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HUMAN PERFORMANCE IN THE TROPICS I: MAN-PACKING A TYPICAL LOAD OVER A STANDARD JUNGLE COURSE IN THE WET AND DRY SEASONS

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Army Tropic Test Center
APO New York

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HUMAN PERFORMANCE IN THE TROPICS I: MAN-PACKING A TYPICAL LOAD OVER A STANDARD JUNGLE COURSE IN THE WET AND DRY SEASONS

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In 1972, the US Army Tropic Test Center conducted studies of the performance of combat soldiers in the natural jungle of the Panama Canal Zone. A standard 4-kilometer course was established in rugged jungle terrain and vegetation to yield group and individual scores on timed performance events and physiological factors.

This study compares seasonal foot mobility by testing soldiers in the dry and wet seasons. A total of 100 soldiers traversed the course carrying a standard 25-pound load. Measurements were made of a forced march, an uphill run, double timing, normal walking, total course time, weight loss, and water consumption.

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This investigation, along with others in varying stages of completion, has demonstrated the feasibility of soldier testing through standard physical facilities and minimally controlled activities in the natural environment. The benefit of the tropic facility and procedures is the establishment of a maximum challenge man-materiel systems measurement bed that can be used to standardize human performance tests and compare data on item-soldier relationships.

SUMMARY

In 1972, the US Army Tropic Test Center conducted studies of the performance of combat soldiers in the natural jungle of the Panama Canal Zone. A standard 4-kilometer course was established in rugged jungle terrain and vegetation to yield group and individual scores on timed performance events and physiological factors.

This study compares seasonal foot mobility by testing soldiers in the dry and wet seasons. A total of 100 soldiers traversed the course carrying a standard 25-pound load. Measurements were made of a forced march, an uphill run, double timing, normal walking, total course time, weight loss, and water consumption.

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I. BRIEF OF RESULTS AND CONCLUSIONS

● There has been little previous effort to develop man-pack performance data, measurement techniques, or instrumentation under tropic conditions. The results of the US Army Tropic Test Center's (USATTC) investigations of human factors in tropic materiel tests have provided valid and reliable measurement techniques for man-packed equipment.[1] Human performance methodologies developed through this investigation may be used as standards for materiel designed for use in the tropics. The procedures and baseline data in this report are the first in a series on human performance in man-packing equipment in the jungle. Further studies are needed to determine the effect of size, weight, and configuration of equipment on man-pack portability in the jungle.

● A typical combat patrol in jungle areas as determined from literature reviews and interviews with Vietnam veterans was about 4 kilometers in distance--one day or less in duration; main objectives were search, clear, observation or reconnaissance; equipment carried typically included pistol belt, small pack, canteens, tools for clearing areas or setting up bases, individual or crew-served weapons, ammunition, and radios; main difficulties encountered while on jungle patrol were overly heavy loads, improperly secured loads, discomfort and irritation caused by straps, awkward equipment configurations, and entanglement of equipment in heavy underbrush and vines; patrol activities included walking at slow, normal, and fast paces, double timing or running for short distances; typical load was about 25 pounds, depending upon equipment required for a given mission.

● The interviews and literature survey resulted in the following guidelines for selecting objective test course events with a minimum sacrifice of realism: test in a natural environment as similar as possible to use conditions; select test site or course that includes terrain and vegetation representative of use areas; select test subjects who represent the user population; perform operations closely related to tactical situations; consider unexpected variables in the natural environment (animals, insects, fear) as valid behavior influencing factors that should not be controlled; when possible, use objective measures (interval scales such as time, distance, weight, counts) that provide reliable data with minimum interference to the conduct of tests; use expertly devised subjective measures when the level of technology does not permit objectivity.

● Timed performance events provide reliable data when classified in a two-way classification scheme: short time (under 2 minutes) versus long time (½ hour or more) being the classification in one direction; soliciting extra effort (some continued exertion beyond a normal pace) versus no extra effort solicited (typical or normal performance) being the classification in the other direction. Reliable data may be obtained from the following three cells: a) short time/extra effort, such as the uphill run and double time, b) long time/extra effort, such as forced march, and c) long time/no extra effort, such as normal walk. Data from short time/no extra effort events, such as the low crawl, proved to be unreliable. Short time/extra effort events and long time/no extra effort events were

[1] Letter, AMSTE-TO-P, Headquarters, TECOM, subject, DT and OT Relationship, 5 December 1974.

independent estimates of performance levels. This is true when the short time event solicits near maximum effort and the long time event is measured in an unobtrusive manner. Extra effort solicited for long events should allow the subject to continue through the event safely (adhering to precautions in TB Med 175)[1] without having to stop to rest, such as in the forced march event of this investigation.

- Adherence to safety precautions in TB MED 175 resulted in no heat casualties under a standard 25-pound load with WBGT index (inside the jungle) not exceeding 79.5°F, traversing the 4-kilometer course according to the procedures outlined in this report.

- The physical facility and course events described in appendices A through C provide valid, safe, standardized procedures for portability tests of items weighing up to 25 pounds that must be man-packed through the jungle. The procedures drafted into TOP 1-3-550, *Man-pack Portability Testing in the Tropics*[2] are valid measures of portability. For tests of items weighing over 25 pounds, unscheduled rest breaks should be instituted when indicated by physiological monitoring and recording instrumentation.

- The Canal Zone weather pattern is characterized by two seasons, mainly on the basis of amount of rainfall. January through March is the dry season, when it rains on 27 percent of the days, averaging 0.31 inch on rainy days. May through November is the wet season when it rains 70 percent of the days, averaging 0.53 inch on rainy days. April and December are transition months. Significantly longer performance times were obtained in the wet season on the total 4000-meter course time, 1585-meter forced march time, 2263-meter normal walk time, and 91-meter uphill run time. The ratio of wet season to dry season time was about 1.2 to 1 for those timed events. The increased amount of rainfall and the resultant increase in percent soil moisture (from 26.3 percent in the dry season to 63.3 percent in the wet season) were the main reasons for the seasonal performance differences. Increased rainfall enlarged streams and increased depths of rivers. Increased soil moisture caused loss of foot traction, slowing progress through the jungle at all points. The degree of wet season decrement in foot mobility is based on the established course and may change for other areas.

- Consistent differences in seasonal course performance have practical significance for tropic materiel testing. Many tropic tests require testing in both seasons in order to document seasonal effects. Usually data from previous tests of similar items are not appropriate for predicting the effects of one season from the other season. However, the data on performance times from this investigation indicated that a multiplier of 1.2 may be used with confidence to convert certain dry season man-pack performance data to wet season performance data. Thus, it is not necessary to duplicate man-pack testing to obtain timed performance data for two seasons for the same test item on the established course.

- The double time event did not produce significantly different seasonal data. The double time event was too short (200 feet) and too easy, occurring over relatively unencumbered, flat terrain, to yield seasonal differences. The higher soil moisture percent

[1] TB Medical 175, *The Etiology Prevention, Diagnosis, and Treatment of Adverse Effects on Heat*, 7 August 1957.
[2] TECOM Test Operation Procedure 1-3-550, *Man-Pack Portability Testing in the Tropics*, 22 January 1973. (draft)

did not produce traction problems on the flat terrain. On an analysis of variance of season (2) x subject age (3 levels) x subject weight (2 levels), there were no significant main effects or interactions. There was a one-to-one correspondence between seasons.

- The uphill run event produced significantly different seasonal scores, the wet season times were approximately 1.2 times longer than the dry season times for the reasons explained previously. The uphill run scores did not differ among the season x age x weight groups used in a *post hoc* analysis of variance, except for the main effect for seasons.

- No significant seasonal effects were found for physiological indicators of absolute body weight loss, absolute amount of water consumed, absolute amount of sweat lost, and percent of body weight lost as sweat. A 2 (age level) x 2 (weight level) analysis of variance of sweat loss percent produced no significant differences among age/weight groups. In both seasons, subjects lost one percent of their body weight per hour while traversing the course. Because the age and weight groups were restricted in range and in numbers of subjects, the similarity of performance among the groups should not now be generalized. Future reports on jungle portability resulting from continuing studies will provide more definitive data with respect to characteristics of subjects, loads carried, and course performance.

- Jungle march rates were slow. The march rate for the uphill run, a 100-yard dash up a steep slope through mud and vines, was 19.7 minutes per mile: the double time rate, over flat, less tangled terrain, was 12.6 minutes per mile. The fast paced, long distance forced march was performed at a rate of 27.5 minutes per mile, while the normal walk rate was slower at 35.6 minutes per mile. All march rates were achieved under a standard equipment load of 25 pounds which included clothing and M-16 rifle (see figure 6).

- Physiological indicators, performance times, and subjective measures each constitute a relatively independent domain within the performance envelope, and all are necessary for a complete evaluation of man-materiel systems in the tropics.

- The preceding conclusion regarding subjective measures is based on actual materiel tests and was not investigated in the present study. This investigation, and others in varying stages of completion, have demonstrated the feasibility of approaching human factors measurement through the establishment of standard physical facilities and controlled activities in the natural environment. The usefulness of the facilities and procedures is the establishment of a reproducible measurement bed that can be used to standardize tests of item-soldier relationships. Data from various test items may be compared and a reliable data bank can accumulate to provide guidelines, in the form of military standards for equipment design, to CONUS agencies without the need for field testing.

II. INTRODUCTION

"The foot-soldier must be wed to the dust if he doesn't want to bite it!" A French Infantry Lieutenant described the link between the soldier, his equipment, and his environment at the turn of the 20th century after having made on historical review of the load of the foot soldier.[1] The need for making the link has been increasingly recognized by organized armies from the Roman Legion to the major powers of today. The U.S. Army developed procedures and details for making the link in the form of the Man-Materiel Systems Human Factors Engineering (HFE) program.[2] The HFE program outlines steps and responsibilities for merging the man, his equipment, and the environment in which they are to operate "to achieve the most effective, efficient, and reliable man-equipment combination under use conditions."[2]

Kennedy, *et al*,[3] pointed out that, "It is evident that we are dealing with very heavy loads for any soldier to carry. Despite the continually increasing awareness of the impact of heavy loads on the soldiers' mobility in any climate, and his susceptibility to heat exhaustion collapse in jungle or desert operations, current loads have reached very high levels. As indicated above, these problems of very high loads tend to be overlooked since most load carriage studies are conducted in comfortable environments. Thus the physiological impact of a heavy load is underestimated when the soldier is committed to combat in extreme environment."

The requirements for assessing man-materiel performance characteristics under expected use conditions point to the need for test and evaluation in the tropics. Approximately three-fourths of the world conflicts through the years 1960–72, occurred within the tropics.[4] There is no reason to believe that the trend will not continue.

To the dismay of many senior US Army officers there is little systematic knowledge of tropic effects on man-equipment performance. In the opinion of the authors, there seem to be four major reasons for this: a) CONUS research and development elements with *environmental* missions do little or no actual tropic field work, b) Everyone thinks someone else is doing the work, c) Very few people even think about the problem until a conflict situation arises in the tropics and the United States becomes involved, and d) Most military personnel believe that there is systematic documentation of these problem areas abstracted from actual combat situations such as in Vietnam and the South Pacific. Systematically derived documentation is largely nonexistent in DOD information repositories. Because the tropics continue to produce effects that cannot be predicted from chamber testing, the US Army Tropic Test Center is charged with the responsibility of assessing tropic effects on man-materiel systems in the Canal Zone.[5,6]

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1 Carre, Lt., 13th Infantry Regiment, French Army, *Historical Review of the Load of the Foot Soldier*, Circa 1900.

2 AR 602-1, *Human Factors Engineering Program*, 4 March 1968.

3 Kennedy, S. J., *et al*, *The Carrying of Loads Within an Infantry Company*, Technical Report 73-51-CE, US Army Natick Laboratories, May 1973.

4 Batelle Memorial Laboratories (TACTEC), Letter Report R-4172, List of Conflicts, 31 October 1972.

5 Dobbins, D. A. and Downs, G. F. III, *Laboratory vs. Field Tests: A Limited Survey of Materials Deterioration Studies*, USATTC Report 7307002, July 1973.

6 Jones, R. D., *Effects of Thermal Stress on Human Performance: A Review and Critique of Existing Methodology*, HEL APG Tech Memo 11-70, May 1970.

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III. BACKGROUND

A. PROBLEM

There is a substantial difference between *human engineering* and *human factors*[1] Distinguishing the two terms will help to clarify the problem addressed by the present report. *Human engineering* is a term applied to the technology which deals with methods of designing machines and work environments in ways to match human capabilities and limitations. Examples are the design of controls and workspace to reduce error, fatigue, and discomfort. The engineering phase of development testing in the Army addresses the design, safety, and technical characteristics of "item-centered" human engineering problems.[2] The term *human factors* applies to a wide variety of internal and external environmental variables that motivate, modify, limit, or somehow affect human behavior. Examples of internal variables include perception, intelligence, aptitudes, physiology, personality, attitude, and physical strength. Examples of external variables include heat, humidity, noise, vibration, shock, light, vegetation, and terrain. The tropic service phase of development testing centers on "item-soldier-environment" interaction in order to complete the assessment of design characteristics under use conditions.

This study was prompted by a lack of standardized human factors test methods. The problem is not merely measuring general item-soldier performance in an extreme environment, but in establishing controlled, standard, and reliable measurement techniques and instrumentation that will identify specific item-soldier performances that contribute to failures, malfunctions, or errors; i.e., casual analysis. Most tests contain a "Human Factors" subtest. However, there has been little generalization of human factors results beyond the specific problems studied, and little payoff in the form of human factors guidance for the future design of materiel.

In a recent critical review of methodology used in investigating effects of thermal stress on human performance, Jones[3] offered the following summary comment: "Taken as a whole, the literature reviewed provided no clear-cut criteria upon which to base predictions of mental or psychomotor performance under thermal-stress conditions. The basic lack of agreement between the various studies is primarily the result of generalized failure to standardize experimental conditions. The use of a wide variety of temperature levels, exposure times, etc., makes any direct comparisons of results difficult." Kennedy, *et al*[4] concluded, "In summary, the whole area of load carrying within the infantry company presents numerous problems to which there are no fully satisfactory solutions. A systems approach, which would include all items which are expected to be man-carried, is required in all stages of their development to make sure the problems of carrying are adequately defined and maximum effort made to reach optimum decisions as to configuration, weight, and utilization."

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1 *Tropic Environmental Effects*, USATTC Report 720200, Revised February 1974.

2 Letter, AMSTE-TO-P, Headquarter, TECOM, subject, DT and OT Relationship, 5 December 1974.

3 Jones, R. D., *Effects of Thermal Stress on Human Performance: A Review and Critique of Existing Methodology*, HEL APG Tech Memo 11-70, May 1970.

4 Kennedy, S. J., *et al*, *The Carrying of Loads Within an Infantry Company*, Technical Report 73-51-CE, US Army Natick Laboratories, May 1973.

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Until human factors relationships among various materiel tests are established systematically through standardized test procedures, tropic human factors test capability cannot go forward in the area of causal analysis. The ability to develop generalizable results will lead to quicker and more effective application of development test results to future design of Army materiel.

B. OBJECTIVE

The objective of this study was to compare wet season and dry season human performance baseline data (no test item) in the jungle using the man-pack portability course as a standard measurement technique.

C. DEVELOPMENT OF MAN-PACK PORTABILITY COURSE (MPPC)

A tropic man-pack portability test facility was designed as a basis for evaluating whether a test item "can be carried and used by a fully encumbered combat soldier and whether the item interferes with the performance of other tasks."[1] Research and development of the MPPC resulted in TECOM draft Test Operations Procedure 1-3-550, Man-pack Portability Testing in the Tropics.

1. Test Site Selection. To acquire needed data for establishing a portability test site, information was obtained from a review of scientific and military literature and from interviews with Vietnam veterans.

a. Literature Review. An extensive review was made of 210 documents containing information on Southeast Asia (SEA), combat and combat-related activities in SEA, and past "state-of-the-art" man-pack portability evaluations and techniques, including all service tests conducted at USATTC that included portability evaluations. From this review the following major conclusions were drawn:

- Large land areas in SEA have terrain, vegetation, and climate that are analogous to test areas available in the Panama Canal Zone. Areas in South Vietnam that most closely resemble the Canal Zone are the old Delta region and the lower Central Highlands.

- The majority of studies of load-carrying equipment and techniques was limited to one particular type of equipment. Some studies involved comparisons between a test item and a standard item similar in function.

- Test results from USATTC portability evaluations could not be related to past or future evaluations because of lack of standard terrain, course length and test methods.

- Portability evaluations during tropic service tests usually consisted of questionnaires only.

[1] TECOM Supplement 1 to AR 602-1, *Man Materiel Systems*, Human Factors Engineering (HFE) Program, April 1973.

b. Interviews with Vietnam Returnees. Structured interviews were conducted with 50 enlisted men stationed in organizational elements of the US Army Forces Southern Command. All interviewees had patrol experience in South Vietnam within 6 months prior to being interviewed. Major conclusions drawn from the interview data were as follows:

- Duration of patrols was usually 1 day or less.

- Typical distance traversed was 4000 to 5000 meters. Distance was determined for either a one-way trip when individuals were to stay at a base camp for a prolonged period or for a complete round trip to the point of original departure.

- Major missions of patrols were primarily for purposes of search and clear, or for observation and reconnaissance.

- Most comments obtained on difficulties encountered while carrying equipment and gear were concerned with loads being too heavy, loads not properly secured, discomfort and irritation caused by straps and projections, or equipment becoming entangled in heavy underbrush and vines.

- Equipment most frequently carried and used included pistol belt, small pack, canteens, tools for clearing areas or setting up bases, individual and crew-served weapons, ammunition, and radios.

- Most of the interviewees expressed the opinion that the terrain and vegetation were similar to that in the Canal Zone, especially those who had been stationed either in the Annamite Cordillera or Central Highland areas.

c. The Physical Facility. Based on the above information, an extensive search was made of the test areas available in the Canal Zone. A portability course was established at the USATTC Gamboa A-1 test area (see figures 1 and 2). The course approximated the distance covered by daylight patrols on terrain and vegetation representing large land areas in humid tropics. The complete course is 4000 meters in length and contains a variety of topographic features including hills, large gullies, streams and rivers, thick underbrush, vine entanglements, and flat, relatively sparse areas. Appendices A and B describe the vegetation, soils and topographic features of the course.

2. Test Event Selection

a. Rationale. The physical facility and the course events were selected and established to allow objective portability testing, while at the same time maintaining maximum realism. The aim was to recreate a representative physical facility from the findings of the literature review and interviews with veterans, and to couple it with a permanent scenario containing only enough control to yield objective data to insure personnel safety. The rationale used in selecting events is summed up by the following guidelines:

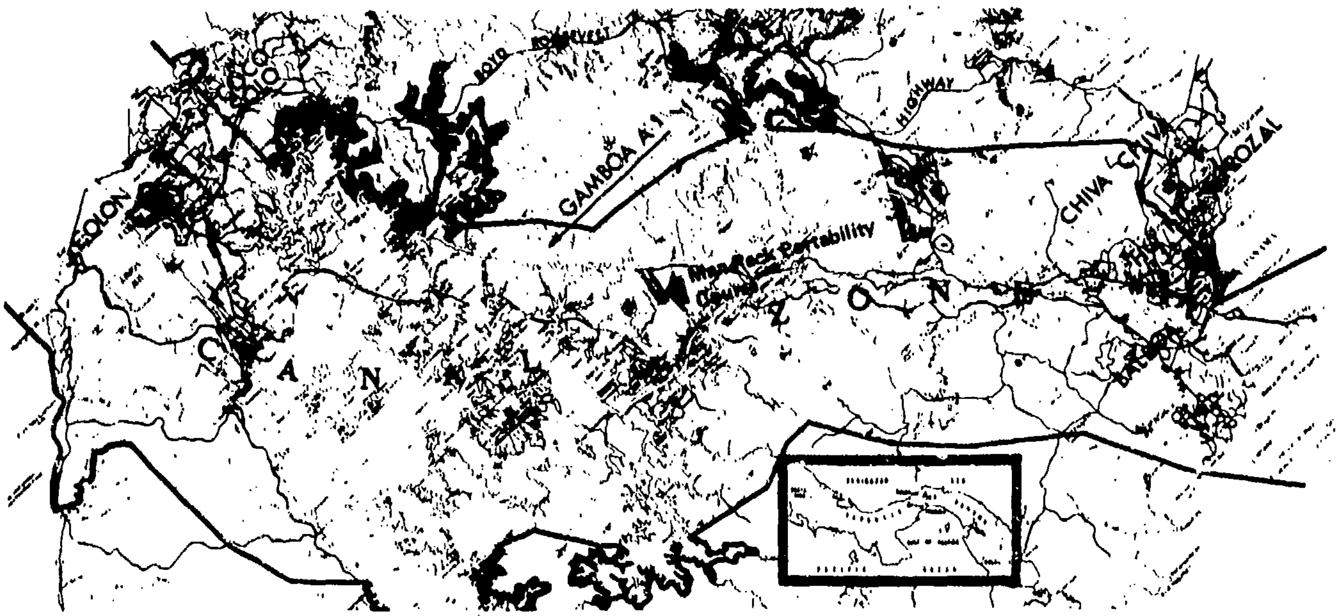

Figure 1. Map of Canal Zone Showing Location of Man-Pack Portability Course.

- Testing in environments where terrain, vegetation, duration, and task difficulty are representative of areas where test items may be deployed.

- Obtaining performance data on user populations under use conditions.

- Performing operations closely related to tactical situations.

- Using objective measurement methods that provide reliable data with minimum test interference.

- Using reliable subjective measures to supplement the information derived from objective measurement.

b. Course Events. Applying the above rationale, five timed course events were established over a 4-kilometer distance through the jungle: forced march, uphill run, double time, normal walk, and total course time. Figure 3 is a course diagram showing events and rest breaks. The following types of measures were developed:

- Short-maximum (SM). For events of short duration (lasting only 1 or 2 minutes and measured to the 10th of a second), maximum performance was solicited (i.e., 300-foot uphill run and 200-foot double time).

- Long-typical (LT). For events of long duration (approximately 30 minutes and measured to the nearest minute or second), typical performance was solicited (i.e., 5200-foot forced march, 6700-foot normal walk, and 2½-mile total course exercise).

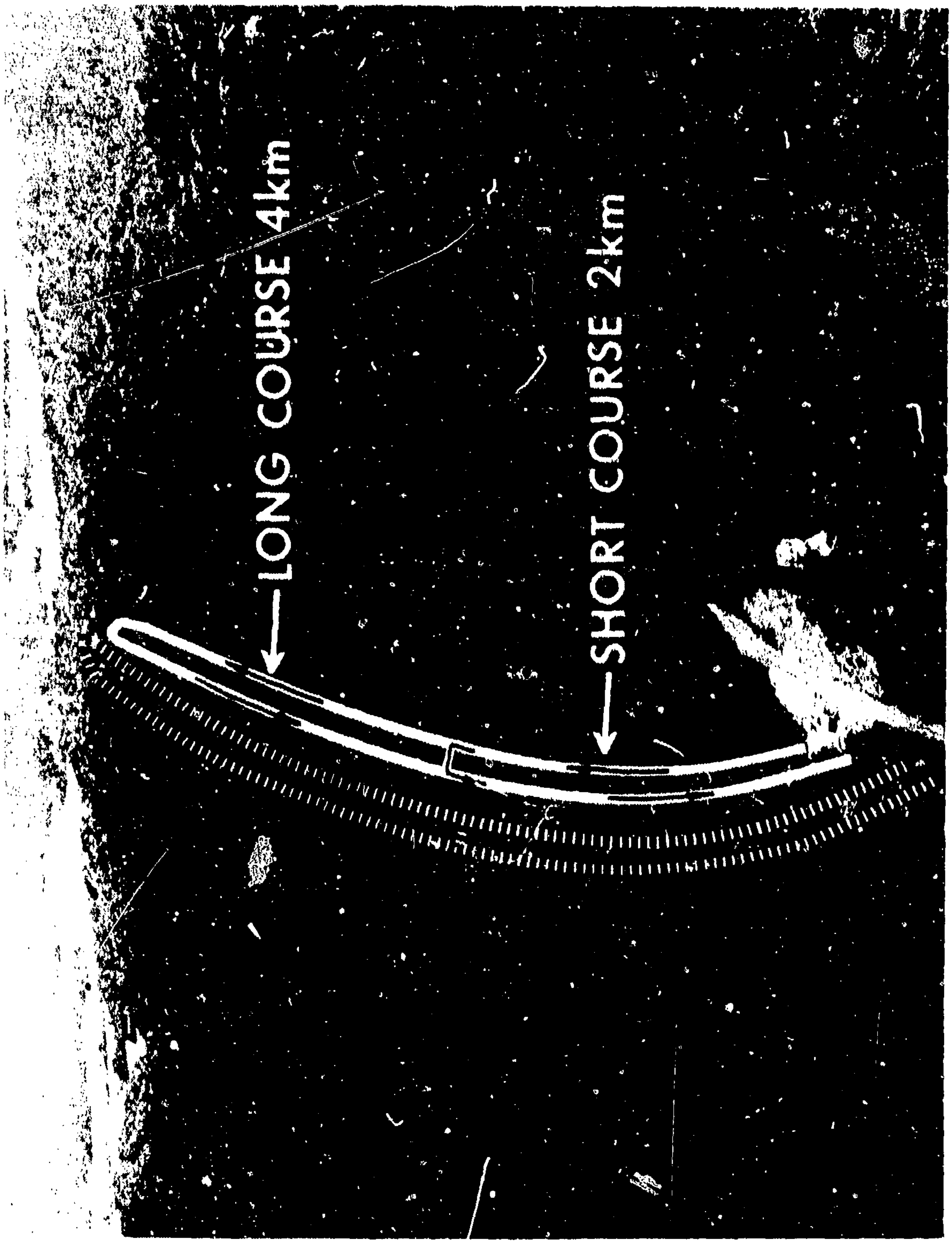

Figure 2. Aerial View of Man-Pack Portability Course.

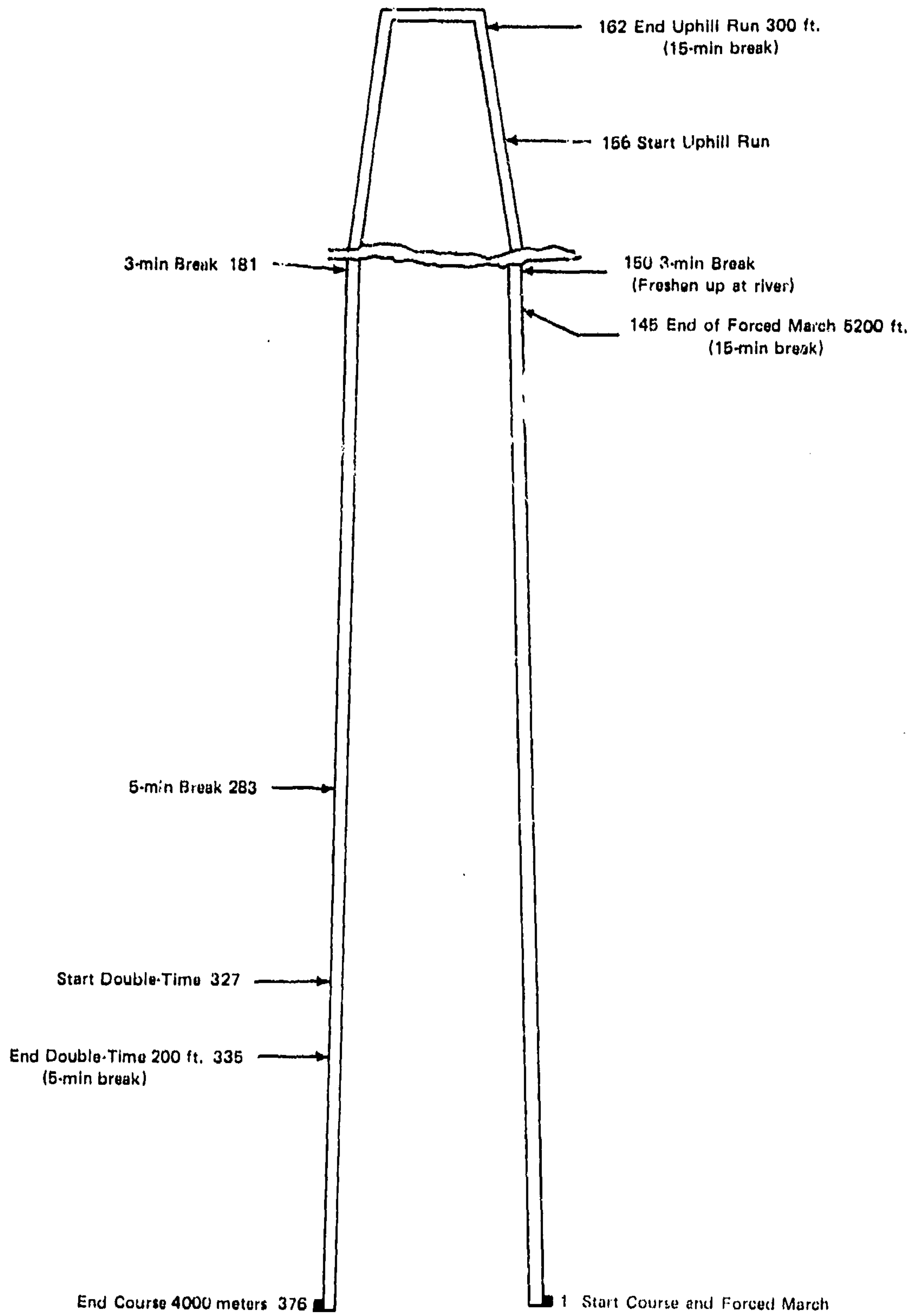

Figure 3. Diagram of Man-Pack Portability Course Showing Events and Breaks.

- Estimates of physiological cost of traversing the course were obtained by measuring individual weight loss and water consumption.

- Short-typical performance events were not included because individual differences in motivation and competitiveness among subjects contributed error variance that masked the performance being measured. Long-maximum performance events were not included in the scenario because of safety considerations.

3. Safety Precautions. In order to insure that the activities of the test course were within the limits set for activity in the tropic heat, the following factors stressed in TB MED 175[1] were covered procedurally.

a. Water. During heavy activity in the jungle at temperatures above 85°F, a man may need 13 quarts of water to drink per day; if less than 85°F, 9 quarts per day.[1] Each man who traversed the MPPC carried a 1-quart canteen. Extra water was available in containers at various points on the course. Most subjects did not drink a full canteen of water. The data of interest was measuring individual water consumption.

b. Salt. The need to replace salt lost in sweat varies among individuals. A solution to the salt problem is drinking water with a 0.1-percent salt concentration, or use of impregnated salt tablets.[1] Men who had experienced a need for salt tablets carried salt tablets with them. They were seldom used.

c. Acclimatization. A minimum of 2 weeks in the tropics performing physical activities is necessary for acclimatization. Combat troops going over the test course had more than 2 weeks acclimatization.

d. Physical Condition. The general physical condition of the individual has a significant bearing on reaction to heat stress. Individual susceptibility to heat may be enhanced by a large number and variety of conditions.[1] Troops going over the test course were informed ahead of time of the nature of the test course and were required to have a Code A physical profile.[2]

e. Work Schedule. Reduction of work load decreases the total heat stress. Alternate work and rest periods are desirable. Under severe conditions, duration of rest periods should increase beyond 5 minutes of rest after 25 minutes work in the sun. On the test course there are a total of 46 minutes of mandatory rest breaks in 2 hours (two 15-minute, two 5-minute and two 3-minute) appropriately spaced over the course. Additional breaks are allowed if needed.

f. Protection from the Environment. Jungle fatigues and jungle boots were worn by troops.

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[1] TB Medical 175, *The Etiology Prevention, Diagnosis, and Treatment of Adverse Effects on Heat*, 7 August 1957.
[2] AR 40-501, *Standards of Medical Fitness*, 5 December 1960.

g. Use of Wet Bulb Globe Temperature (WBGT) Index. In the Control of physical activity, TB Med 175 gives the following standards for application of the WBGT index. The measurements must be taken in a location which is the same as, or closely approximates, the environment to which personnel are exposed. When the WBGT index exceeds 80°F, discretion should be used in planning heavy exercise for unseasoned personnel. When the WBGT reaches 85°F, strenuous exercises such as marching at standard cadence should be suspended in unseasoned personnel during their first 2 weeks of training. At this temperature, training activities may be continued on a reduced scale after the 2nd week of training. Outdoor classes in the sun should be avoided when the WBGT exceeds 85°F. All physical training should be halted when the WBGT reaches 88°F. Acclimatized personnel can carry on limited activity at a WBGT of 88°F to 90°F, for periods not exceeding 6 hours a day.[1] WBGT readings in the jungle during the present study did not exceed 79.5°F. WBGT readings taken in the jungle are little influenced by direct solar radiation and therefore may be interpreted as "conservative" in the sense that readings in a nearby open area may be higher on the black globe portion of the index. However, the wet bulb portion of the index may decrease. The nature and effect on human physiology and comfort of these possible changes in the value of the WBGT readings are not known.

[1] TB Medical 175, *The Etiology Prevention, Diagnosis, and Treatment of Adverse Effects on Heat*, 7 August 1957.

IV. METHOD

A. PROCEDURES

The physical facility and course events are described in appendices A through C. A complete test operation procedure is contained in the US Army Test and Evaluation Command draft TOP 1-3-550, Man-pack Portability Testing in the Tropics.[1] In order to obtain data on seasonal differences in course performance, subjects were tested during two 2-week periods during 1972. Variables, load carried, seasonal characteristics and sample characteristics are described below.

The procedures were as follows: On the morning of a test day, five combat troops including one NCO were transported from the 193rd Infantry Brigade, Fort Clayton, Canal Zone. The troops and test personnel drove (45 minutes) to the entrance to the test course. The men were briefed on their task, filled out personal data forms, and stripped to shorts and socks for weighing (figure 4). After the men and their filled canteens were weighed, the men donned clothes and equipment and entered the jungle at course marker number one at approximately 0900 hours each test day. The group followed the markers shown in figure 5, and completed the events shown in figure 3. The course events marker numbers were a series of signs through the jungle which marked the course that the subjects traveled. The markers were placed so that a numbered arrow (black numbers on a yellow background) pointed the way to a numbered square placed within the limits of visibility as shown in figure 4. There were 376 markers placed throughout the 4-kilometer course. After completing the course, the men and their canteens were reweighed. Different men were tested each day.

The equipment carried (figure 6) by each test subject on each test day of both seasons was exactly the same. The equipment carried was a typical tropic combat load totaling 25 pounds, including all clothing except undershorts and socks.

B. VARIABLES

The variables of this study, together with a designation of type of data, when the data were taken, and the units of measurement are listed in table 1.

C. SEASON CHARACTERISTICS

In the Canal Zone, there are two distinct weather patterns, each having its own set of climatic characteristics. The patterns are referred to as the dry season and the wet season. The dry season is characterized by very low rainfall, higher wind speed, and slightly higher temperatures compared with the wet season. Table 2 outlines the basic differences between the seasons.

Figures 7 and 8 compare tropic temperature and rainfall, respectively, with temperate and arctic areas of the world. It can be seen that tropic seasonal effects are described by characteristics opposite from other areas of the world. While temperate and arctic areas have

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[1] TECOM Test Operation Procedure 1-3-550, *Man-Pack Portability Testing in the Tropics*, 22 January 1973. (draft)

Figure 4. Test Soldier and Canteens Being Weighed.

Figure 5. Jungle Course Showing Men and Course Markers.

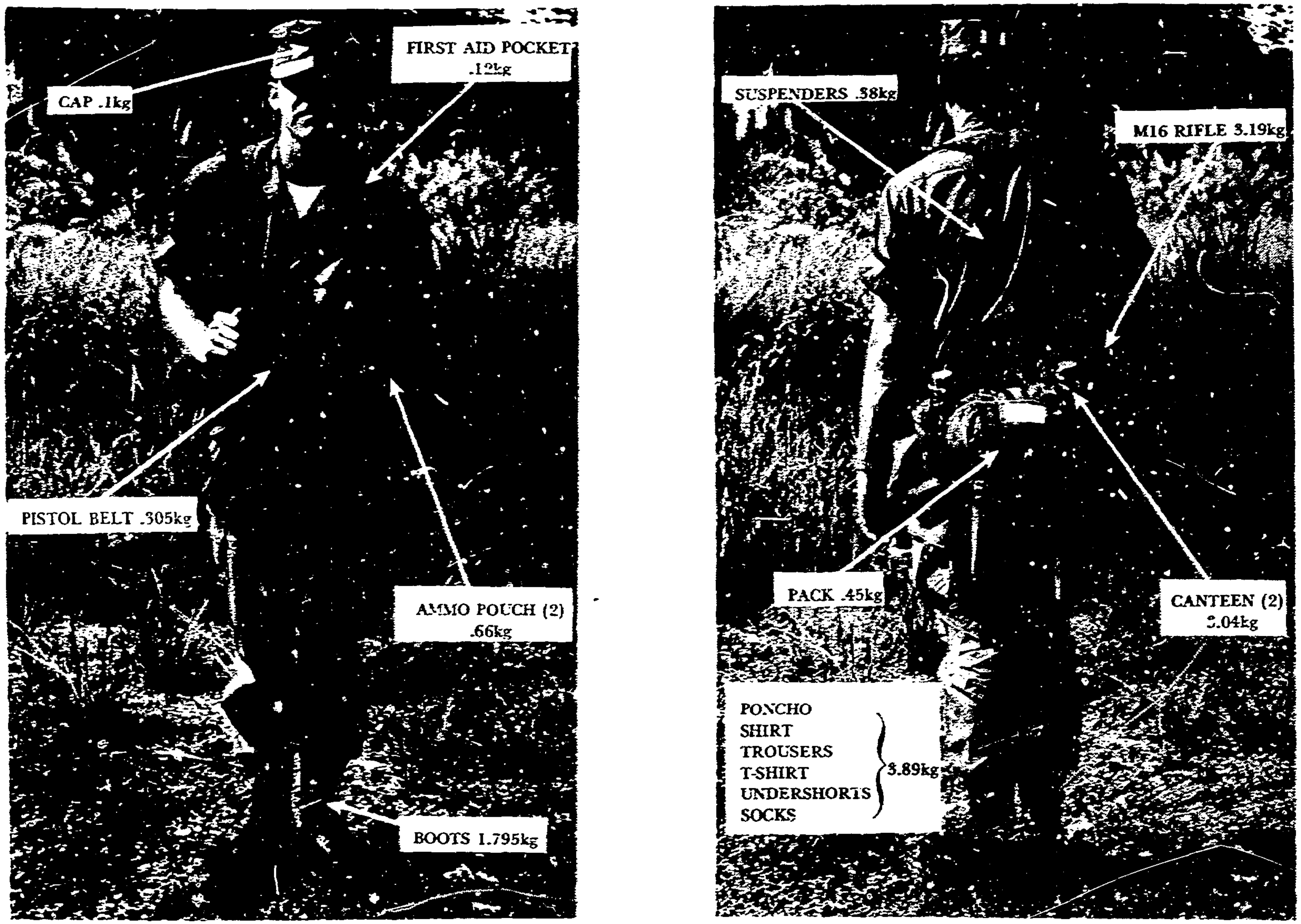


Figure 6. Test Subject with Nomenclature and Weight of Equipment.

TABLE 1. VARIABLES

Type/Number/Name	Type of Data	When Measured	Units of Measurement
Background			
1 MOS	I	B	Nominal
2 Acclimatization	I	B	Months in Canal Zone
3 Age	I	B	Years
4 Body Weight	I	BA	Kg to nearest 5g
Natural Environment Treatment			
5 Tropic Season			Nominal
Performance Events			
6 Total Time	G	C	Nearest Minute
7 5200 Forced March	G	C	Nearest Second
8 Normal Walk	G	C	Nearest Minute
9 300' Uphill Run	I	C	Nearest 0.1 Second
10 200' Double Time	I	C	Nearest 0.1 Second
11 Body Weight Loss	I	BA	Kg to nearest 5g
12 Water Consumed	I	BA	Kg to nearest 5g
13 Sweat Loss, Absolute	I	*	Var. 11+ Var. 12
14 Sweat Loss, %	I	*	Var. 13/Var. 4, to 0.1%

LEGEND: I = Individual Score G = Group Score
B = Before Course C = On Course A= After Course
*Computed

TABLE 2. COMPARISON OF SEASONAL CHARACTERISTICS IN CANAL ZONE (Gamboa A-1 Human Factors Jungle Test Area)

Characteristic	Season: Dry	Season: Wet
Approximate Duration	January–March	May–November
Temperature /Relative Humidity	Night 75°F/100% Day 85°F/70%	74°F/100% 83°F/85%
Percent Days with Rain	27%	70%
Average Daily Rainfall (Rainy Days)	0.31 in	0.53 in
Average Soil Moisture	26.3%	63.3%
Wind Speed	0-3 MPH	0-1 MPH

NOTE: The missing months, December and April, are transition months. Their characteristic values lie somewhere between those for dry season and for wet season.

a wide range in temperature and a narrow range in rainfall throughout the year, tropic areas have a narrow range of temperature and a very wide range of rainfall. The data shown in figures 7 and 8 describe the USATTC human factors jungle test area in Gamboa. The Atlantic and Pacific slopes of the Canal Zone and other tropic areas in the world may show a few degrees more variation in temperature. However, the natural day-to-day and

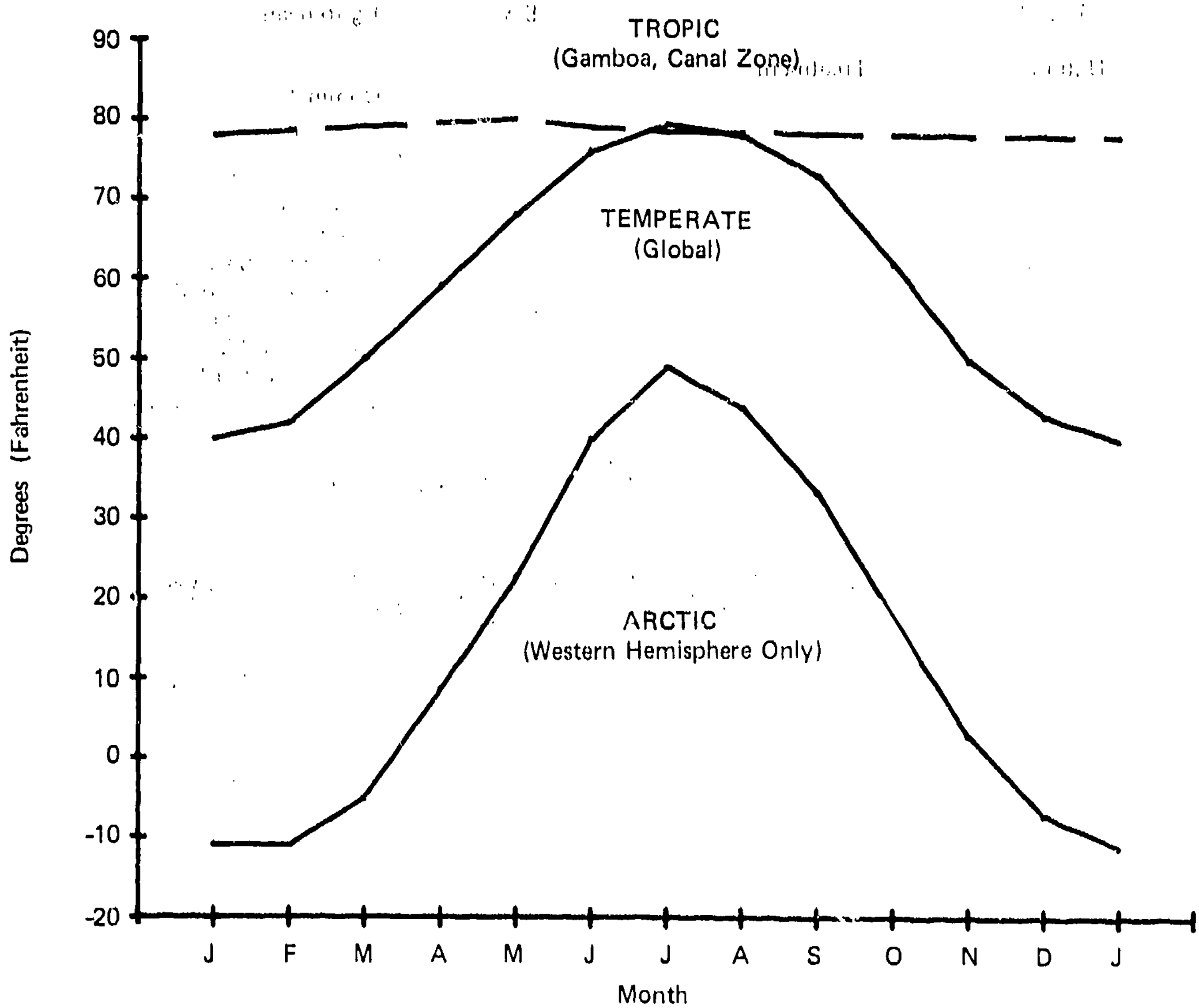


Figure 7. Comparison of Tropic, Temperate, and Arctic Temperature Levels Throughout a Typical Year.

month-to-month consistency of the temperature/humidity combination of the Gamboa jungle provides an important experimental control in human factors testing at no sacrifice of realism.

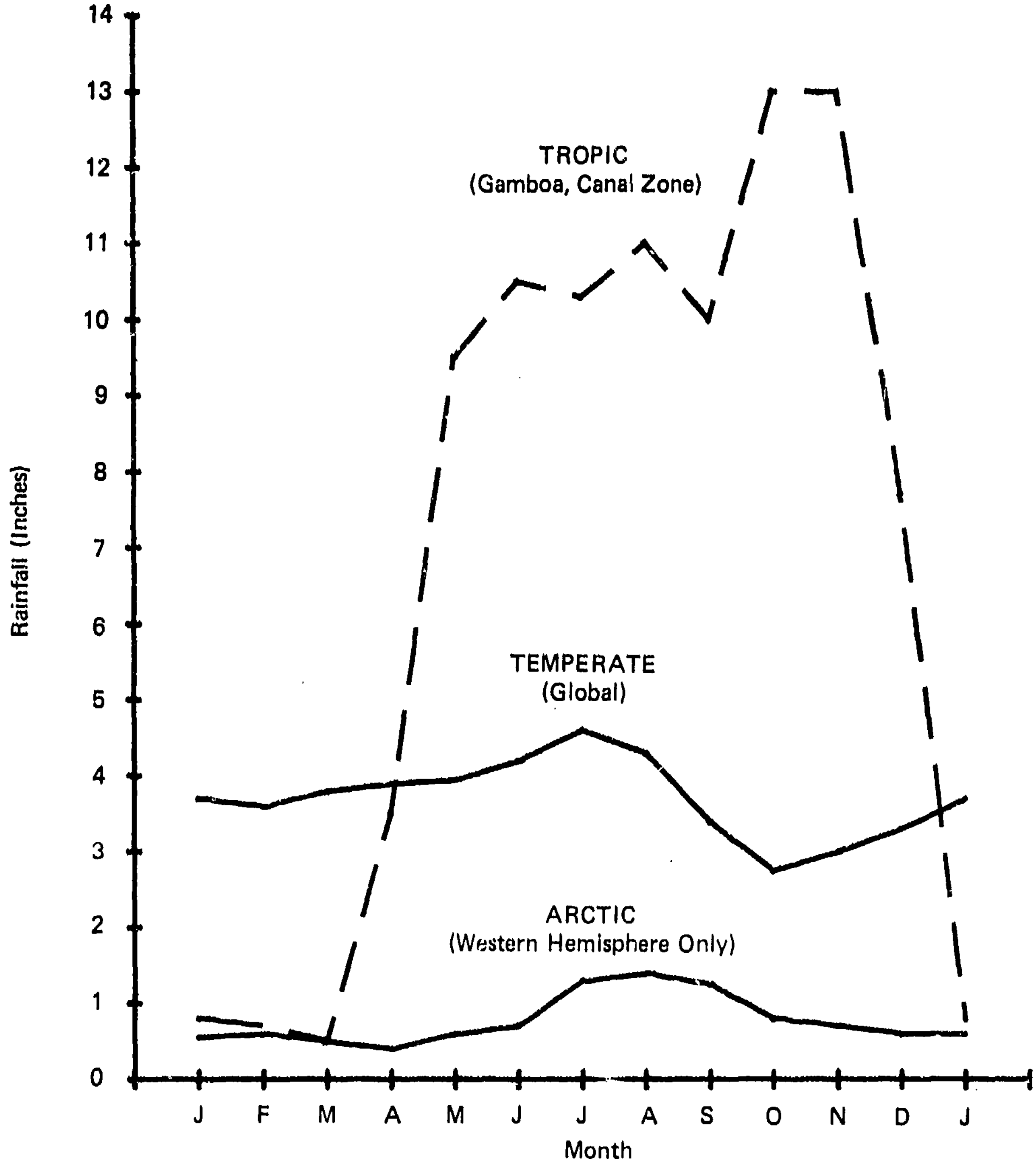


Figure 8. Comparison of Tropic, Temperate, and Arctic Rainfall Levels Throughout a Typical Year.

D. SAMPLE CHARACTERISTICS

Each group of test subjects consisted of five combat infantry troops, one of whom was an NCO. Because the literature review and returnee interviews revealed that soldiers who engaged in jungle activity generally traveled in groups, five subjects were chosen as a convenient sample with which to work. The test subjects traveled the long portions of the course as a group. As a result group scores, rather than individual scores, were obtained for those portions. On the shorter events, and for the physiological data, individual scores were obtained. A summary of the variables and scoring system is shown in table 1. Characteristics of test subjects are shown in table 3.

TABLE 3. SAMPLE CHARACTERISTICS FOR SEASONAL TESTS

	Season	
Characteristics	Dry	Wet
Test Dates	24 Feb–8 Mar 72 plus 4–8 Dec 72	27 Nov–1 Dec 72
Sample sizes		
Test Groups	15	5
Test Subjects	74	26
Variable 1: MOS	Combat Infantry	Combat Infantry
Variable 2: Acclimatization (months in Canal Zone)	Mean: 7.4	11.8
	SD: 6.0	5.2
Variable 3: Age (years)	Mean: 21.5	22.2
	SD: 2.4	3.6
Variable 4: Body Weight (pounds)	Mean: 160.6	153.2
	SD: 22.0	17.7

IV. RESULTS

A. EFFECT OF SEASON ON COURSE PERFORMANCE

1. Event Performance Levels by Season.

Table 4 lists course performance levels separately for the dry and wet seasons. An inspection of the sizes of the means in table 4 and the calculated t values, reveals significantly longer performance times in the wet season for each on-course timed event except for double time. The seasonal performance trends are not only in the same direction but are also of about the same magnitude. The next to last column in table 4 shows the ratios of wet season to dry season performance as generally consistent at about 1.2 to 1 for the timed events.

For the physiological data, the trend was not consistent. Absolute weight loss (variable 11) was about the same level in both seasons but in the opposite direction, with more total weight lost in the dry season although not to a statistically significant extent. Absolute water consumption was the same in both seasons--averaging 1 quart per man for the 2-hour 4-kilometer course. Variable 14, sweat loss as a percent of body weight, was calculated by combining weight loss and water consumption and presenting the sum as a percent of body weight, compensating for individual body weight differences. Subjects lost a fairly consistent 2 percent of their body weight in sweat as a result of having traversed the course, regardless of the season. The sweat loss rate in each season, then, was 1 percent of the subjects body weight per hour during the 2-hour test period.

An explanation of the difference in seasonal timed performance can be made on the basis of the main difference between the two seasons--that is, the amount of rainfall. One effect of frequent heavy rain in the wet season was to increase the soil moisture from an average of 26.3 percent (by weight) in the dry season to an average of 63.3 percent in the wet season. The ground was extremely slippery underfoot in the wet season, slowing progress through the jungle at all points along the course. Another factor, also related to amount of rainfall, was that many streams were little more than small depressions in the ground during the dry season, whereas in the wet season they were full of water and had slippery banks, creating a series of obstacles in the wet season not present in the dry season.

The consistent differences in seasonal course performance have practical significance for tropic testing. Many tropic tests require testing in both seasons in order to document seasonal effects, because neither data on previous specific tests nor general seasonal data are available for predicting the effects of one season given the effects of the other season. The data on march rates from this investigation indicate that a multiplier of 1.2 may be used to convert dry season to wet season performance for all timed course events except the double time event. The double time event data and the physiological data of weight lost and water consumed may be converted by a 1.0 multiplier. The need for duplicate seasonal testing is eliminated by use of the multipliers for the same item on the established course. Specific uses of such multiplied will be outlined in subsequent reports after further study.

TABLE 4. TEST COURSE PERFORMANCE IN DRY SEASON AND WET SEASON

Variable Number	Test Course Event	Performance Data: Season	Sample Size	Mean	Standard Deviation	Wet/Dry Ratio	t Test: Dry versus Wet Season Means
	Group Scores						
6	Total Time (Minutes)	Dry	15	123.5	8.7		
		Wet	5	142.2	8.1	1.24†	4.25‡
7	Forced March (Minutes)	Dry	15	25.5	2.0		
		Wet	5	31.8	4.8	1.25	4.33‡
8	Normal Walk (Minutes)	Dry	15	47.2	7.2		
		Wet	5	59.0	4.0	1.25	3.49‡
	Individual Scores						
9	Uphill Run (Seconds)	Dry	74	63.7	20.7		
		Wet	26	76.6	25.7	1.21	2.57‡
10	Double Time (Seconds)	Dry	74	27.8	5.9		
		Wet	26	31.0	11.1	1.12	1.85
11	Weight Loss* (Kg)	Dry	74	.90	.46		
		Wet	26	.70	.60	0.78	1.46
12	Water Consumed* (Kg)	Dry	74	.72	.30		
		Wet	26	.75	.27	1.04	1.07
13	Sweat Loss* (Kg)	Dry	74	1.62	.48		
		Wet	26	1.45	.56	0.89	1.49
14	Sweat Loss* (% Body Weight)	Dry	74	2.22	.55		
		Wet	26	2.09	.75	0.94	0.07

*Sweat loss = body weight loss + water consumption. Expressing these physiological data as percent of body weight reduces the effect of correlation between body weight and absolute sweat produced. Comparisons of individuals and groups using percent body weight are thus made on a common basis.

†Total time wet/dry season performance ratio computed after subtracting constant 46 minutes at rest time from each mean.

‡$p < .05$

2. Effect of Subject's Age and Weight on Performance

The previous section discussed differences in performance due to differences in season—the objective of this investigation. Differences among individuals and the relationships of those differences to performance were not addressed. Because individuals differ in ability and performance, it is beneficial from the standpoint of selection of individuals for jungle combat activities to identify human factors that contribute to high or low performance.

Although this investigation was not designed to elicit age and weight effects, the data provide an opportunity to inspect a limited range of age of subjects (18 to 34 years) and a limited range of weight of subjects (113 to 213 pounds with only a few subjects at the extremes). The extents to which age and weight groups differed in course performance are shown through unweighted means analyses of variance (ANOVA).[1] Two of the ANOVAS performed were 2x2x3 complete factorials of individual uphill run scores and double time scores (variables 9 and 10, respectively, using square root transformations to attain homogeneity among cell variances); each ANOVA was based on two seasons (dry versus wet), two weight groups (113–151 pounds versus 152–213 pounds) and three age groups (18–20.4 years versus 20.5–22.4 years versus 22.5–34 years).

A third ANOVA was performed on the physiological effect of percent body weight lost as sweat (variable 14). Table 4 indicated no seasonal differences for sweat loss. Therefore, seasonal data were combined in order to obtain a relatively equal number of subjects in each ANOVA cell. The cell structure was further condensed to two age groups to achieve homogeneity of variance among cells. The result was a 2x2 factorial: two age groups (18–20 years versus 21–34 years), and two weight groups (113–151 pounds versus 152–213 pounds). The hypothesis tested in this ANOVA involves percents of body weight lost as sweat for different weight/age groups, rather than absolute body weight lost as sweat. The reason for using percents rather than absolute values was that body weight and absolute sweat lost are related ($r = .56$) such that heavier subjects can be expected to lose more sweat. Because percent body weight lost may be more related to stress than absolute weight lost, the question addressed in this analysis is whether heavier (or older) subjects lose a different percent of body weight than lighter (or younger) subjects.

Table 5 shows the cell data and summary ANOVA for the uphill run scores (variable 9). There was only one significant effect—the main effect for seasons (which was also shown to be significant by the t-test result shown in table 4). Among the restricted age and weight groups of this analysis there were no differences in uphill run performance. An identical analysis for the double time scores (variable 10, analysis not shown) showed no significant effects for season, age, weight, or their interactions.

Table 6 shows the cell data and summary ANOVA for sweat loss (percent body weight, variable 14). Although there appeared to be a trend toward higher sweat loss in older age and greater weight test subjects, the sweat loss levels for age and weight groups analyzed were not statistically different at the .05-level of significance.

The analyses of variance were performed not as a complete explanation of the effects of age and weight on course performance, but as an indication of the variability that existed within the restricted ranges of age and weight of the 100 soldiers used as subjects in this investigation. Future reports on jungle portability resulting from continuing studies will provide more definitive data with respect to physical and mental characteristics of subject, loads carried, on-course performance, and before- and after-course combat relevant performance tests to gauge performance decrement due to having traveled the course under limited extra loads.

[1] Winer, B. J., *Statistical Principles in Experimental Design*, McGraw-Hill, New York, 1962.

TABLE 5. SEASON BY AGE BY WEIGHT ANALYSIS OF VARIANCE FOR UPHILL RUN SCORES

Cell Sample Sizes (N) and Means (M, minutes)

Weight (pounds)		Age Group (Years of Age)					
		A: 18--20.4		B: 20.5–22.4		C: 22.5–34	
		113–151	152--213	113–151	152–213	113–151	152--213
Season							
Dry	N =	15	11	7	20	8	13
	M =	1.014	1.041	0.923	1.077	0.978	1.246
Wet	N =	6	3	4	5	4	4
	M =	1.297	1.094	1.254	1.315	1.526	1.106

Summary of Analysis of Variance (Uphill Run Scores)

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Season	1	.175	.175	6.48*
Weight	1	.000	.000	0.00
Age Groups (A, B and C)	2	.036	.018	0.66
[I: A vs C]	[1]	.033	.033	1.22
[II: ½(A+C) vs B]	[1]	.003	.003	0.11
Season x Weight	1	.094	.094	3.48
Season x Age	2	.012	.006	0.22
[I]	[1]	.001	.001	0.04
[II]	[1]	.011	.011	0.41
Weight x Age	2	.026	.013	0.48
[I]	[1]	.000	.000	0.00
[II]	[1]	.026	.026	0.96
Season x Weight x Age	2	.067	.034	1.26
[I]	[1]	.035	.035	1.27
[II]	[1]	.032	.032	1.19
Within Cells	88	2.345	.027	
Total	99			

*p $<$ .05

TABLE 6. AGE BY WEIGHT ANALYSIS OF VARIANCE FOR PERCENT BODY WEIGHT LOST AS SWEAT

Cell Sample Sizes (N) and Means (M)

	Years of Age	
Weight (lbs)	18–20.99	21–34
113–151	N = 29 M = 2.04	24 2.08
152–213	N = 20 M = 2.22	27 2.32

Summary of Analysis of Variance

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Age	1	0.130	0.130	0.358
Weight	1	1.024	1.024	2.821
Age x Weight	1	0.023	0.023	0.063
Within Cells	96	34.890	0.363	
Total	99			

3. March Rate Comparisons

In determining tactical performance capabilities of men on jungle patrols, the rate they are able to move through the jungle under various conditions is extremely important. Seasonal jungle march rates may be compared with march rates in other geographic areas to gauge the terrain and climatic effects. Table 7 compares seasonal rates of travel achieved by the test subjects under the timed event conditions used in this investigation. The rates are expressed in various units to fit different reader interests.

The first event in table 7, total time, includes 46 minutes of mandatory rest breaks. Because the break times are included in the total time, a second set of travel rates for total time could be calculated by subtracting 46 minutes from the time shown. However, the resulting rate of travel (disregarding rest breaks) would be misleading because it is not known how the amount of rest between events influences rate of travel during events. It is probable that traveling the same course without scheduled breaks would increase the event performance times, but the extent of the increase cannot be predicted. Another caution in interpreting the rates of travel is that each rate should be considered with respect to the schedule of events accomplished immediately preceding the event of interest. For instance, the uphill run rate of travel was probably influenced by the 1-mile forced march and 15-minute break, plus a 5-minute walk and 3-minute break (figure 3) that preceded it.

The last four events in table 5 were performed without rest during the events for the distances indicated. The differences between seasonal rates of travel are an expression of the same wet season to dry season performance ratio of 1.2 to 1 pointed out above.

TABLE 7. MARCH RATES DURING DRY SEASON AND WET SEASON

Event/Season	Distance (meters)	Distance (feet)	Mean Time (minutes)	Rate of Travel (Km/h)	Rate of Travel (min/Km)	Rate of Travel (mi/h)	Rate of Travel (min/mi)
Total Time*							
Dry	4000	3,124	123.6	1.94	30.9	1.21	49.7
Wet			142.2	1.69	35.6	1.05	57.2
Combined			128.2	1.87	32.1	1.16	51.6
Forced March							
Dry	1585	5200	25.5	3.74	16.1	2.32	25.8
Wet			31.8	2.99	20.1	1.86	32.3
Combined			27.1	3.51	17.1	2.18	27.5
Normal Walk							
Dry	2263	7424	47.2	2.88	20.6	1.79	33.5
Wet			59.0	2.30	26.1	1.43	42.0
Combined			50.1	2.71	22.1	1.68	35.6
Uphill Run			(seconds)				
Dry	91	300	63.7	5.14	11.7	3.21	18.7
Wet			76.6	4.27	14.0	2.67	22.5
Combined			67.1	4.89	12.3	3.38	19.7
Double Time							
Dry	61	200	27.8	7.92	7.6	4.92	12.2
Wet			31.0	7.09	8.5	4.41	13.6
Combined			28.6	7.68	7.8	4.77	12.6

*Includes forced march, normal walk, uphill run, and double time events, plus 46 minutes of mandatory breaks.

Table 7 shows that jungle march rates were slow. The march rate for the uphill run (100-yard dash up a steep slope through mud and vines taking over a minute) was 19.7 minutes per mile, with the double time rate (over flat, less tangled terrain) somewhat faster at 12.6 minutes per mile. The *fast* paced, long distance forced march was performed at a rate of 27.5 minutes per mile, while the normal walk rate was slower at 35.6 minutes per mile. It is reemphasized that all march rates were achieved under a standard equipment load of 25 pounds which included clothing and an M-16 rifle (figure 6).

B. INTERRELATIONSHIPS AMONG PERFORMANCE MEASURES

As explained earlier in this report, the test course measures were selected to represent several dimensions of human performance: short duration–maximum effort events, long duration–typical effort events, and physiological cost. An analysis of the interrelationships among the performance measures will provide an empirical check on the construct validity of the *a priori* human performance dimensions used. NOTE: Construct validity, operationally, is a judgment that a test measures a specified attribute or construct, and that it can be used to promote the understanding and prediction of behavior.[1]

Data used for this dimension analysis were the combined season data. The basis for dimension analyses are usually intercorrelation coefficients of the variables of concern, such as those shown in table 8 of this report. Separate seasonal data were not used because each of the 36 intercorrelationships shown in table 8 showed no difference between separate seasonal values, with one exception. The exception was the correlation between the uphill run (UR) event and the double time (DT) event. The Z–transformation technique was used to test for significance of the difference between seasonal coefficients of correlation. The wet season $r = .87$; the dry season $r = .41$. An explanation for the higher relationship between the two measures in the wet season may be that the wet season slipperiness made the tasks more difficult, providing a wider separation of scores based more on ability and less on motivation or chance. The higher wet season standard deviations for the two events, shown in table 4, lend credence to this explanation. Because DT and UR correlations were positive and were significantly different from zero correlation (the relationship between the two variables for each season was in the same direction but of different strength) an average of the two coefficients based on combined seasonal data may be used in this dimension analysis. The interaction of seasonal differences and course event performance levels was addressed in the previous section of this report.

Table 8 shows the sample sizes, means, standard deviations, and intercorrelation coefficients of performance variables. Where data represent the performance of a group of subjects, the sample size was one (N=1) for each group; for data on individuals, the sample size was one (N=1) for each separate test subject. Intercorrelation coefficients of group scores versus individual scores were based on the group score versus the mean of individual scores of subjects within that group, yielding a correlation coefficient based on a sample size of 20. Although averaging individual scores may increase the value of the correlation coefficient (over the value produced by duplicating the group score for each individual and using a sample size of 100), the reduction in the degrees of freedom tends toward a conservative test for significance of the difference of the correlation coefficient from zero. Standard deviations shown in table 8 are based on the full sample sizes for each event as shown in the table.

An inspection of the intercorrelation coefficients in table 8 reveals two basic clusters of significant relationships among the measures of performance. The timed events, variables 6 through 10, achieved significance in eight out of the 10 possible intercorrelationships. The physiological measures, variables 11 through 14, achieved significance in all of their possible intercorrelationships. None of the intercorrelation coefficients among the timed events versus the physiological measures achieved

[1] Guion, R. M., *Personnel Testing*, McGraw-Hill, New York, 1965.

TABLE 8. INTERCORRELATIONS AMONG PERFORMANCE VARIABLES (COMBINED SEASON DATA)

Performance Variable† Number	Performance Variable† Name	Sample Size	Mean	Standard Deviation	Intercorrelation Coefficients‡ TT	FM	NW	UR	DT	WL	WC	SLA	SL%
6	Total Time (TT) (Minutes, G)	20	128.2	11.07	TT								
7	Forced March (FM) (Minutes, G)	20	27.1	3.98	84*	FM							
8	Normal Walk (NW) (Minutes, G)	20	50.1	8.27	81*	63*	NW						
9	Uphill Run (UR) (Seconds, I)	100	67.1	22.68	47*	59*	17	UR					
10	Double Time (DT) (Seconds, I)	100	28.6	7.63	52*	60*	27	62*	DT				
11	Weight Loss (WL)§ (Kg, I)	100	0.85	0.50	-07	-15	-05	06	02	WL			
12	Water Consumed (WC)§ (Kg, I)	100	0.72	0.29	21	-02	27	03	04	-31*	WC		
13	Sweat Loss Absolute (SLA)§ (Kg, I)	100	1.57	0.50	-19	-25	-20	11	05	82*	23*	SLA	
14	Sweat Loss (SL%)§ (% Body Wt, I)	100	2.19	0.60	02	-23	11	06	03	67*	27*	89*	SL%

*Indicates significance.

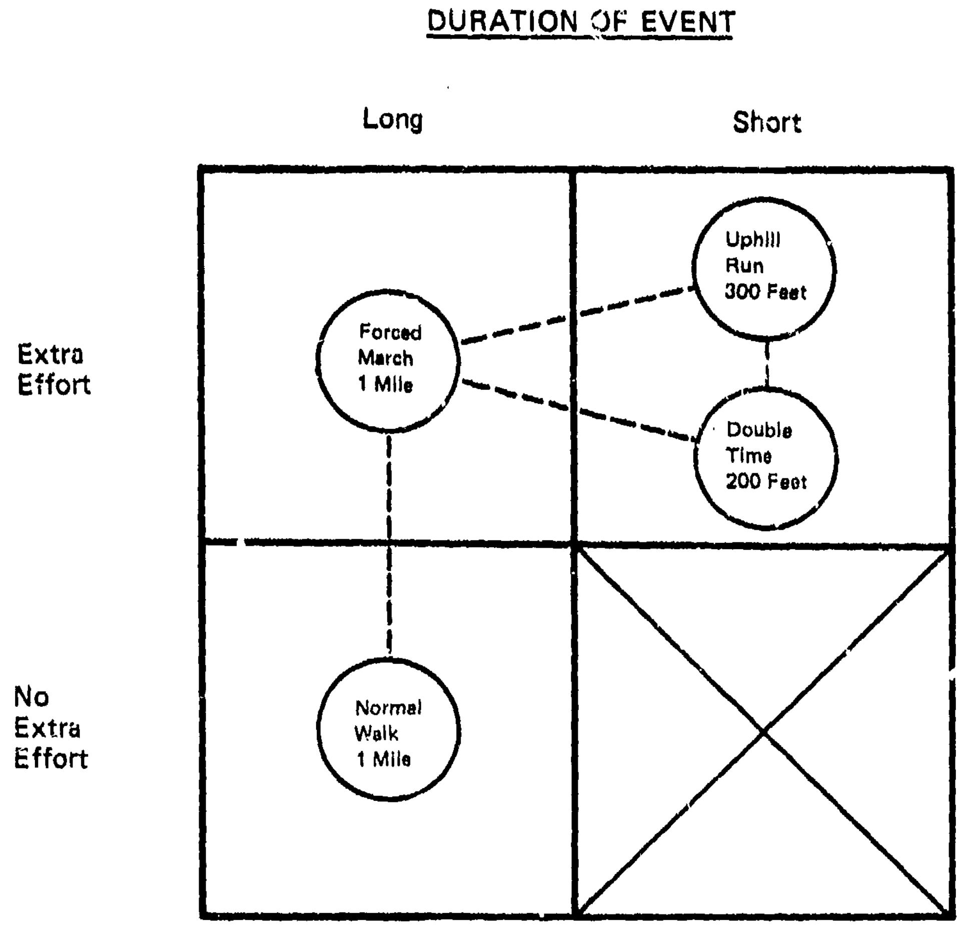
†G = Group scored. I = Individually scored.

‡N = 20 for G versus G variables and G versus I variables. N = 100 for I versus I variables. Critical values at .05-level of significance for nondirectional hypothesis that rho=0: ±.444 for N=20; ±.197 for n=100. Decimal points are omitted.

§Sweat lost = Body weight lost + water consumed. Expressing these physiological data as a percent of body weight reduces the effect of correlation between absolute body weight and absolute sweat produced ($r = .56$). Comparisons of individuals and groups using percent body weight are thus made on a common basis.

significance. The lack of association of the timed and physiological variables indicates the independence of the manner in which they measured the effect of jungle activity on soldier performance. That is, the timed course events and the physiological measurements were two separate human factors, each having accounted for a different type of variance in human reaction. Lack of correspondence between performance scores and physiological effects is a common finding which underscores the need for both, along with subjective measures, to provide a complete performance envelope.

Within the cluster of timed performance variables, there was a pattern of association that differed from the rationale used in establishing the events. The uphill run and double time events were set up as short duration-maximum performance (SM) measurements; the forced march and normal walk were established as long duration-typical performance measurements (LT). The data show that a variation of that rationale may be a better way of classifying the timed events into useful dimensions. A classification scheme resulting from the data is presented in figure 9.



(Broken Line Indicates Significant Correlation between Scores on Events)

Figure 9. Classification of Timed Events Resulting from the Data.

The timed events fell into three of the four cells of the new four-way classification scheme. The classification of events on the basis of time duration remained the same as in the rationale section--long versus short. But the classification on the basis of amount of effort solicited, changed from considering *maximum* effort as the important point to consideration of *any extra effort at all* as being an important point on which to classify the events. The classification was redone on the basis of *extra* effort because of the pattern of intercorrelation coefficients produced by the data.

The broken lines in figure 10 connect pairs of events between which there were significant correlation coefficients in performance time (tested against the hypothesis that correlation in the population is zero). The forced march (FM), double time (DT), and uphill run (UR) scores were interrelated at the same level ($r = .60$). A plausible explanation for their similar effect on performance is the extra effort required for those events; subjects who were more physically fit tended to score higher, while less fit subjects scored lower. UR and DT were short events and were placed in the extra effort/short duration cell of figure 10. The long FM was placed in the extra effort/long duration cell.

The normal walk (NW) performance scores were significantly related to the FM scores ($r = .63$). Because the NW was a long event, it was placed in the long duration classification along with FM. However, the NW was different from the FM in that the NW was not related to UR or DT. The absence of any requirement for extra effort during the unobtrusively timed portions of normal walking generated a pace more related to an attitude factor (more cooperative or willing groups walked faster) than to the physical fitness factor of the extra effort events. The NW then was placed in the no extra effort/long duration cell of figure 10. A fifth on-course event, low crawling for 200 feet, is the type of event that could appear in the empty cell (no extra effort/short duration). However, pilot tests of a low crawl event produced totally unreliable data rendering the low crawl useless as a timed performance measure.

In summary, the cluster of timed performance variables was rationally separated into two independent subsets (the short, extra effort double time and uphill run timed events, versus the long, no extra effort unobtrusively measured normal walk) with one event that linked the two subsets (the long, extra effort forced march). The physiological measures provided a separate basic cluster of data, independent from the timed events as shown by the overall low correlation of total time on the course versus sweat lost (percent body weight) on the course $r = .02$ (see table 8).

APPENDICES

APPENDIX A. VEGETATION FEATURES OF TEST COURSE

As shown in figure A-1, the course runs through four distinguishable successional stages of tropical vegetation and two major edaphic vegetational types. The whole area falls under the Holdridge system Tropical Moist Forest life zone, although only a few hundred meters north of the course the vegetational type abruptly shifts to the Holdridge system Premontane Wet Forest life zone. The course follows a general successional gradient from mature, secondary forest near its beginning and end to very young second growth along the Rio Frijoles; some of the intermediate area is quite low and swampy while most of it is well drained. Each of these vegetational types presents a characteristic set of hazards to the foot soldier and his equipment.

The very young secondary growth is encountered in two places along the course and is by far the densest and most difficult vegetation to penetrate. Without a machete it could almost be classed as impenetrable. Typical of such sites is a total absence of canopy; instead there are thick growths of large palmettos, especially *Heliconia latispatha*, *Calathea insignis*, and *Calathea macrostrobilus (C. lacunae)*, and dense tangles of thorny vines like *Buettneria* and *Uncaria*.

The areas of young secondary growth (circa 2–10 years old) are characterized by a canopy less than 10 meters tall composed of fast-growing weed trees, notably *Annona spraguei*, *Apeiba tibourbou*, *Cecropia obtusifolia*, *Didymopanax morototoni*, and *Ochroma lagopus*. These have a great abundance of slender vines causing poor visibility and great difficulty of movement.

Areas of intermediate secondary growth (perhaps 10–30 years) are characterized by a taller canopy, usually 10 to 20 meters composed of larger individuals of essentially the same trees as above, especially *Annona spraguei*, *Apeiba tibourbou*, and *Didymopanax morototoni*. Interspersed in these areas are occasional, much larger trees (circa 2–3 feet in diameter) of *Enterolobium cyclocarpum* and *Anacardium excelsium* which are evidently open-grown relicts from a time when these areas were otherwise cleared. Common also are trees of *Gustavia superba* and the palms *Scheelea zonensis* and *Astrocaryum elatum*, the latter noteworthy for its vicious spines. Undergrowth varies greatly from place to place but among its commonest elements are spiny clusters of *Bactris* palms and shrubs like *Rinorea squamata*, these plants often growing so close together as to severely limit visibility. Vines are common but are usually larger in diameter and less of a physical obstacle to penetration than in the younger growth; however these older vines tend to sprawl along the ground and are prone to trip unwary passersby. The spiny climbing palm, *Desmoncus isthmicus*, is common in these areas and its modified spine-tipped leaflets are among the most difficult from which a soldier on the trail may have to extricate himself.

The mature secondary forest is by far the easiest vegetation type to navigate. It is characterized by a high canopy of 20 to 30 meters composed of relatively diverse tree species with *Terminalia amazonica* and *Hieronyma laxiflora* among the commonest. Visibility is generally good; vines are a problem only in limited areas where old tree falls

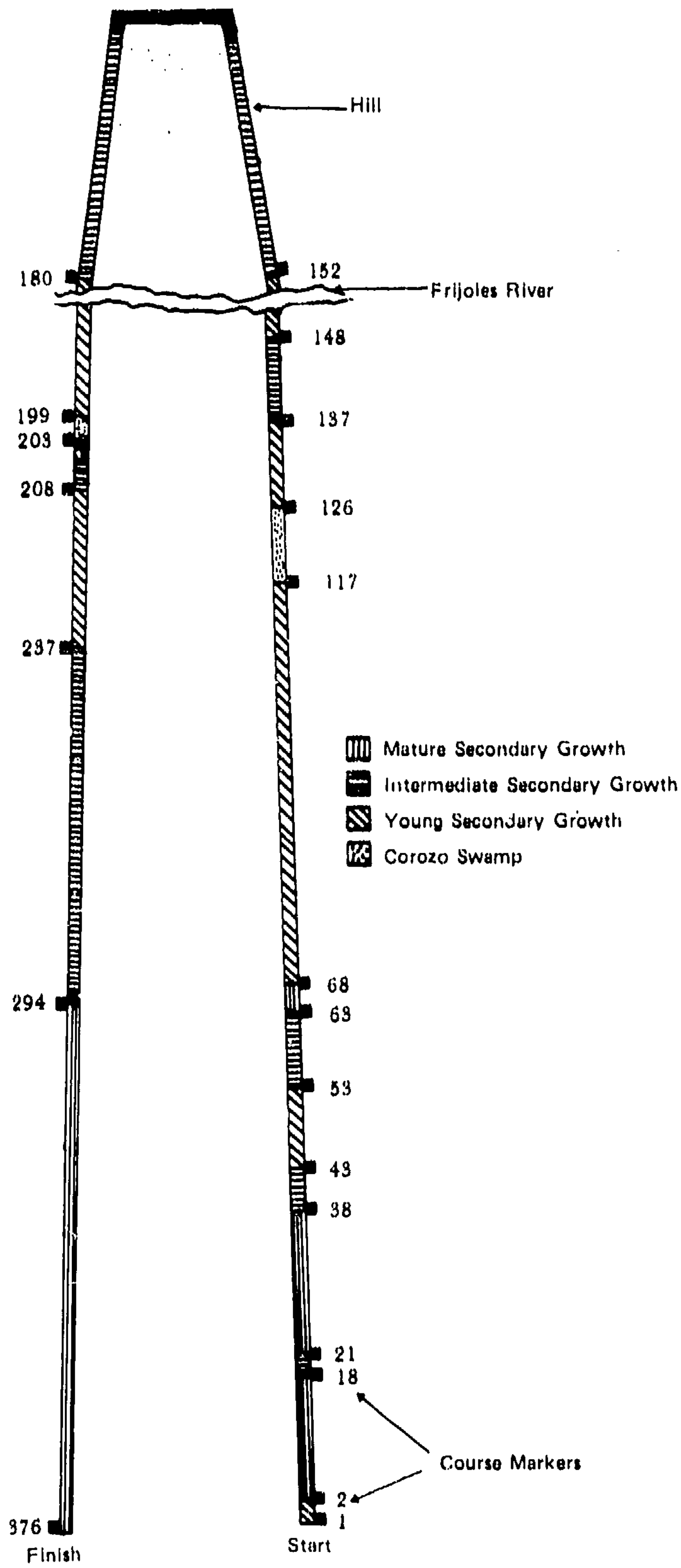


Figure A-1. Vegetation Types Along Test Course.

have deposited a tangle of lianas, and the shrub layer is composed mostly of diverse and relatively scattered Palmettos (*Heliconia erosa* and *Stromanthe lutea* are especially common) and younger individuals of canopy species. Problems peculiar to movement in this area include long-spined vines of *Combretum* and the palmetto-like dumb-cane *Dieffenbachia longispatha* whose sap is extremely painful to many people.

The only significant edaphic association encountered on this trail is a swampy area of *Corozo oleifera* from stake 117 to 126. Much of this area is characterized by its virtual lack of undergrowth except for the scattered *Corozo* palms whose giant fallen leaves with short recurved spines along their petioles provide some impediment to navigation. More serious is the associated spiny palm *Astrocaryum elatum* whose fallen leaves have spines quite sufficient to puncture jungle boots. The canopy of this swamp forest is very low—about 5 meters—being formed mostly by the *Corozo* palms.

The trail begins at stake 1 with a typical young second-growth fringe along the road. Immediately after leaving the roadside one enters mature secondary forest dominated especially by long-buttressed *Hieronyma laxiflora* (whose unchewed buttresses indicate a relatively low level of herbivorous mammals). Commonest vines include *Phryganocydia corymbosa* and *Petrea volubilis*. *Poulsenia armata* is a small tree which also reaches mid-canopy and is conspicuous due to the small thorns on its trunk and leaves—difficult to see and frequently a source of cuts to a person who inadvertently grabs them for support. Common in the area from stakes 2 to 6 are small Melastomes, *Renealmia* sp, *Calathea* sp, and *Heliconia erosa*. At stake 7 the first clumps of spiny *Bactris* are encountered, conveniently placed on a creek bank to act as painful supports for climbing the bank. Also present near stake 7 are trees of the stilt-rooted palm *Socratea durissima* whose thorn-covered roots reach far from the trunk base to snag packs or trouser legs. Spiny vines of *Combretum* are also encountered near stake 8. This area is quite open. At stake 14 the undergrowth is notably full of *Heliconia*. Going uphill to stakes 18 and 19 is an intermediate stage of second growth, with a much denser growth of vines, especially *Paullinia* and species of *Bignoniaceae*. The palm *Astrocaryum elatum* clothed with long, sharp spines is present here as are two species of the spiny *Bactris* palms. *Luehea seemannii*, a typical older-second-growth tree, is the chief canopy species. Proceeding from stake 21 to 23 the mature second growth is reentered with a more open understory including *Pentagonia*, *Stromanthe lutea*, thorny trunked *Zanthoxylum*, and thickets of *Bactris* palms. From stakes 23–26 the trail is through andd along the edge of a dense thicket of *Aechmea magdalenense*, a densely clustered spiny leaved terrestrial bromeliad which would be a severe obstacle to penetration had a trail not been beaten through it. In this area is also encountered some old tree-fall areas and many *Poulsenia armata* and *Bactris*. From stakes 38–41 the undergrowth is mostly a thick stand of *Rinorea* and *Quassia amara* but the vegetation is still intermediate second growth, with some large trees encountered along a small stream near stake 42. After crossing the stream a younger stage of second growth is entered with canopy at only 10 to 15 meters, many vines, and rather dense undergrowth. Important canopy trees are *Didymopanax morototoni* and *Luehea seemannii* with scattered older trees of *Enterolobium cyclocarpum*. *Astrocaryum elatum* is also abundant. At stake 53 the undergrowth of the flat lowlands becomes mostly palmettos with plants such as *Calathea insignis*, *Heliconia erosa*, *Carludovica palmata*, and *Dieffenbachia longispatha*; the canopy trees are *Gustavia*, *Luehea* and

Scheelea. This area would again be classified as intermediate second growth. At stake 63 the undergrowth becomes less dense and *Terminalia* becomes an important canopy tree reaching 30 meters in height; this is the last short-lived reentrance to mature second growth until almost the end of the trail. On reaching stake 68 the area is again a low-canopied young second growth with many vines. The undergrowth thins out briefly at stake 96 where leaf-cutter ants are clearing; interspersed nearby are some much older remmants of a previous vegetation. At stake 109 a newly fallen giant *Didymopanax* indicates the successional stages taking place; its replacement will be a species of the mature forest. At stake 117 the vegetation changes abruptly with entrance into a swampy area dominated by the palm *Corozo oleifera.* The *Corozo* swamp ends at stake 126 as the trail goes up a hillside; the area from 131 to 135 is young second growth and from 137 to 148 intermediate second growth; a thick stand of *Astrocaryum* at 142 to 144 makes that area especially hazardous to foot soldiers. At stake 148 the trail drops abruptly into very young almost impenetrable second growth along the Rio Frijoles. Across the river one is back in second growth forest. The return trail is much denser (i.e., younger) second growth than the outbound trail, with the area beginning at stake 193 especially dense and vine-covered. The shrub *Hybanthus prunifolius* is the commonest species here; *Triplaris* is also important. At stake 199 a brief stand of *Corozo* borders a stream; beyond the stream is an open tangle of spiny *Bactris* and *Machaerium arboreum.* From stakes 228 to 230 an area of very young secondary growth is encountered where *Uncaria* (with its strong recurved spines, perhaps the most mobility hampering species of all) predominates. At stake 236 the area has less undergrowth characterized as intermediate second growth. On reaching stake 269 the area is relatively open mature second growth again, and the *Quararibea* tree at stake 294 marks the beginning of the diverse canopy of mature secondary vegetation which lasts to the end of the trail.

APPENDIX B. SOILS AND TOPOGRAPHIC FEATURES OF TEST COURSE

The area along the test course is characterized by fine textured soils occurring on very broken and undulating surfaces with slope gradients ranging from moderate to steep, where the steeper slopes correspond to the short slopes of stream banks (figures B-1 and B-2). Flatlands are localized and extremely limited in extent. The complex dendritic drainage network composed by several tributaries of the Frijoles river, slope in a westernly direction towards the south-westerly flowing Frijoles river. Stream banks are invariably steep, often at angles close to 90° to the stream channel. Exposed, partly decomposed parent-rock material at approximately 1½- to 2-meter depth is visible on the wall of banks and bottom of most streams. The igneous parent-rock is dark colored resembling basalt or andesite.

With the probable exception of a narrow alluvial plain along the Frijoles river, the steep banks on most stream crossings do not give any indication of recent alluvium deposits to any significant extent. The prevailing types of soil found along the course are clay in nature, their development having been largely influenced by climate and relief. Soils are primarily Oxisols and Entisols. Oxisols were recognized as highly weathered residual yellowish-red and reddish soil, occurring on footslopes and hilltops, respectively; Entisols are dark brown to brown soils developed from recent alluvial material deposited mainly along narrow terraces on the floodplain of the Frijoles river.

Comparatively shallow profiles characterize the footslope Oxisols. Representative profiles examined along the course (stations 5, 93, 115) exhibited a 2.5- to 5.0-centimeter mat of partially decomposed organic debris over a relatively thin layer of highly decomposed organic material. The topsoil, between 30 and 40 centimeters thick, is a yellowish-red (5-YR 4/8, moist) to light reddish-brown (5-YR 4/4, moist) silty clay loam to clay loam with well developed, medium-sized, blocky subangular structure. Consistency is friable when moist, moderately sticky and plastic when wet, and usually becomes hard and brittle when dry. It merges quite abruptly into a mottled clay subsoil characterized by strong subangular blocky to weakly developed, small prismatic structure and extends downward for approximately 75 to 150 centimeters into a massive and extremely mottled zone of highly decomposed parent material. Various shades of red, yellow, brown, and gray have produced a variegated color in the material of the subsoil.

Deeper profiles of a brighter reddish (2.5-YR 4/8, moist) color dominate the hilltop Osixols. Organic matter content on the surface closely resembles soil conditions prevailing on footslopes. Physically, there is little or no difference in footslope soils, although there appears to be a slightly higher clay content in profiles of hilltop Oxisols—brought about possibly by more intensive weathering and due to greater leaching conditioned by the existing topography. The massive parent material is generally encountered at slightly greater depth, approximately 1 to 2 meters, extremely mottled with hues of red, yellow, brown, and gray.

Alluvial Entisols present to any significant extent occur only as narrow strips along the flood terraces of the Frijoles river. These Entisols are very homogeneous silty clay loam to clay loam, the incipient profile usually extending down to more than 1-meter

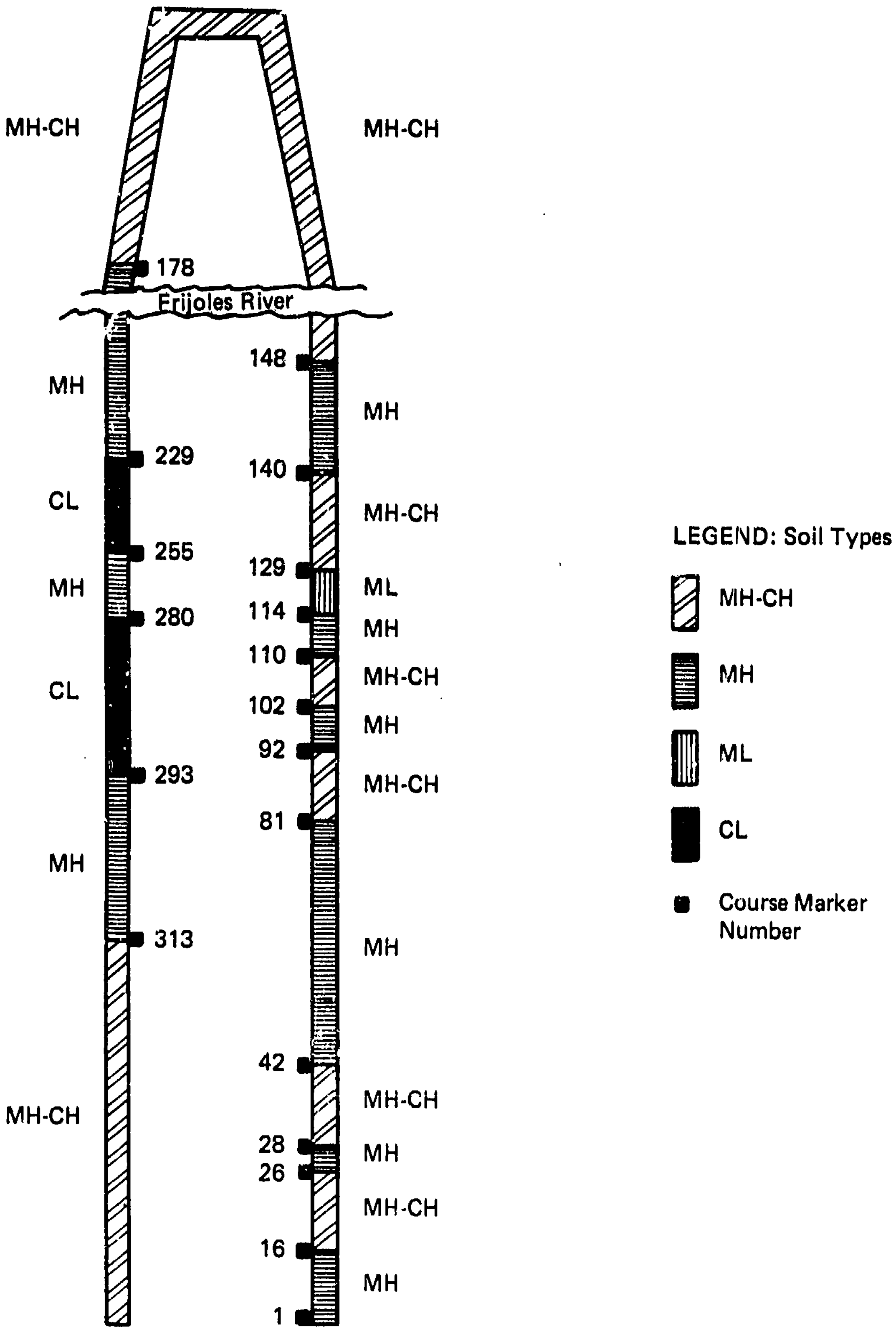


Figure B-1. Soil Types Along Test Course.

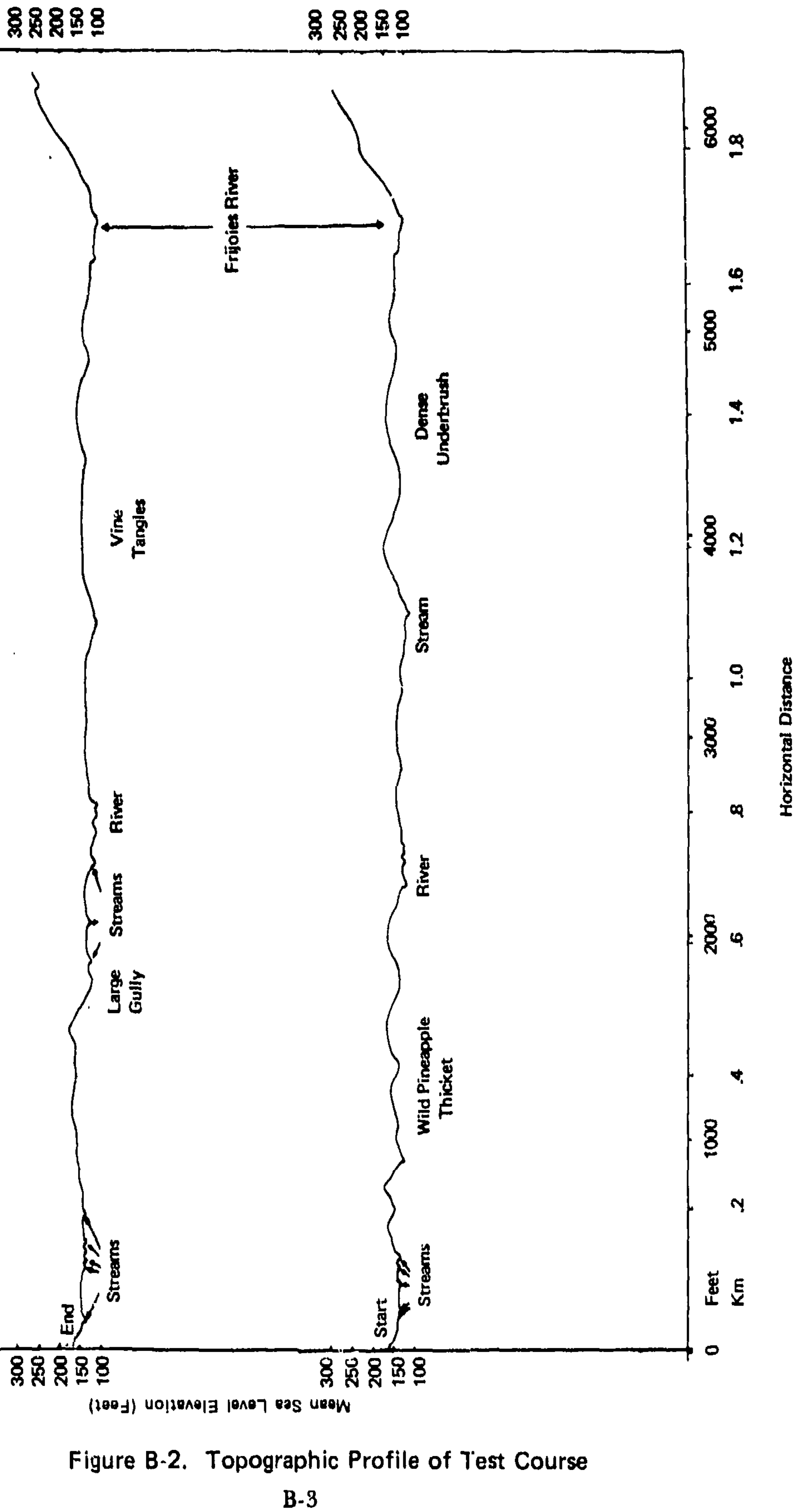


Figure B-2. Topographic Profile of Test Course depth. It consists of 7.5-centimeter dark brown (10-YR 4/3, moist) very friable, slightly sticky and plastic topsoil over a lighter brown (10-YR 5/3, moist) to yellowish-brown (10-YR 5/4, moist) subsoil of the same material. Mottles are generally absent throughout the first 1-meter depth.

Although moderately well-drained and in most cases with excellent surface run-off, soils along the course are invariably very slippery when wet because of their clayey nature. Slipperiness is a critical factor particularly when negotiating steep slopes on hillside and stream banks. Otherwise, the soils are relatively firm and generally with sufficient strength to support unlimited foot traffic. Occasional landslides along stream banks, however, may pose some hazards to mobility.

Soil moisture determined on surface samples (0- to 7.5-centimeters) collected during the dry season indicated a moisture range between 7.1 and 45.3 percent with an average moisture percentage of 26.3. Minimum and maximum values were obtained from samples collected at stations 229 and 310, respectively. Liquid limits varied between 34 and 133.7 percent with a mean value of 72.9 percent. Similarly, plastic limits ranged from a minimum of 21.4 percent to a maximum of 56.7 percent; 37.2 percent was the mean plastic limit value. Based on Atterberg tests the soils in the area classified in the Unified Soil Classification System (USCS) into basically three types: MH, ML, and CL with a large proportion included in a borderline group of MH-CH. Soils in the ML and CL classes are apparently not extensive and occur only on limited short stretches along the test course. Cohron sheargraph tests for rubber-to-soil failures resulted in soil shearing stress values between 1.3 and 4.2 pounds per square inch (psi) under a normal load of 4.0 psi. Soil adhesion is generally low, most often below 1.0 psi and only occasionally exceeds 2.0 psi. Average cohesion value for the soils tested was 0.5 psi. Shear stress values under wet season conditions varied between 1.4 and 4.5 psi whereas soil adhesion ranged from 0.3 to 3.6 psi.

APPENDIX C. SUMMARY OF TEST COURSE PROCEDURES

I Pre-Course Events

(1) State requirement for and request test subjects.

(2) Arrive on site with timers and subjects.

(3) Read instructions.

(4) Assign timers to test subjects.

(5) Fill out top portion of Objective Data Sheet (ODS) for each test subject, including the subject's number.

(6) Make sure that all subjects have the following equipment:

(a) M-16 rifle
(b) Combat boots
(c) Pistol belt
(d) Suspenders
(e) Canteen
(f) Combat pack
(g) Poncho
(h) Ammo pouch
(i) Fatigues and soft cap
(j) Extra pair socks
(k) Entrenching tool and case

(7) Collect canteens from test subjects. Number canteens with tape. Completely fill canteens with water. Weigh canteens. Enter canteen weight to nearest 5 grams on ODS for each subject. Do not return canteens to test subject at this time.

(8) Order subjects to urinate, regardless of how little they feel they need to, enter privacy shelter and strip to shorts and socks. Weigh subjects stripped. Enter weight on ODS to nearest 5 grams.

(9) Have subjects don all clothing and equipment, including M-16 rifle but not canteen. Enter subject's weight (with clothing and equipment) on ODS to nearest 5 grams.

(10) Return canteens to test subjects. Make sure that each subject has the canteen with his own number.

(11) Apply tape to subject's fatigues on chest and both upper arms. DO NOT RESTRICT CIRCULATION OR ARM MOVEMENT.

(12) Enter subject's number on each taped spot. Make sure that numbers are large and clear.

(13) Make sure that each test scorer has the following:

(a) Stopwatch for each of his subjects

(b) ODS for each of his subjects

(c) Scoring pencils

(d) One scorer must have a whistle

(14) Send scorers to end of forced march event, Marker 145, where they will wait for test group. Wait 10 minutes.

(15) Make sure that test official who accompanies subjects has the following:

(a) Two stopwatches, or one stop watch and a personal wrist watch in good working order and fully wound

(b) Small notebook

(c) Pens or pencils

(d) Whistle

(16) Test group will proceed to Marker 1.

(a) On-Course Events (see figure 3, page 0).

Marker Number		Event
(1)	Start Forced March	Instruct subjects that they will start course with a forced march of about 1 mile, with NCOIC leading a single file, and Test Officer last. Instruct subjects how to follow markers. (Arrow points way to next square.) NCOIC is responsible for forced march pace and for keeping men together. Test official will not prod or help laggers. Answer any questions. Tell subjects to move out. Begin timing when first subject (NCOIC) starts. Total Elapsed Time: Make note in notebook of start time from personal wrist watch, or start stopwatch. Forced March Time: Start stopwatch when first man leaves Marker 1.

Marker Number		Event
		Tell subjects they may drink water from canteens as desired, but not to waste water.
(145)	End Forced March	15-minute break. Stop timing forced march when last man reaches marker. Timers will record forced march time on QDS.
		Send timers to Marker 162.
		After 15 minutes, test group proceeds to Marker 156 at NORMAL WALK, single file.
(River)	Break	3-minute break. Test group may freshen-up, but NOT drink river water or fill canteens.
(156)	Start Uphill Run	Tell subjects they will perform a 300-foot uphill run. Run as fast as possible to the finish tape. Stay between white sideline tapes.
		Space out subjects along starting tape according to subject's number. Give three short blasts on whistle to warn timers that test is about to start. (Timer gives one short whistle blast to confirm.)
		Start subject No. 1 with one whistle blast. (Timer starts stopwatch for subject No. 1.) Wait 30 seconds. Start subject No. 2 with one whistle blast. (Timer starts stopwatch for subject No. 2.) Continue starting men at 30-second intervals. (Timers record uphill run time for each subject.)
(162)	End Uphill Run	15-minute break. After 15 minutes, test group and timers proceed to river at NORMAL WALK, single file.
(River)	Break	3-minute break. Test group may freshen-up, but NOT drink river water or fill canteens.
		After 3 minutes, test group proceeds to Marker 283, NORMAL WALK, single file.

Marker Number		Event
(283)	Break	5-minute break. After 5 minutes, test group proceeds to Marker 327, NORMAL WALK, single file.
(327)	Start Double Time	Tell subjects they will perform double time event over flat terrain to a finish line 200 feet away. Stay between white sideline markers. Give three short whistle blasts to alert timers. Timers acknowledge with one blast. Start subject No. 1 with one whistle blast. (Timer starts stopwatch for subject No. 1) Wait 30 seconds. Start subject No. 2 with one whistle blast. (Timer starts stopwatch for subject No. 2.) Continue starting subjects at 30-second intervals. (Timers record double-time time for each subject.)
(335)	End Double Time	5-minute break. After 5 minu... test group proceeds to Marker 376, NORMAL WALK, single file.
(376)	End Course	Test Officer stops timing total elapsed time. Time ends when last subject reaches marker. Timers record finish time on ODS.

II Post-Course Events

(1) Timers collect canteens. Weigh canteens with remaining water to the nearest 5 grams and record on ODS

(2) Weigh subjects fully clothed and equipped, but without canteens. Record weight to nearest 5 grams on ODS.

(3) Have subjects strip to shorts and socks in privacy shelter. Obtain stripped weight of each subject, and record to nearest 5 grams on ODS. Have subjects don clothing. Subjects may now urinate and eat.

(4) Collect all ODS.

(5) Make sure all equipment used during testing is secured.

(6) Testing is now completed.