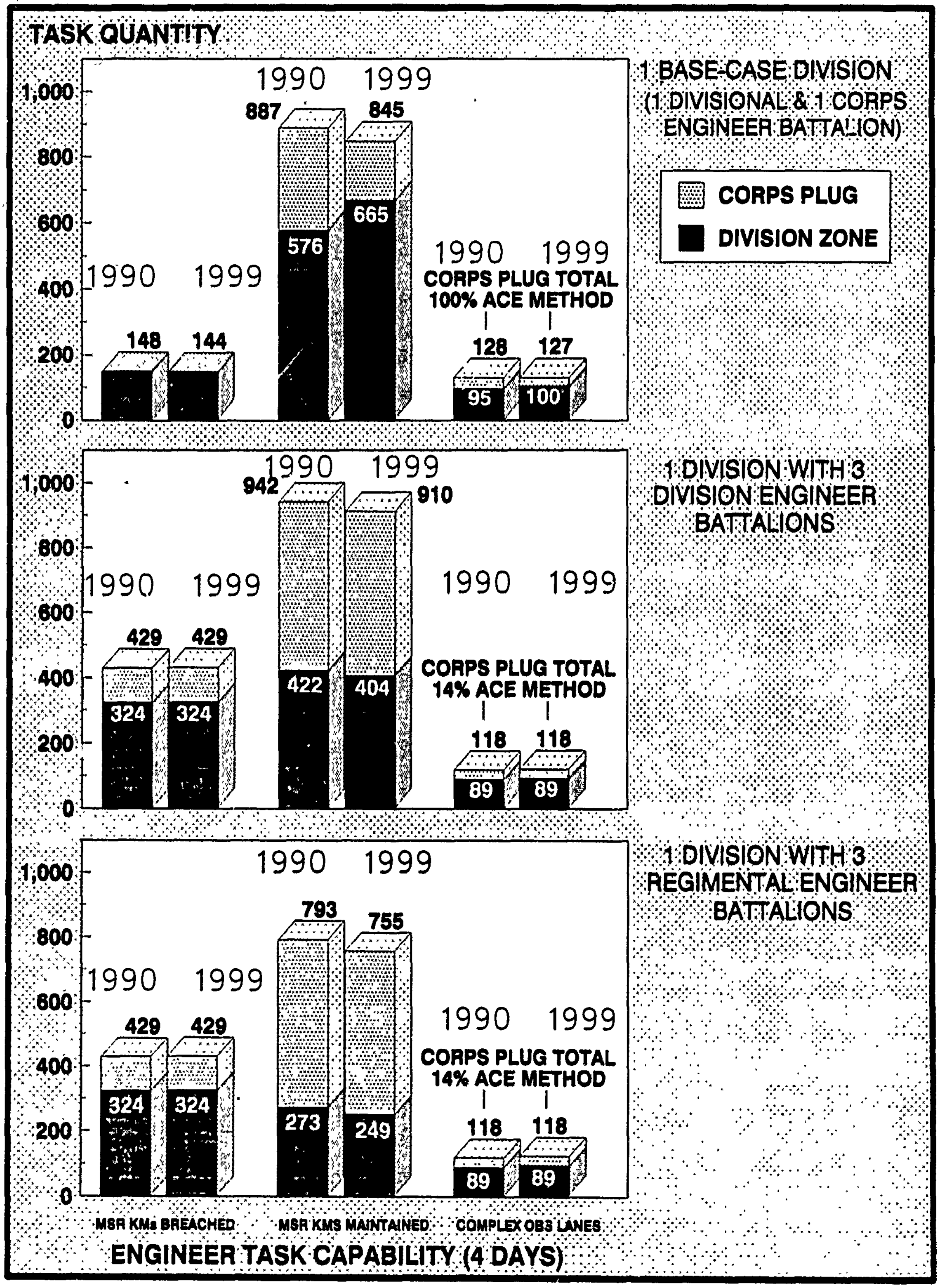


Figure 36. OFFENSE TASK CAPABILITY (CORPS PLUG)

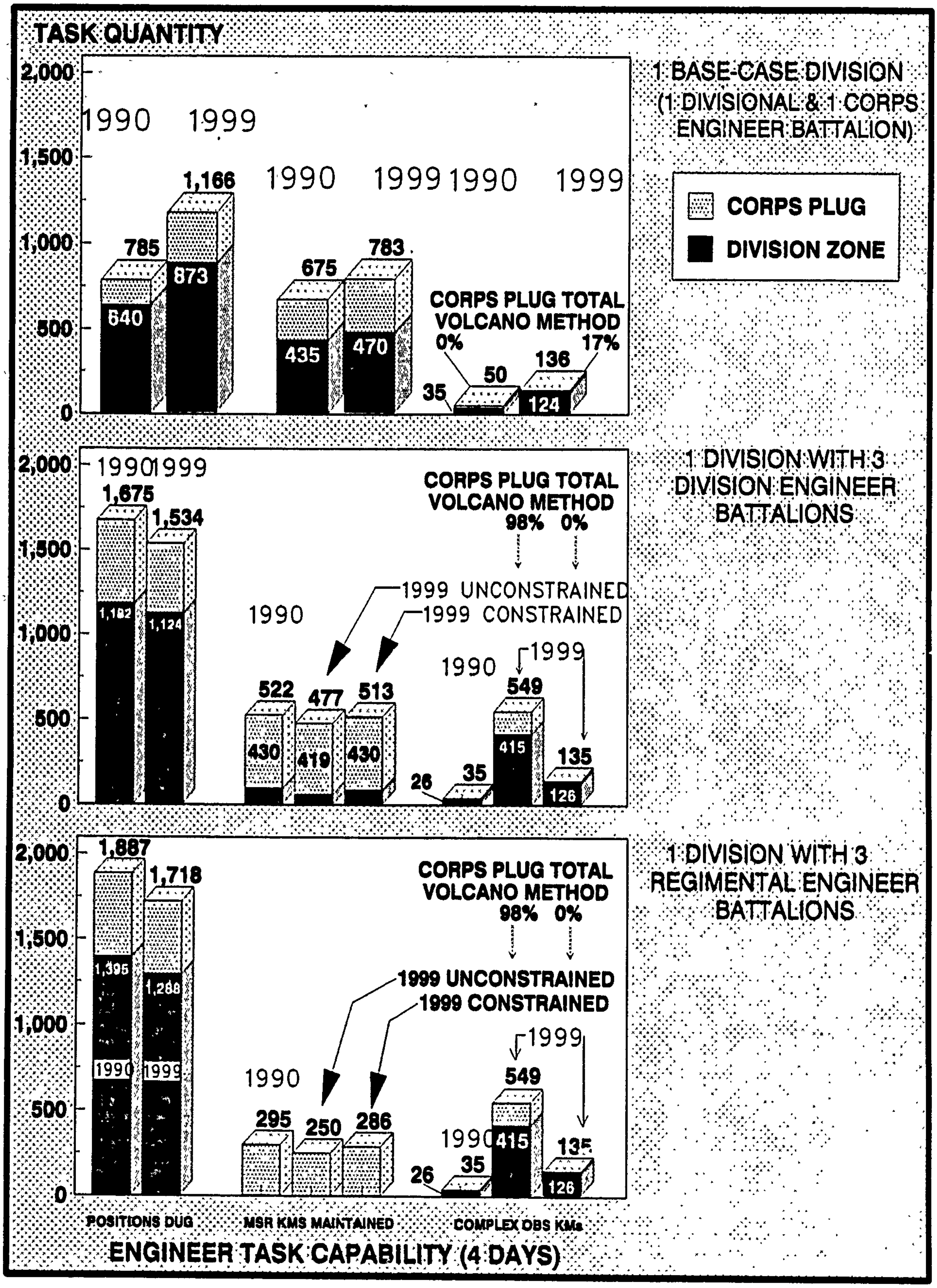


Figure 37. DEFENSE TASK CAPABILITY (CORPS PLUG)

CASES	RANKINGS				
	MOBILITY	COUNTER-MOBILITY	SURVIVABILITY	SUSTAINMENT ENGINEERING	ALL TASK AVERAGE
1990:					
Base Case	3	1	3	1	3
Division Engineer	1	2	2	2	1
Regimental Engineer	1	2	1	3	1
1999 -- Only Equipment:					
Base Case	3	3	3	1	3
Division Engineer	1	1	2	2	1
Regimental Engineer	1	1	1	3	1
1999 -- Munitions & Equipment:					
Base Case	3	1	3	1	3
Division Engineer	1	1	2	2	1
Regimental Engineer	1	1	1	3	1

Figure 38. CORPS PLUG MISSION OBSERVATIONS

14. **DIVISION SLICE EXCURSION.** This option set counts all corps units equally divided between the maneuver divisions. This excursion has more units for a 5-division force than the corps plug. The base case has about 2½ more engineer battalions. The Division Engineer and Regimental Engineer options have 6 and 8 more respectively. (Figure 4 on page 6 lists the TOE quantities of the corps plug units.) **Figure 39** shows the equipment inventory of each option case as used in the calculations.

TYPE	1990			1999		
	BASE CASE	DIV ENGR	REGMT ENGR	BASE CASE	DIV ENGR	REGMT ENGR
ACE	67	162	168	125	347	430
D7 Bulldozer	178	380	378	206	195	116
Total Blades	245	542	546	331	542	546
CEV	41	116	128	40	116	128
AVLB	110	232	180	120	232	257
Ground VOLCANO	0	0	0	20	137	154
MICLIC	0	232	180	166	232	180
Loaders	121	131	90	84	131	90
Graders	69	88	103	45	88	103
Dump Trucks	850	847	739	1132	847	739

Figure 39. DIVISION SLICE EQUIPMENT PER 5-DIVISION FORCE

a. **Unit Allocations.** For this option set, ESC determined the number of corps units using two methods. For the base case, ESC used the actual operation DESERT STORM laydown of VII Corps units. **Figure 40** shows this laydown converted to this report's 5-division force. For the Division Engineer and Regimental Engineer allocation, ESC used doctrinal literature. **Figure 41** shows Division Engineer allocations using the *Engineer Structure Study*[9]. **Figure 42** shows the Regimental Engineer allocations using draft FM 5-71-100, Regimental Engineer Combat Operations.

[9] See footnote 1 on page 2 of this study.

	CORPS LAYDOWN*	DIVISION SLICE	SACAPO STUDY
MANEUVER UNITS:			
ACR	1.00	-	-
Armor Division	2.00	-	-
Mechanized Division	1.00	-	-
Total Divisions	3.33	1.00	5.00
CORPS ENGINEER UNITS:			
Mechanized Battalions	5.00**	1.50	7.50
Wheeled Battalion	2.00	0.60	3.00
CSE Company	2.00	0.60	3.00

* *14 February 1991.*
** *Includes extra divisional battalion.*

Figure 40. DIVISION SLICE ALLOCATION RULES (BASE CASE)

	CORPS LAYDOWN*	DIVISION SLICE	SACAPO STUDY
MANEUVER UNITS:			
ACR	1.00	-	-
Armor Division	1.00	-	-
Mechanized Division	3.00	-	-
Separate Mech Brigade	1.00	-	-
Total Divisions	4.67	1.00	5.00
CORPS ENGINEER UNITS:			
Mechanized Battalions	4.00	0.86	4.30
Wheeled Battalion	5.00	1.07	5.35
CSE Company	7.00	1.50	7.50

* *Page E-10, Volume III, Engineer Structure Study*

Figure 41. DIVISION SLICE ALLOCATION RULES (DIVISION ENGINEER CASE)

	CORPS LAYDOWN*	DIVISION SLICE	SACAPO STUDY
MANEUVER UNITS:			
ACR	1.00	-	-
Heavy Division	4.00	-	-
Separate Heavy Brigade	1.00	-	-
Total Divisions	4.67	1.00	5.00
CORPS ENGINEER UNITS:			
Mechanized Battalions	6.00	1.28	6.40
Wheeled Battalion	4.00	0.86	4.30
CSE Company	10.00	2.14	10.70

** Page 1-3, FM 5-71 (Draft), February 1991.*

Figure 42. DIVISION SLICE ALLOCATION RULES (REGIMENTAL ENGINEER CASE)

b. **5-Division Force.** These comparisons are the same type as presented before for the division zone. The discussions note the differences in ranking from the corps plug results.

(1) **Offense. Figure 43** shows the capability for breaching MSR minefield lanes. The Division Engineer and Regimental Engineer organizations provide slightly more CEVs to the force than the corps plug. Relative rankings remain the same. **Figure 44** shows the capability for developing and maintaining MSRs. Again, the doctrine calling for more construction equipment in corps units is clear. The capability added to the Division Engineer and Regimental Engineer organizational cases is enough to exceed the base case. The difference is greater than 10 percent, making these cases the top option--the reverse of the corps plug. However, the Division Engineer is still slightly higher because its division zone contribution is larger. **Figure 45** shows the final offensive task of breaching complex obstacle lanes. This time the Division Engineer and Regimental Engineer cases slightly exceed the base cases. However, the difference is not significant for either 1990 or 1999 so the rankings are the same as the corps plug. The Division Engineer and Regimental Engineer organizations add CEV as well as ACE/dozer capability. The base case has only added ACE/dozer capability, but, with its extra manpower, almost equals the gains in the other cases. The bottom part of Figure 45 again shows that no bridging, munitions, or marking system quantities limit the offensive tasks.

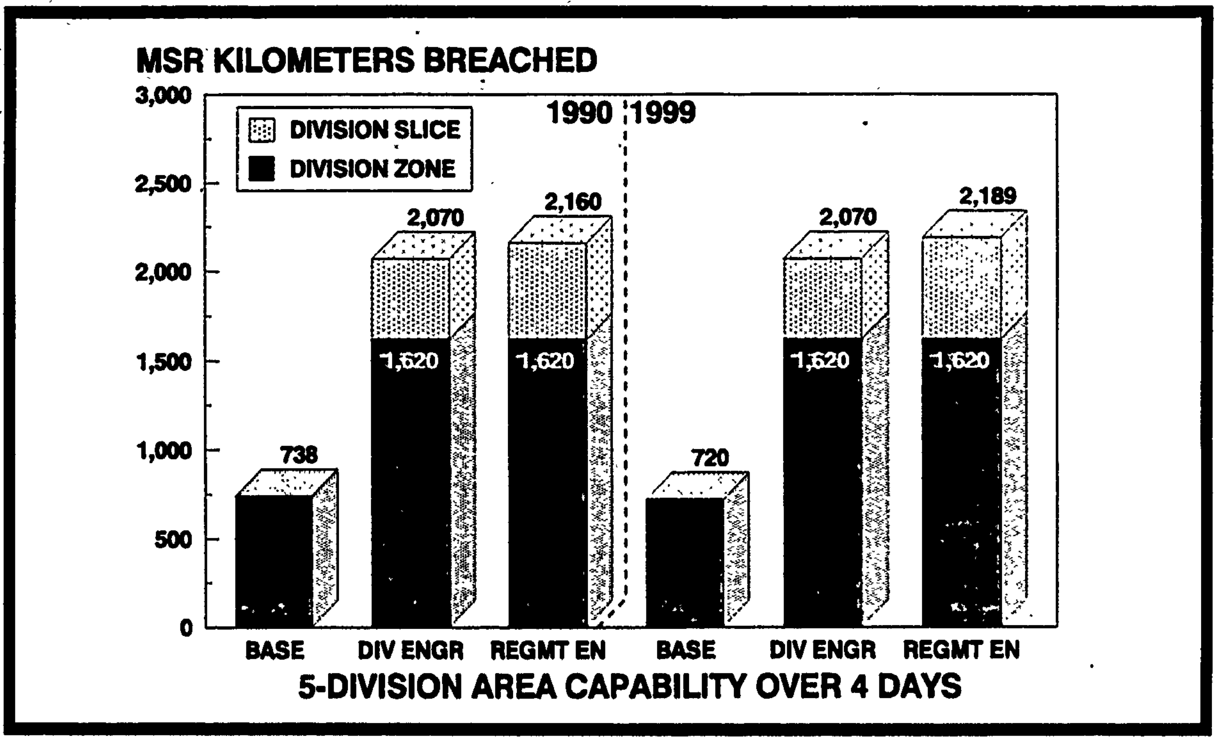


Figure 43. MSR MINEFIELD LANE BREACHING CAPABILITY (DIVISION SLICE)

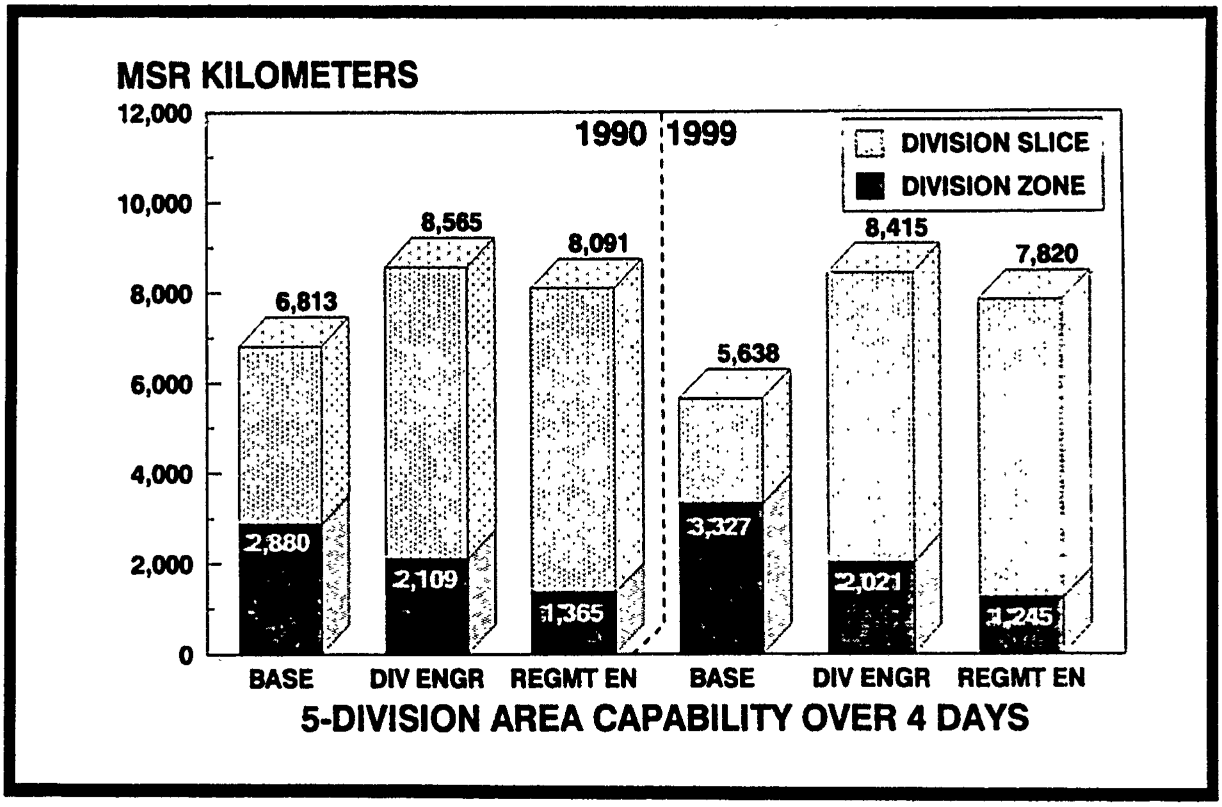
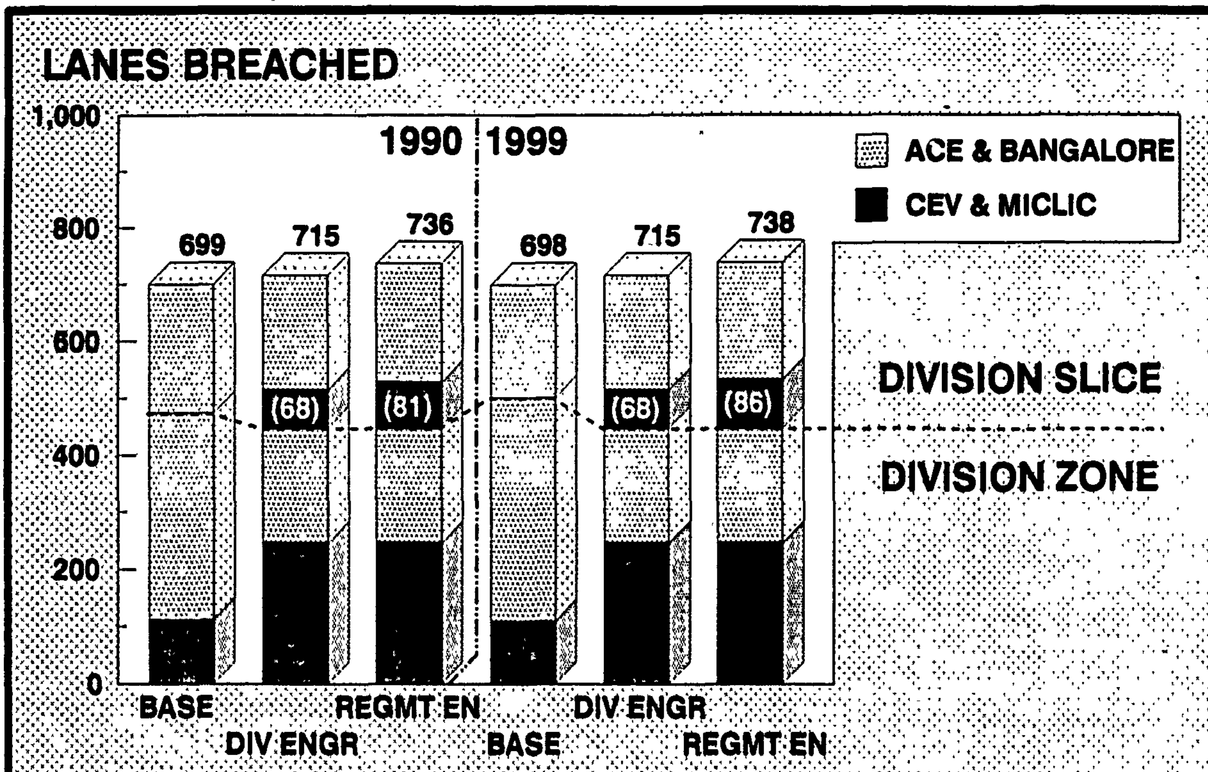


Figure 44. MSR DEVELOPMENT AND MAINTENANCE CAPABILITY (DIVISION SLICE)



5-DIVISION AREA CAPABILITY OVER 4 DAYS

EQUIPMENT AND MUNITIONS USED AND EXPENDED	1990			1999		
	BASE CASE	DIV ENGR	REGMT EN	BASE CASE	DIV ENGR	REGMT EN
AVLB USES PER DAY	175	179	184	174	179	185
MICLIC USES PER DAY	84	235	246	82	235	249
HEMMS USES PER DAY	175	179	184	174	179	185
BANGALORE TORPEDO (4-DAY TOTAL)	12,332	8,421	8,576	12,356	8,421	8,539

Figure 45. COMPLEX OBSTACLE LANE BREACHING CAPABILITY (DIVISION SLICE)

(2) **Defense. Figure 46** shows the first defense task for the capability of digging vehicle fighting positions. The Division Engineer and Regimental Engineer cases tie for first, followed by the base cases. The base case has the lowest capability for both the division slice and corps plug organizational options. However, the Division Engineer cases moved from second to first place tie in this excursion. **Figure 47** shows the capability for maintaining MSRs. Like the corps plug, the 1999 base case has the highest capability. Unlike the corps plug, the Division Engineer is higher and tied now and in 1999 for first place ranking. The Regimental Engineer remains last, but with significantly improved capability. For the similar offensive task, the base case ranked second with the other cases tied for first.

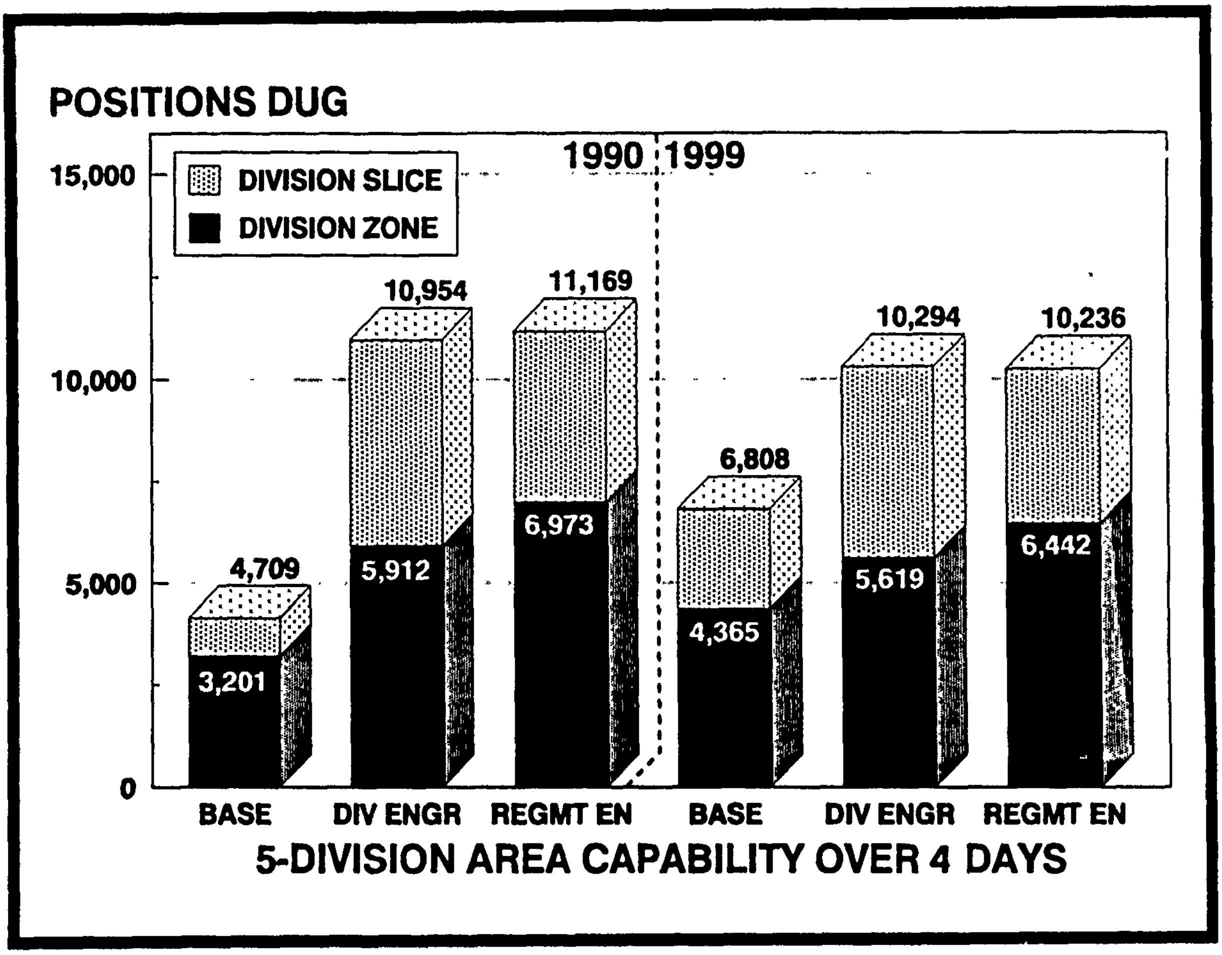


Figure 46. TANK/INFANTRY FIGHTING VEHICLE POSITION DIGGING CAPABILITY (DIVISION SLICE)

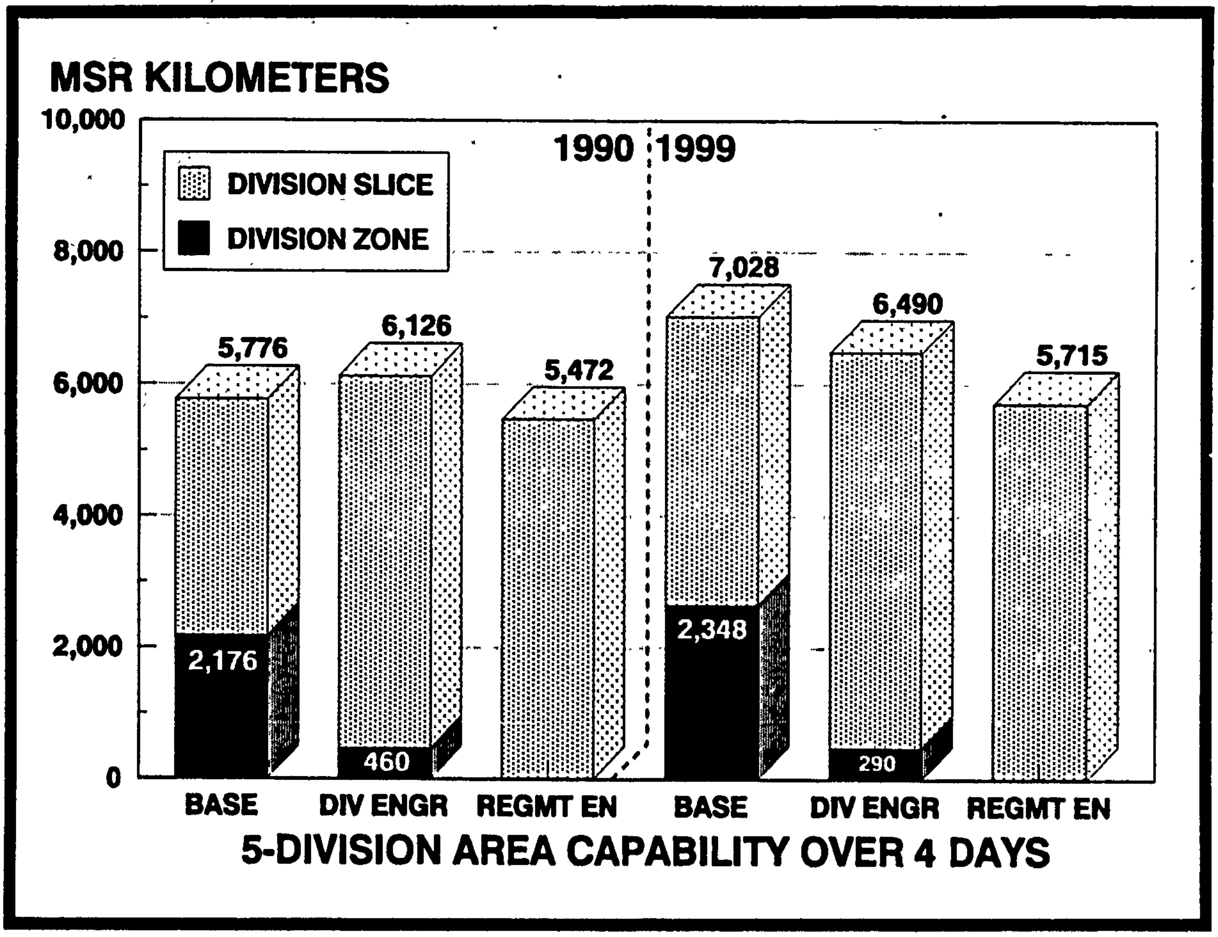
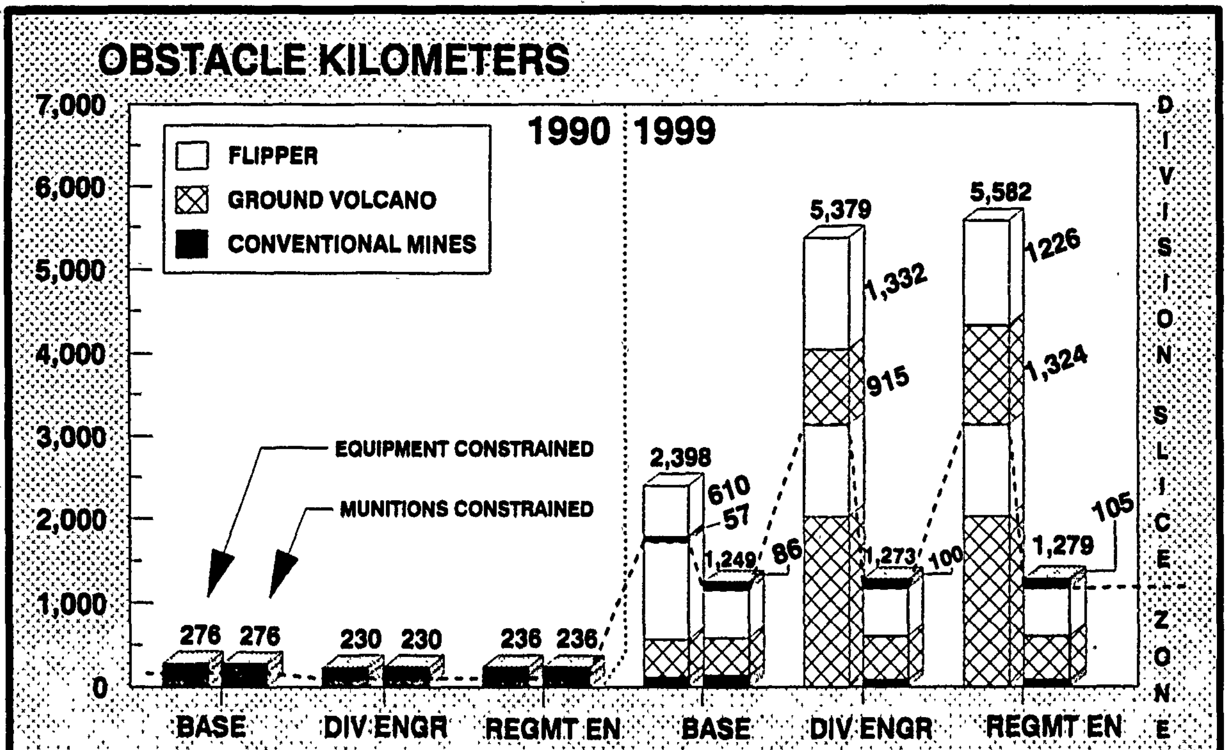


Figure 47. MSR MAINTENANCE CAPABILITY (DIVISION SLICE)

Figure 48 is the final defensive task of obstacle emplacement capability. Again, ESC's analysis shows 12 cases. For 1999, the Division and Regimental cases are equal and more than two times greater than the equipment-constrained base case. This relative difference is about half that attained for the corps plug cases. However, when we constrain capability by the worldwide availability of munitions, all three options are equal as they were in the corps plug. Constrained capability, while equal, is double the corps plug with the extra units and the Flipper capability available. The lack of ground VOLCANO and Flipper mines causes this imbalance. The bottom of Figure 48 more clearly shows us this munitions constraint. The 456 canisters of M139 mines and 317,340 Flipper anti-tank mines produce the constrained capabilities. The MOPMS, HEMMS, and M-180 demolition kits are again smaller because of reduced ground VOLCANO minefield frontage. The Division Engineer and Regimental Engineer cases are unable to emplace many more conventional minefields because of reduced available manpower.



5-DIVISION AREA CAPABILITY OVER 4 DAYS

EQ=EQUIPMENT LIMITED / MUN=MUNITION LIMITED	1990 BASE CASE	1990 DIV ENGR	1990 REGMT EN	1999 BASE CASE	1999 DIV ENGR	1999 REGMT EN
CONV AT MINES - EQ	452,921	377,757	386,991	283,687	0	0
- MUN				379,599	299,906	309,140
CONV AP MINES - EQ	249,191	207,795	212,874	156,050	0	0
- MUN				208,804	164,971	170,051
M139 MINES(960)- EQ	0	0	0	393	2,569	2,927
- MUN				393	456	456
FLIP AT MINES- EQ	0	0	0	989,911	1,362,082	1,247,212
- MUN				317,340	317,340	317,340
FLIP AP MINES- EQ	0	0	0	199,758	274,860	251,680
- MUN				64,037	64,037	64,037
40# SHAPED CHG- EQ	1,655	1,380	1,414	1,036	0	0
- MUN				1,387	1,096	1,129
40# CRATER CHG- EQ	2,758	2,300	2,356	1,727	0	0
- MUN				2,311	1,826	1,882
MOPMS - EQ	0	0	0	12,236	29,583	30,703
- MUN				5,601	5,999	5,999
HEMMS PER DAY - EQ	0	0	0	70	168	174
- MUN				32	34	34
M180 DEMO KIT - EQ	0	0	0	11,124	26,894	27,912
- MUN				5,092	5,453	5,453

Figure 48. MINEFIELD OBSTACLE AND ROAD CRATER EMPLACEMENT CAPABILITY (DIVISION SLICE)

c. **1-Division Average.** These comparisons again look at one-fifth of the full force, or a 1-division average. The comparisons are for the complete 4-day conflict. ESC shows comparisons in the same format as we used for the corps plug analysis--the three offense tasks are shown first, followed by the remaining three defensive tasks.

(1) **Offense.** **Figure 49** shows the capability for the three offensive tasks. The division of method for breaching complex lanes (third task) is shown as before. Again, ESC shows the ACE method percentage with the remainder the CEV method. The results are similar for two of the three tasks. This display clearly shows the Division Engineer and Regimental Engineer organizations better than the base case. The base case is deficient in breaching MSR minefields because of the lack of CEVs. These observations are the same as for the corps plug options.

(2) **Defense.** **Figure 50** shows the capability for the three defensive tasks. For the third task, ESC shows the percentage of added effort by one of three methods. For 1990 and the munitions-constrained 1999 cases, the method is 100 percent use of conventional explosives and mines. For the equipment-constrained 1999 cases, the figure shows the percentage used by the Flipper method. The remainder of the effort varies by capability option. For the base case, the second method is conventional explosives. For the Division Engineer and Regimental Engineer cases the second method uses the ground VOLCANO system. The Division Engineer and Regimental Engineer cases have the highest overall capability. These results show that a blade excursion would only amplify the current rankings.

d. **Observations.** **Figure 51** shows case rankings after calculating 12 division slice cases. ESC again arranged the results by engineer missions. The last column of Figure 51 shows us a clear distinction between organizational options. The results rank the Division Engineer cases first, the Regimental Engineer second, and the base cases last. The corps plug rankings had the base case last, but the other two concepts tied for first. The changes from the corps plug derive primarily from the new rankings in the survivability and sustainment engineering missions. The results of the division slice excursion show the desirability to convert to the newer organizations now as well as in the future. This conversion assumes all corps units are available as generously distributed. These corps units are available for a 5-division corps. For more than one corps, all units are available except CSE companies. There are only enough CSE companies for two 5-division corps. If ESC gives double weight to mobility and countermobility, the rankings do not change. Significant observations also include:

(1) The Division Engineer case now has the highest MSR maintenance capability. Engineer planners' intention to switch this capability to Corps units is now apparent. However, it takes many corps units to make this doctrine work.

(2) The Division Engineer and Regimental Engineer organizations have gained an edge in mobility. This observation supports the thrust of new and emerging doctrine that emphasizes the offense. Overall the Division Engineer organization is better than the Regimental Engineer organization.

(3) Munitions, not equipment or squad, capability still severely limits mine-laying capability. However, even without these munitions, the Division Engineer and Regimental Engineer organizations are better than the base case in 1999.

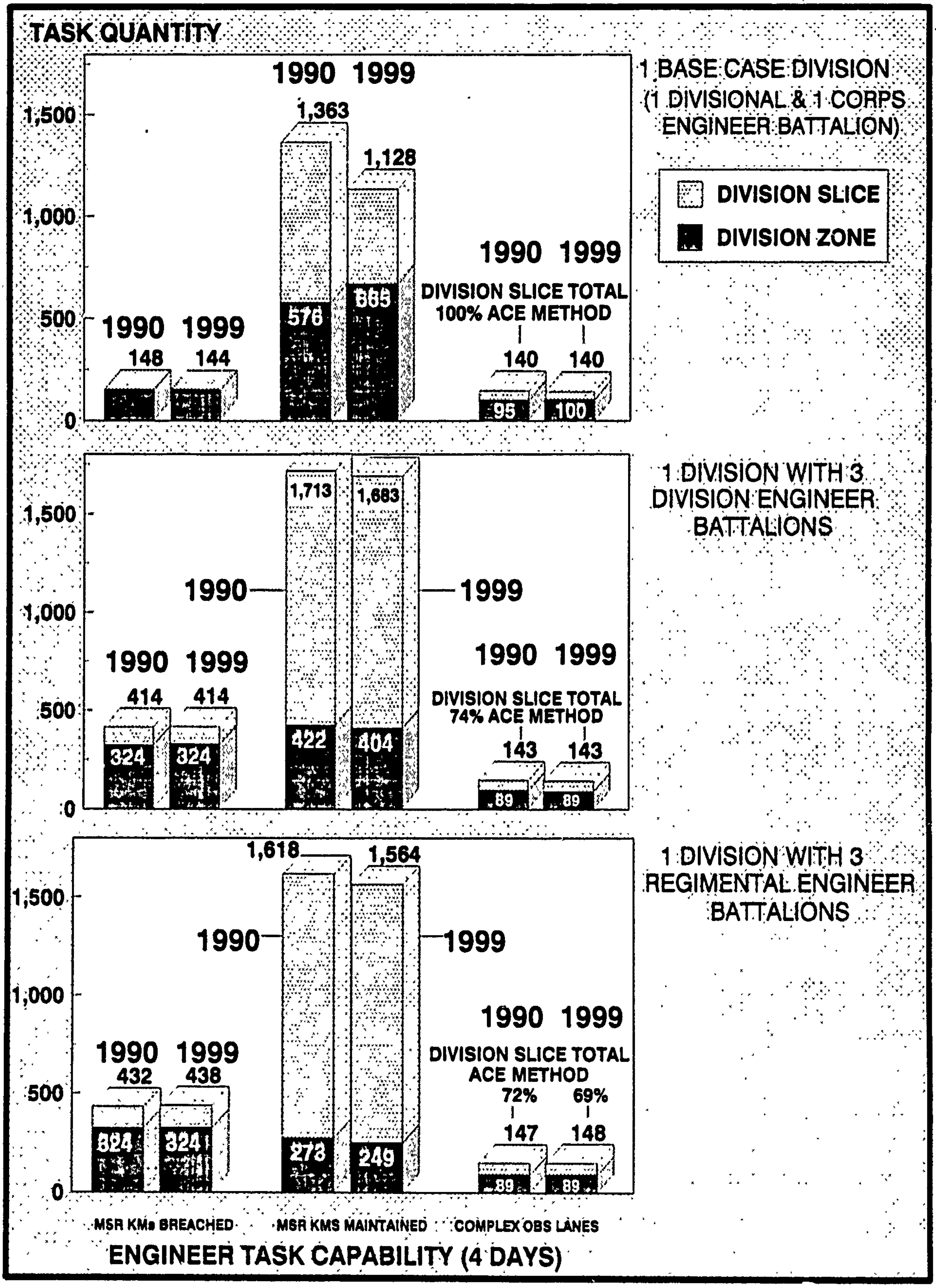


Figure 49. OFFENSE TASK CAPABILITY (DIVISION SLICE)

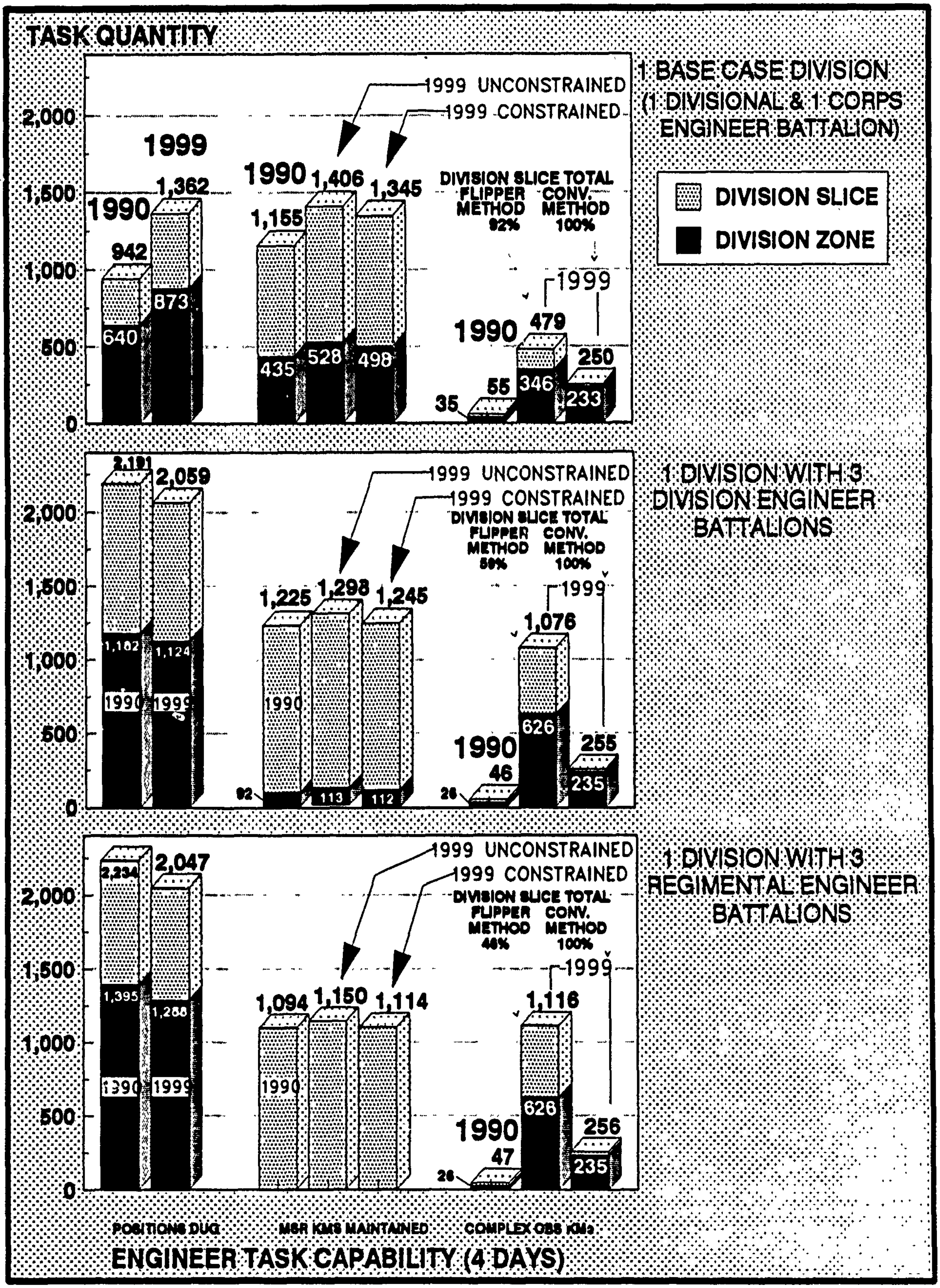


Figure 50. DEFENSE TASK CAPABILITY (DIVISION SLICE)

CASES	RANKINGS				
	MOBILITY	COUNTER-MOBILITY	SURVIVABILITY	SUSTAINMENT ENGINEERING	ALL TASK AVERAGE
1990:					
Base Case	3	1	3	2	3
Division Engineer	1	2	1	1	1
Regimental Engineer	1	2	1	2	2
1999 -- Only Equipment:					
Base Case	3	3	3	2	3
Division Engineer	1	1	1	1	1
Regimental Engineer	1	1	1	2	2
1999 -- Munitions & Equipment:					
Base Case	3	1	3	2	3
Division Engineer	1	1	1	1	1
Regimental Engineer	1	1	1	2	2

Figure 51. DIVISION SLICE MISSION OBSERVATIONS

15. **FLIPPER EXCURSION.** This option set adds the Flipper scatterable mine system to the division base comparisons. Earlier in paragraph 12, ESC compared the division base without the Flipper. Figure 10 shows that, for 1999, we can use 42 percent of the scatterable mine stockage with either the GEMSS or the Flipper. ESC study assumptions excluded the GEMSS. So this excursion adds a valuable resource. Unit designs show four GEMSS in some of the division zone base case battalions. The basis of issue calls for two Flippers to supplement these four GEMSS. ESC added six Flippers per battalion for the totals shown in **Figure 52.** The rest of the equipment for each case is the same as in Figure 17. This excursion will only look at a 5-division force comparison.

TYPE	1990			1999		
	BASE CASE	DIV ENGR	REGMT ENGR	BASE CASE	DIV ENGR	REGMT ENGR
Divisional Battalions	0	0	0	30	90	90
Corps Battalions	0	0	0	30	0	0
Total Flippers	0	0	0	60	90	90

Figure 52. DIVISION ZONE FLIPPERS PER 5-DIVISION FORCE

a. **Comparisons.** The top of **Figure 53** shows the division zone results with the Flipper capability. The Flipper only affects the obstacle emplacement task of the defense. The bottom of Figure 53 shows us the results without the Flipper. Overall rankings do not change. The Division Engineer and Regimental Engineer organizations rank first with no munitions constraints. Similarly, with munitions constraints, all three cases are equal in 1999. However, there are significant differences in total quantity. Using the Flipper system gives the munitions-unconstrained cases 1\2 to 3 times more capability. Also, this system almost doubles the munitions-constrained cases capability. **Figure 54** shows how the munitions constraints change mine and explosive use. The ground VOLCANO canisters and both Flipper mines constrain the analysis. This causes other quantities to change as capabilities adjust. The Division Engineer and Regimental Engineer organizations add conventional mines during this adjustment. The number of added conventional minefields is small. The conventional minefields use many man-hours, and these two options have little manpower available.

b. **VOLCANO Effect.** The increase of Flipper capability decreases the reliance on VOLCANO minefields. The Flipper equipment has the capability to emplace 4.3 times the current mine stockage of the study's defensive conflict. All the Army Flippers can emplace 4.85 times the current stockage in a similar 4-day period. This excursion uses 45 percent of the Army's stated ground VOLCANO AAO quantities for a deployed 5-division force[10]. With more reliance on the Flipper, ground VOLCANO use could be reduced by half.

c. **Observations.** ESC sees only good for the future use of Flipper capability.

(1) The Division Engineer and Regimental Engineer organizations are at their highest capability when all scatterable mine systems are available. These systems use less manpower, and manpower is being reduced.

(2) Flipper almost doubles 1999 capability for all organization options when considering munitions constraints.

(3) Buying more Flipper mines would nearly double 1999 base case capability. This purchase increases capability while spending less than any other countermobility alternative.

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[10] As of December 1990, Army Acquisition Objective for the ground VOLCANO was 271 dispensers and 6,270,000 mines.

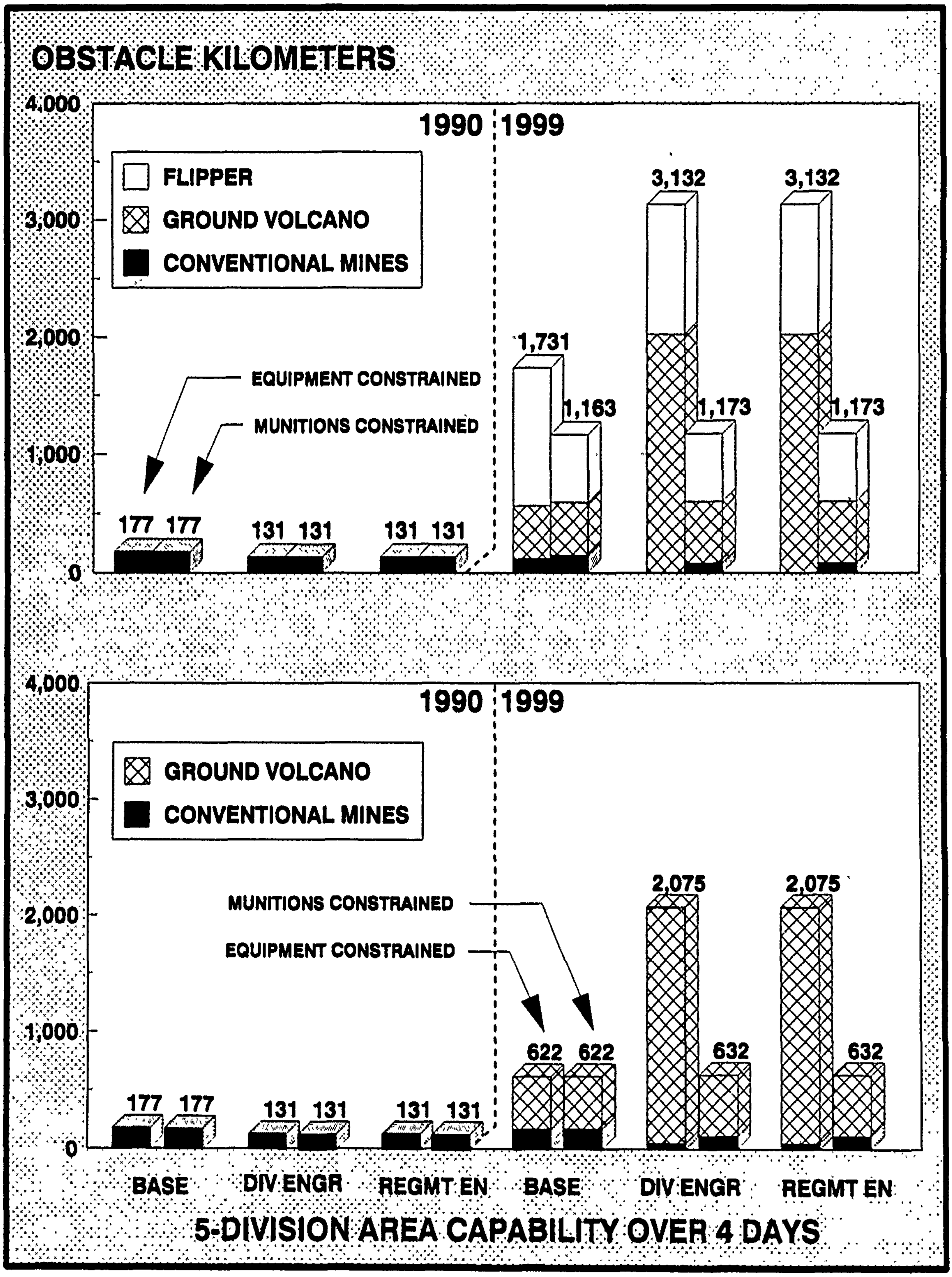


Figure 53. MINEFIELD OBSTACLE AND ROAD CRATER EMPLACEMENT CAPABILITY (FLIPPER EXCURSION)

5-DIVISION AREA CAPABILITY OVER 4 DAYS

EQ=EQUIPMENT LIMITED	1990			1999		
MUN=MUNITION LIMITED	BASE CASE	DIV ENGR	REGMT EN	BASE CASE	DIV ENGR	REGMT EN
CONV AT MINES - EQ	291,029	214,639	214,639	191,255	0	0
- MUN				238,716	136,788	136,788
CONV AP MINES - EQ	160,088	118,068	118,068	105,205	0	0
- MUN				131,312	75,244	75,244
M139 MINES(960)- EQ	0	0	0	393	1,768	1,768
- MUN				393	456	456
FLIP AT MINES- EQ	0	0	0	650,184	619,118	619,118
- MUN				317,340	317,340	317,340
FLIP AP MINES- EQ	0	0	0	131,203	124,934	124,934
- MUN				64,037	64,037	64,037
40# SHAPED CHG- EQ	1,063	784	784	699	0	0
- MUN				872	500	500
40# CRATER CHG- EQ	1,772	1,307	1,307	1,164	0	0
- MUN				1,453	833	833
MOPMS - EQ	0	0	0	8,885	17,224	17,224
- MUN				5,601	5,999	5,999
HEMMS PER DAY - EQ	0	0	0	50	98	98
- MUN				32	34	34
M180 DEMO KIT - EQ	0	0	0	8,077	15,658	16,658
- MUN				5,092	5,453	5,453

Figure 54. MINEFIELD OBSTACLE AND ROAD CRATER TASK MUNITIONS CAPABILITY (FLIPPER EXCURSION)

16. **BLADE SENSITIVITY EXCURSION.** This excursion examines blade capability associated with the ACE. ESC decided to divert some ACE capability from digging fighting positions to helping construct expedient MSRs. The purpose of this excursion is to reexamine the overall capability of the Division Engineer and Regimental Engineer organizations. These organizations have mostly ACEs. ESC used the division slice database for this excursion. **Figure 55** shows the excursion's main assumption. This assumption fixed all dug positions at 5,000 per case. The previous totals are on Figure 46. We raised the base case from 4,709 positions and lowered the Division Engineer and Regimental Engineer cases from more than 10,000 positions each.

a. **Comparisons.** The excursion comparison looks at a 1-division average or 1,000 positions per case. **Figure 56** shows the results of recalculating the division slice cases holding positions at the 1,000 level. You can compare these results directly to Figure 50. The base case is basically unchanged. However, since ESC raised positions, MSR capability declined slightly. The changes occurred with the Division Engineer and Regimental Engineer organizations. These organizations now exceed the base case in 1990 MSR capability. For 1999, the three organizations are about even. Overall, the Division Engineer and Regimental Engineer organizations show greater capability using the ACE for digging positions.

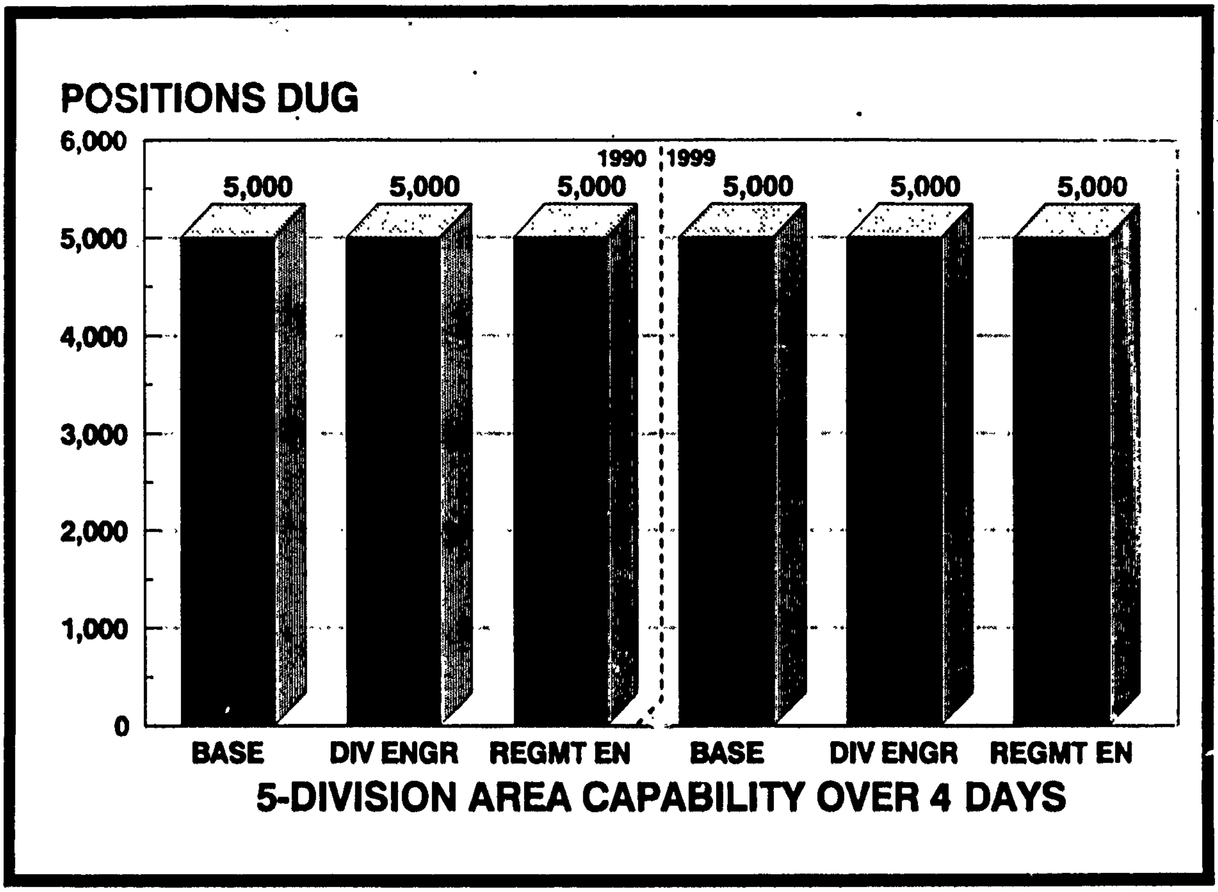


Figure 55. TANK/INFANTRY FIGHTING VEHICLE POSITION DIGGING CAPABILITY (BLADE SENSITIVITY EXCURSION)

b. **Equipment.** To rate this excursion fully, ESC challenged its own methodology. This methodology uses all four pieces of construction equipment to maintain MSRs no matter what ratio. Figure 15 shows that the planning factor uses just more than 250 hours of this equipment to maintain 100 kilometers of loose surface, 2-lane road. ESC amended the planning factor when four items of equipment were no longer available. ESC then used the remaining equipment at more than 500 hours to maintain the same MSR network. **Figure** 57 shows this in detail. The top part of Figure 57 shows the equipment available in all cases by division zone and supplemented by division slice corps units. (Note: The division slice totals include the division zone totals.) The bottom of this figure translates this equipment to the MSR planning factors. The total capability shows the base case with a respectful total compared to the other two cases. However, the Division Engineer and Regimental Engineer organizations have over twice the equipment capability when only considering the efficient method of using all four items of equipment. The efficient method also has the Regimental Engineer case with the highest capability. When considering the less efficient method, the Division Engineer case has the highest capability.

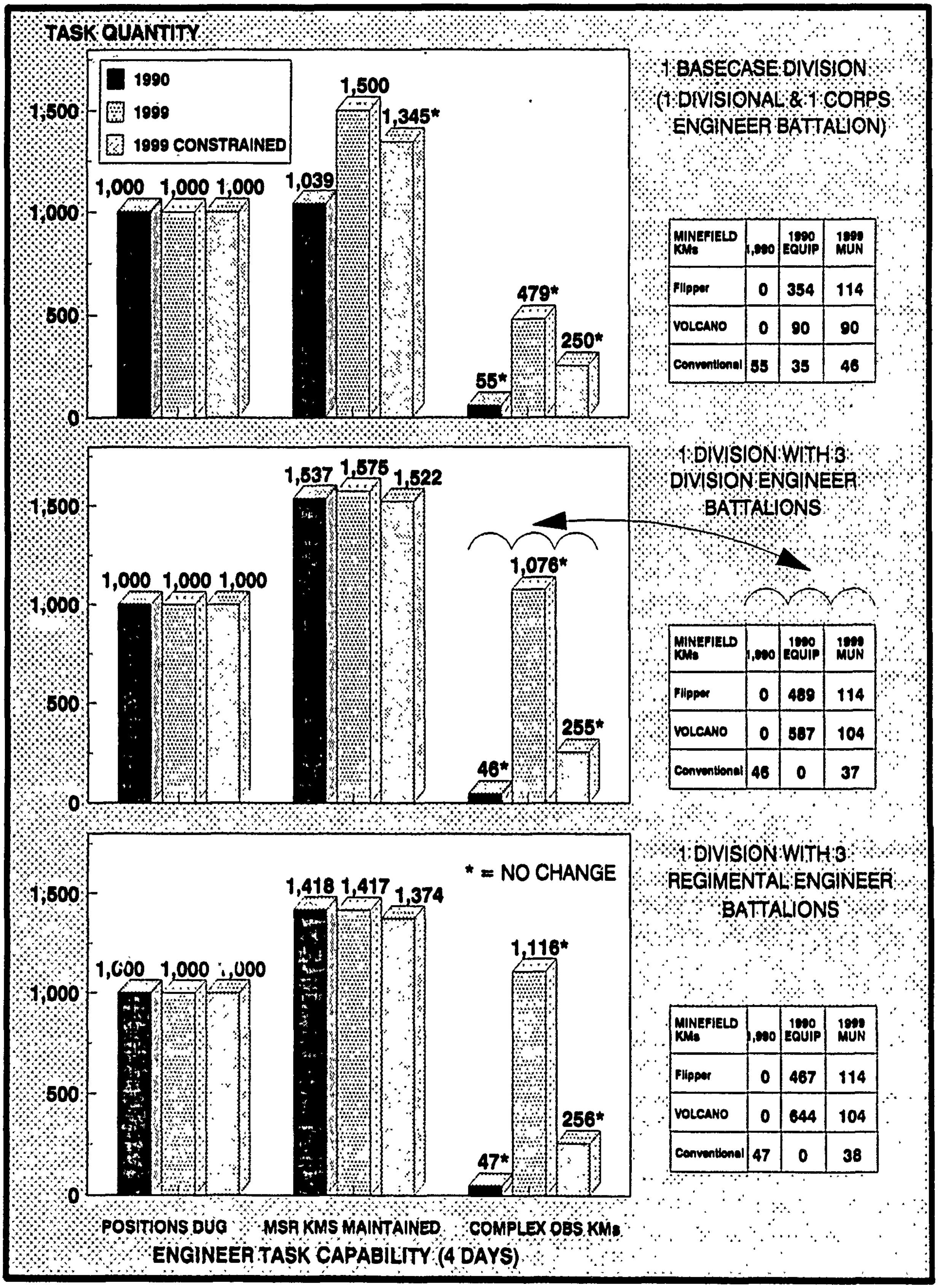
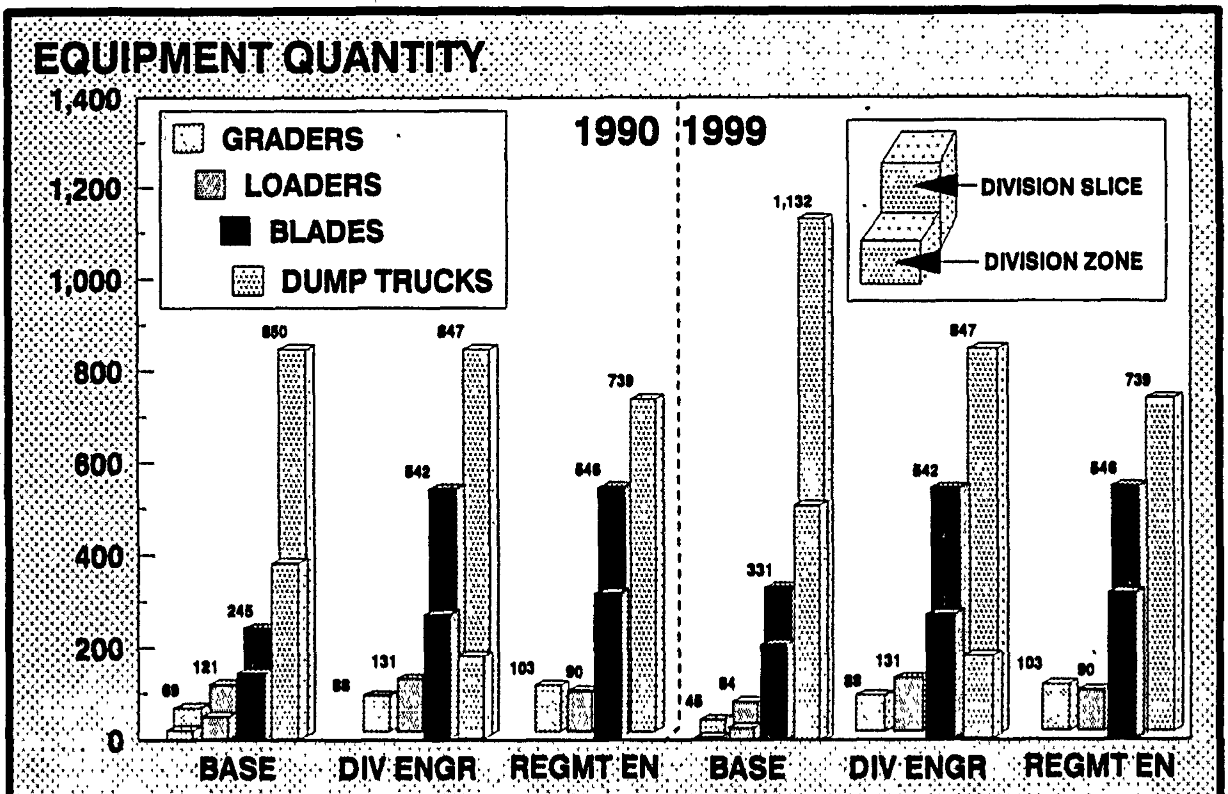


Figure 56. DEFENSE TASK CAPABILITY (BLADE SENSITIVITY EXCURSION)



5-DIVISION AREA CAPABILITIES

EQUIPMENT USED (SINGLE TASK - FOUR DAYS):	MSR KILOMETER MAINTENANCE CAPABILITY					
	1990			1999		
	BASE	DIV ENGR	REGMT EN	BASE	DIV ENGR	REGMT EN
ALL FOUR PIECES	1,052	2,477	2,903	1,270	2,477	2,903
DUMP-LOADER-GRADER	587					
DUMP-LOADER-BLADE		1,734	1,026	1,232	1,735	1,026
DUMP-LOADER	907					
DUMP-BLADE		1,965	2,550	126	1,618	2,060
DUMPS ONLY	2,650	1,510	610	4,874	2,047	1,098
TOTAL CAPABILITY	5,196	7,686	7,089	7,502	7,877	7,087

Figure 57. MSR MAINTENANCE EQUIPMENT AND CAPABILITY (BLADE SENSITIVITY EXCURSION)

c. **Observations.** **Figure 58** shows the ranking for this excursion. For reference purposes only, this figure also shows the MSR maintenance ranking for the division zone and division slice calculations. These first two columns show that the highest capability changes from the base case to the Division Engineer. This is not surprising given the loaders and graders of the corps units in the division slice. The excursion results are shown in two ways--by using all equipment in any mixture (1 to 4 pieces) and by using the set mixture (4 pieces only) determined by the planning factor. ESC equally averages the two ways in the last column of Figure 58. The averages do not change if the two ways are weighted equally or if the set mixture is given double weight. The Regimental Engineer option ranks first. The Division Engineer ranks second except when considering using all equipment in any mixture. In the latter case, the Division Engineer option ties the Regimental Engineer option for first. In all cases the base case is last.

CASES	DIVISION ZONE	DIVISION SLICE	BLADE EXCURSION EQUIPMENT		
			1 TO 4 PIECES	4 PIECES ONLY	AVERAGE
1990:					
Base Case	1	2	3	3	3
Division Engineer	2	1	1	2	2
Regimental Engineer	3	2	1	1	1
1999 -- Only Equipment:					
Base Case	1	2	1	3	3
Division Engineer	2	1	1	2	2
Regimental Engineer	3	2	1	1	1
1999 -- Munitions & Equipment:					
Base Case	1	2	3	3	3
Division Engineer	2	1	1	2	2
Regimental Engineer	3	2	1	1	1

Figure 58. MSR MAINTENANCE RANKINGS (BLADE USE EXCURSION)

In summary--

(1) The base case option must cease survivability to increase MSR maintenance capability.

(2) The Division Engineer and Regimental Engineer options can significantly increase MSR maintenance capability by reducing survivability workload.

(3) Using the ACE differently between tasks does not change overall comparative capability rankings.

17. **OTHER FINDINGS.** These findings reinforce emerging doctrine and actual operations DESERT SHIELD/DESERT STORM experiences.

a. **Doctrine.** The AirLand Operations' doctrine for the divisional battalion of the Regimental Engineer organization is FM 5-71-100. The USAES title, for the February 1991 coordinating draft of this field manual, is *Regimental Engineer Combat Operations.* The preface of this manual states a key premise:

> *"The divisional sapper battalions are designed to be focused 80 percent on mobility and 20 percent on countermobility, survivability, and sustainment (engineering)."*

The focus is on mobility since the maneuver tactics emphasize the offense. The study methodology lets us test this premise and **Figure 59** captures this result. Using offensive tactics, engineers commit more than 90 percent of their effort to mobility for all three organizations. The Division Engineer organization was the predecessor to the Regimental Engineer organization. The Division Engineer organization should, and does, parallel the doctrine of the Regimental Engineer organization. However, the base case also captures this focus. Perhaps, even more interesting is the Figure 59 columns showing the defensive tactics. In the 1990 defense, engineers commit to non-mobility missions more than 80 percent of their time. Again, this is for all three organizations. In 1999, the percentage is more than 90 percent. ESC's analysis shows that the engineers still have the equipment to switch between offense (mobility) and defense (countermobility and survivability). So, engineers can maintain offensive focus and still execute any defensive mission associated with the offense without any problems. This mission flexibility is a time-honored engineer capability that engineers used to emphasize.

CASE*	OFFENSIVE SCENARIO		DEFENSIVE SCENARIO	
	MOBILITY	OTHER	MOBILITY	OTHER
Base	100%	0%	3-4%	96-97%
Division Engineer	91%	9%	9-18%	82-91%
Regimental Engineer	91%	9%	9-18%	82-91%

* No GEMSS/Flipper and assumes MICLIC = AVLB capability (both not shown).
Split percentages are 1990/1999 calculations (single percentage = same for 1990 and 1999).

Figure 59. MOBILITY CAPABILITY (DIVISION ZONE)

b. **Operations DESERT SHIELD/DESERT STORM.** Certain study assumptions recreate conditions the U.S. Army engineers experienced for operations DESERT SHIELD/ DESERT STORM. However, it was neither the sponsor's nor ESC's intention to replicate all conditions. For example, the situation and terrain did not call for road craters. Road craters were part of one of our three defensive tasks. The task is still valid for mountain areas of Southwest Asia. However, the MSR analysis shows a problem with the graders and loaders retained in the newer organizations. Initial after-action reports from Saudi Arabia reveal the same need. **Figure 60** excerpts some of these observations. This figure's information is from a conference held at King Khalid Military City on 17 March 1991[11]. The observations vary since the corps rear areas and the communications zone were intermixed in the same terrain space. The solutions vary but the root equipment problem is the same--low equipment capability in the division areas.

OBSERVATIONS OF ENGINEER OPERATIONS

- 7th Engineer Brigade, VII Corps
  - Need for CSE Company in Division Regiment (Regimental Engineer)
  - Grader is mobility asset excellent for roads during dry spells

- 20th Engineer Brigade, XVIII Corps
  - Increase horizontal capability in combat heavy battalion
  - Need equipment platoon in corps battalion companies

- ARCENT Engineer
  - Possible need for a horizontal-only combat heavy battalion

- CENTCOM Engineer
  - Need 35-ton dump trucks, D9-sized bulldozers, and 14-foot blade graders

Figure 60. OPERATIONS DESERT SHIELD/DESERT STORM EQUIPMENT OBSERVATIONS

[11] This conference, called the "Engineer Operations Hotwash," was sponsored by the 416th Engineer Command. The information in this figure is from a letter from CENTCOM, Directorate of Logistics and Security Assistance, Office of the USCENTCOM Engineer, SUBJECT: Engineer After Action Conference for Operation DESERT SHIELD/STORM at KKMC, 17 Mar 91, dated 20 March 1991.

c. **Combined Findings.** ESC combined the division slice and blade sensitivity excursions to get its overall findings. This combination gives the best doctrinal position joined with the ability of commanders to rank missions. **Figure 61** shows ESC's final overall rankings. The corps units that support the Regimental Engineer concept have the highest sustainment engineer capability. These rankings also show the Division Engineer and Regimental Engineer concepts best for the remaining three engineer missions in 1999. Overall, the Regimental Engineer concept has the best capability when considering all four engineer missions.

CASES	RANKINGS				
	MOBILITY	COUNTER-MOBILITY	SURVIVABILITY	SUSTAINMENT ENGINEERING	ALL TASK AVERAGE
1990:					
Base Case	3	1	3	3	3
Division Engineer	1	2	1	2	2
Regimental Engineer	1	2	1	1	1
1999 -- Only Equipment:					
Base Case	3	3	3	3	3
Division Engineer	1	1	1	2	2
Regimental Engineer	1	1	1	1	1
1999 -- Munitions & Equipment:					
Base Case	3	1	3	3	3
Division Engineer	1	1	1	2	2
Regimental Engineer	1	1	1	1	1

Figure 61. COMBINED OBSERVATION RANKINGS

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IV. CONCLUSIONS AND RECOMMENDATIONS

18. **GENERAL.** This section brings together the many findings of the previous section. This report lists in general terms four sets of conclusions and recommendations. ESC's charter specified this report finish in time to influence the Program Objective Memorandum process for FY 99. ESC's conclusions and recommendations are also pertinent to future POM cycles of the Army. Our recommendations are somewhat sensitive to the study's assumptions involving future engineer equipment. However, as equipment quantities become more focused, engineer planners can also adapt our findings in more detail. Such detailed uses include:

a. **Ranking Limited Funds.** For example, planners can determine if resources should go toward munitions versus new equipment or toward new equipment versus research and development.

b. **Phasing Unit Reorganizations.** Planners can incrementally phase in new organizations to match limited equipment and munitions resources.

c. **Modifying Force Allocation Rules.** Once unit designs and resources are known, planners can efficiently adjust forces to meet working needs.

d. **Providing Theater Deployment Guidance.** Again, working with known capabilities, planners can ensure balanced and adequate planning forces for overseas operational plans.

19. **DIVISION ENGINEER AND REGIMENTAL ENGINEER ORGANIZATIONS SHOW IMPROVEMENTS.**

a. **Conclusions.** If the Army buys more scatterable mines in the future, the Division Engineer and Regimental Engineer organizations are equal to the base case and better. Both organizations now have effective survivability and mobility capability using fewer Sappers than the base case organizations. However, the newer Division Engineer units depend on corps for effective MSR maintenance and countermobility capability.

b. **Recommendations.**

(1) The Army should implement the Regimental Engineer organization for 1999 because it has the highest overall capability of any option.

(2) The Army should deploy the Regimental Engineer organization along with corps units equivalent to a full division slice to have the most effective capability.

20. BASE CASE ORGANIZATION HAS SEVERAL ADVANTAGES.

a. **Conclusions.** The 1991 base case organization has the highest capability for the countermobility mission when employed alone. The base case continues as the highest capability option when supplemented by either study corps-support option. The base case also has the highest capability for MSR maintenance when employed alone or with the corps plug support. The MSR maintenance ranking is for both now and 1999.

b. **Recommendations.**

(1) Maintain conventional mine stocks until scatterable anti-tank mine stocks exceed four million mines.

(2) Keep the wheeled corps battalions in the force as 4-company, 36-squad units until the ground VOLCANO is fully available.

21. GROUND VOLCANO AND FLIPPER MINE SYSTEMS NEED WATCHING.

a. **Conclusions.**

(1) Ground VOLCANO. The Army has balanced the Authorized Acquisition Objectives' for the Ground VOLCANO mines and launcher. This study uses 45 percent of the Army's stated ground VOLCANO AAO quantities for a deployed 5-division force.

(2) Flipper. All the study capability options can almost double 1999 countermobility capability by using available Flipper mine systems. The Flipper equipment available in the study options can emplace 4.3 times the current mine stockage. The U.S. Army does not plan to buy any more Flipper mines. However, if the Army bought more mines, the total 1991 on-hand equipment could emplace 4.85 times available mine capability. The latter assumes study conditions which only allow 4 days of mine laying. The Flipper is a very potent system.

b. **Recommendations.**

(1) Ground VOLCANO. If the Army buys less or more Ground VOLCANO mines and launchers than the AAO states, the revised quantities should be in the same proportion as now authorized. Consider reducing Ground Volcano launchers in units by 50 percent (and mine authorizations also by 50 percent).

(2) Flipper. Buy additional Flipper mines to increase existing stocks by a factor between 2 and 5.

22. CORPS SUPPORT UNITS "MAKE OR BREAK" THE REGIMENTAL ORGANIZATIONAL CONCEPT.

a. **Conclusions.** The new Regimental organizational concepts (the Division Engineer and Regimental Engineer options) have permanently altered the separation of missions between division and corps. A deploying force will experience different mobility and MSR maintenance risks depending on the size of the corps support package. This report shows the corps plug package inadequate for the MSR maintenance mission and the division slice adequate but too costly.

b. **Recommendations.**

(1) Reallocate graders and loaders needed for 1999 MSR maintenance between a few corps units. Also, add graders and loaders to the Division Engineer structure. Planners can accomplish both of these recommendations by redistributing 1991 quantities.

(2) Consciously maintain the equal balance between mobility and countermobility capabilities. All 1991 and 1999 organizational structures studied in this report have this equal balance.

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LAST PAGE OF STUDY

	SOUTHWEST ASIA ENGINEER CAPABILITY OPTIONS FOR HEAVY DIVISIONS (SACAPO)	**STUDY GIST** CEESC-R-91-29

PRINCIPAL FINDINGS:

• *Divisional Engineer and Regimental Engineer Organizations Show Improvements.* If the Army buys more scatterable mines in the future, the Division Engineer and Regimental Engineer organizations are equal to the base case and better. For 1991, both organizations have effective survivability and mobility capability using fewer Sappers than the base case organizations. For 1999, the Army should use the Regimental Engineer organization because it has the highest overall capability of any option. However, the newer Division Engineer units depend on corps for effective MSR maintenance and countermobility capability. To effectively increase the Regimental Engineer organization's capability, the Army should deploy it with the equivalent of a full division slice of corps units.

• *Base Case Organization Has Several Advantages.* When employed alone, the 1991 base case organization has the highest capability for the countermobility mission. The base case continues as the highest capability option when supplemented by either study corps-supported option. Until the Ground VOLCANO is fully available, the engineers need to keep the wheeled corps battalions in the force as 4-company, 36-squad units. Engineers need this manpower to emplace the conventional mines now in stock. This need will fade when scatterable anti-tank mine stocks exceed four million mines. The base case also has the highest capability for MSR maintenance when employed alone or with the corps plug support. This MSR maintenance ranking is sound for 1991 through 1999.

• *Ground VOLCANO and Flipper Mine Systems Need Watching.* This study's defensive conflict uses 45 percent of the Army's planned ground VOLCANO quantities for a 1999 deployed 5-division force. Considering this capability, the Army could reduce authorizations for unit ground VOLCANO launchers and theater mine stocks by 50 percent. The Flipper is a very potent system with the same mine features as the ground VOLCANO. The Flipper exceeds its designed emplacement rate. Considering the doctrine of surface laid mines and decreased emphasis on defense, the Flipper is a very cost-effective mine system. For example, all the study capability options can almost double 1999 countermobility capability by using available Flipper mines. The Flipper equipment available in the study options can emplace 4.3 times the current mine stockage. If the Army bought more Flipper mines, the total 1991 on-hand equipment could emplace 4.85 times available mine capability. These statistics are for only 4 days of mine laying! The Army can easily justify buying between 2 and 5 times or even 10 times more Flipper mines.

• *Corps Support Units "Make or Break" the Regimental Organizational Concept.* The new Regimental organizational concepts (the Division Engineer and Regimental Engineer options) have permanently altered the separation of missions between division and corps. A deploying force will experience different mobility and MSR maintenance risks depending on the size of the corps support package. This report shows that the corps plug package is inadequate for the MSR maintenance mission and that the division slice is adequate but too costly. ESC would reallocate graders and loaders needed for 1999 MSR maintenance between fewer corps units. ESC would also add graders and loaders to the Division Engineer structure. Planners can accomplish both of these actions by just redistributing available 1991 quantities. All 1991 and 1999 organizational structures studied in this report have an equal balance of mobility and countermobility capabilities.

MAIN ASSUMPTIONS:

- This study uses unit plus equipment and munitions forecasts as of 15 January 1991.
- The Army will make accessible all available engineer equipment and munitions (of any theater) needed for the study's 5-division force.
- The study's base case will use actual DESERT SHIELD/DESERT STORM conditions.

PRINCIPAL LIMITATION: This study assumes all capability unit options have perfect planning and the same command and control capability. The study also uses a sample task list to represent the total engineer task list.

STUDY SCOPE: This study--

- Determines the engineer capability of 24 engineer alternative structures constrained by unit personnel and equipment.
- Determines the capability of the same 24 structures constrained by available and forecasted engineer munitions.
- Determines this capability for a 5-division corps and an average heavy division.

STUDY OBJECTIVE: This study's aim is to determine the comparative engineer capability of alternate unit structures. These structures support heavy divisions in a SWA theater.

BASIC APPROACH: ESC's methodology parallels the 5-heavy division force sent to DESERT SHIELD/DESERT STORM. In this study, ESC rated the engineer capability of three structures in both 1991 and 1999 (6 cases). The three structures are the Division Engineer, Regimental Engineer, and current structure or base case. ESC expanded the basic 6 cases to 12 by analyzing both a 4-day offense and defense tactical situation. ESC then expanded the cases to 24 by analyzing each division area with and without a corps support package with more engineer units. Additional excursions changed the size of this corps support package and the use of some key mining and digging equipment.

REASONS FOR PERFORMING THE STUDY: No one has rated the Regimental Engineer structure using task capabilities plus actual and programmed resources. Also, no former study compared the base case to the Division Engineer/Regimental Engineer structures for 1991. The Office of the Chief of Engineers on the Army staff sponsored this study to make these comparisons. This office oversees the optimal design of the engineer force structure for the Army staff.

STUDY SPONSOR: Office of the Chief of Engineers, (ATTN: DAEN-ZCM), U.S. Army.

PERFORMING ORGANIZATION AND PRINCIPAL AUTHORS: ESC performed this study under the general direction of Mr. Bruce W. Springfield. Mr. Douglas K. Lehmann was the Project Manager and author.

DTIC ACCESSION NUMBER OF FINAL REPORT: DA Accession Number DA334771.

COMMENTS AND SUGGESTIONS MAY BE SENT TO: Director, U.S. Army Engineer Studies Center, Casey Building #2594, Fort Belvoir, Virginia 22060-5583. (703-355-2286, DSN 345-2286.)

START DATE OF STUDY: January 1991.

COMPLETION DATE OF STUDY: September 1991.