09:47:22 OCA PAD AMENDMENT - PROJECT HEADER INFORMATION 08/11/89

Active

Project #: D-48-628 Cost share #: Rev #: 1
Center # : R6614-0A0 Center shr #: OCA file #: 119
Work type : RES
Contract#: DACA88-88-D-0020-0006 Mod #: P00001 Document : DO
Prime #: Contract entity: GTRC

Subprojects ? : Y
Main project #:

Project unit: ARCH COLL Unit code: 02.010.164
Project director(s):
CIRCEO L JR ARCH COLL (404)894-3390

Sponsor/division names: ARMY / CON ENG RES LAB, IL
Sponsor/division codes: 102 / 020

Award period: 880929 to 890930 (performance) 891123 (reports)

Sponsor amount	New this change	Total to date
Contract value	0.00	65,503.36
Funded	0.00	65,503.36
Cost sharing amount		0.00

Does subcontracting plan apply ?: N

Title: BASE RDT&E INVESTMENT STRATEGY

PROJECT ADMINISTRATION DATA

OCA contact: William F. Brown 894-4820

Sponsor technical contact

MR. ALAN MOORE
(217)373-7267
US ARMY CONSTRUCT. ENGR. RES. LAB.
NEWMARK DR., P.O. BOX 4005
CHAMPAIGN, IL 61820-1305

Sponsor issuing office

MS. V. IVERSON/CONTRACTS BRANCH
(217)373-6798
US ARMY CONSTR. ENGR. RES. LAB.
2902 NEWMARK DR., P.O. BOX 4005
CHAMPAIGN, IL 61820-1305

Security class (U,C,S,TS) : U
Defense priority rating : DO-C9
Equipment title vests with: Sponsor
NONE PROPOSED

ONR resident rep. is ACO (Y/N): N
N/A supplemental sheet
GIT X

Administrative comments -
MOD. P00001 REVISES S.O.W AND DELIVERABLES AND EXTENDS COMPLETION DATE.

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

SR. 149 N.

Closeout Notice Date 01/22/90

Project No. D-48-628 | Center No. R6614-0A0

Project Director CIRCEO L JR | School/Lab DEAN ARCH

Sponsor ARMY/CON ENG RES LAB, IL

Contract/Grant No. DACA88-88-D-0020-0006 | Contract Entity GTRC

Prime Contract No. ______

Title BASE RDT&E INVESTMENT STRATEGY

Effective Completion Date 890930 (Performance) 891123 (Reports)

Closeout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	Y	900529
Final Report of Inventions and/or Subcontracts	Y	900130
Government Property Inventory & Related Certificate	Y	900212
Classified Material Certificate	N	
Release and Assignment	Y	900529
Other ______	N	

Comments ______

Subproject Under Main Project No. ______

Continues Project No. ______

Distribution Required:

Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Managment	Y
Research Security Services	N
Reports Coordinator (OCA)	N
GTRC	N
Project File	Y
Other ______	N
______	N

NOTE: Final Patent Questionnaire sent to PDPI.

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT (SUBPROJECTS)

Closeout Notice Date 01/22/90

Project No. D-48-628 Center No. R6614-0A0

Project Director CIRCEO L JR School/Lab DEAN ARCH

Sponsor ARMY/CON ENG RES LAB, IL

Project # E-20-616	PD RIGGS L S		Unit 02.010.116	T
DO # DACA88-88-D-0020-000		MOD# ADMIN.	CIVIL ENGR	*
Ctr # R6614-0A1	Main proj # D-48-628		OCA CO WFB	
Sponsor-ARMY		/CON ENG RES LAB, IL		102/020
BASE RDT&E INVESTMEN				
Start 880929 End 890930	Funded	65,503.36	Contract	65,503.36

LEGEND
1. * indicates the project is a subproject.
2. I indicates the project is active and being updated.
3. A indicates the project is currently active.
4. T indicates the project has been terminated.
5. R indicates a terminated project that is being modified.

STATEMENT OF WORK

CHANGE ORDER MANAGEMENT PROGRAM
(COMP)

1. **Introduction:** By any standard, the real property responsibilities of the Corps of Engineers are immense. Annually, the Corps manages a budget of some $9 billion to acquire, operate, and maintain its physical plant. Of this amount, approximately $1.5 billion is allocated to the construction of new facilities. Most of these construction funds are fixed and therefore little control can be exercised over their expenditure. However, one area of non-fixed costs with significant potential for control is change orders.

2. **The Problem:** Cost overruns are, in most instances, reflected in change orders. Cost overruns are a major concern on any construction project, but with construction budgets of the size managed by the Corps, cost overruns have a serious impact. Modification or alteration work is especially prone to cost overruns. Studies have shown that change order work accounts for approximately six percent of the total dollar volume of construction projects. Changes during the design phase also contribute to cost overruns. More than ever, in the 1990's and beyond, the Army must respond to the challenge of changing missions and declining budgets. Faced with the prospect of severe budget limitations, even modest savings in the amount of change orders are worthy of pursuit.

   In order to develop a strategy to improve the management of cost extras on design and construction projects, it is first important to understand the specific causes of change orders. Although the AMPERS database will give an overall indication of the amount of change order work performed Corps-wide, it does not give the detail necessary for in-depth analysis. Research is needed to determine the amount and causes of change orders Corps-wide. This statement of work outlines a methodology to gain an deeper understanding of the change order problem as related to military construction, to develop a set of recommendations to improve the change order process, and to identify any aspects which might prove amenable to further research.

3. **Objective:** The objective of the work to be performed under this delivery order is the following:

   a. Gain an in-depth understanding of change order costs related to military construction work. Specifically, to determine the dollar amounts and causes of change orders. Identify any patterns which emerge from this investigation.

   b. Identify and recommend improvements to current techniques for managing change order work which could be useful to USACE and DEH construction representatives.

   c. Identify any areas in the change order process which require additional research.

4. **Major Requirements:**

   a. **Task 1:** Visit one Corps of Engineers District office and one DEH office to examine the type data maintained on change order work. The purpose of this visit is to establish and collate the basic parameters of the study and to discuss the change order problem with pertinent Army field agencies. Prepare a summary matrix showing the causes of change orders against the dollar value of the change orders. Prepare an interim progress report on the results of these visits.

   b. **Task 2:** Based on the results of Task 1, develop a methodology for expanding the search to other Districts and DEH offices to broaden the data base. (Number of visits and locations to be discussed) Prepare a written report describing the results of Task 2.

   c. **Task 3:** Consolidate and analyze the data collected. Identify areas in the change order process which warrant further investigation for improvement. In each area, develop a course of action and a set of recommendations to reduce the problem of change orders and improve change order management policies. Note additional research requirements. Prepare draft final report. USA-CERL will review and make comments, if any.

   d. **Task 4:** Prepare final report incorporating any Governmental review comments..

5. **Government Furnished Information:** The Government will provide any Government-owned document the Contractor requires in conducting this delivery order.

6. **Point of Contact:** The USA-CERL technical POC is Mr. Alan Moore, (217) 373-7267.

7. **Meetings/Reviews:** The Contractor shall attend the following meetings, to be scheduled at mutually agreeable dates and times:

   a. One (1) meeting at USA-CERL, Champaign, IL within thirty (30) days after the award of this delivery order to review the research plan for this delivery order.

   b. One (1) meeting at USA-CERL, Champaign, IL approximately twelve (12) months after the award of this delivery order to present the final report.

   c. Other required meetings, as determined by the Government and Contractor, at a mutually agreeable location, date, and time to discuss the progress of the work.

   d. Periodic review meetings, telephonic or at the Contractor's site, to discuss the progress of the work.

8. **Travel Requirements:** Anticipated travel under this delivery order shall consist of the following:

   a. Two (2) trips, two calendar days per trip, two persons to USA-CERL, Champaign, IL, to attend meetings and brief results of research.

   b. (Trips mutually agreed upon to satisfy requirements of Task 2)

c. Any additional travel shall be approved by the USA-CERL technical POC. USA-CERL will provide U.S. Government travel orders and direct reimbursement to Contractor employees for any additional travel approved by the Government under this delivery order.

9. **Level of Effort:** Approximately one (1) professional man-year of effort is anticipated to complete the described work.

10. **Reports/Deliverables:** The following reports/deliverables shall be submitted to the Government:

    a. Two (2) copies of the written interim progress report within 90 days after delivery of this delivery order (see Task 1).

    b. Two (2) copies of the written interim progress report within eight (8) months after delivery of this delivery order (see Task 2).

    c. Two (2) copies of the written draft final report within ten (10) months after delivery of this delivery order (see Task 3).

    d. Two (2) copies of the written final report within twelve (12) months after delivery of this delivery order (see Task 4).

    e. All reports shall also be submitted on diskettes in WordPerfect 5.1 or Ventura Publisher 2.0 as appropriate.

11. **Period of Service:** All work to be performed under this delivery order shall be completed within twelve (12) months after award of this delivery order.

Georgia Institute of Technology
A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
ATLANTA, GEORGIA 30332
TELEX: 542507 GTRC OCA ATL

SCHOOL OF
CIVIL ENGINEERING
LELAND S. RIGGS

TELEPHONE
(404) 894-2246

November 23, 1988

Mr. Alan Moore
Program Manager
Facilities Systems Division
USA-CERL
Champaign, Ill 61820-1305

Dear Alan,

Please consider the attachments to this letter as our first interim report on the RDT&E Investment Strategy project. The attachments include your updated outline (it has been revised slightly), a summary graph showing user needs compared with CERL and academic research efforts, a detailed backup for this summary graph, and a proposed roadmap for one particular thrust area.

We look forward to discussing these charts as well as the outline with you and the Facilities Systems team leaders

Cordially,

Leland S. Riggs
Associate Professor

F. S. BASE SUPPORT R&D INVESTMENT STRATEGY DEVELOPMENT AND EVALUATION PROCESS

I. BASE SUPPORT R&D NEED IDENTIFICATION (Defining Our Business/Customers Concerns)

- FS Vision
- CERL Vision
- CE Vision
- Installation Needs (ACOE)
  - Large plant, unique mission rqmts, decreasing budget, smart buyers
  - Relationship of facilities to Army mission
- ACE Facility Strategy
- Army Workforce Problems
  - Retiring personnel
  - Contract mode
  - Loss of institutional memory)
- Construction Industry Productivity Decrease
- 17 National Concerns
  - Infrastructure
  - Energy Supply
  - U.S. in Space
  - Etc
- OTA Report - Technology in Architecture, Engineering, and Construction
- ASCE R&D Study (Greg Howard - UNM)
- AIA Concerns

II. CE BASE SUPPORT R&D ORGANIZATION RESPONSE (Defining our Structure)

- CE R&D Organization
- Army Relationship – Tech Based Master Plan (TBMP)
- DOD Relationship
- Relationship to Other Services/Fed labs (AF Technology 2000 Rpt)
- Relationship to academia (ERC) (URI) (CIFE)
- Relationship to industry (CPAR, CRDA)
- CERL (5 step process)
- FS Division/Teams
  - Relationship to other divisions
- Facility life cycle orientation
  - Functional
  - Integration/synergism impacts
  - Problem ownership/champions/MADS
  - Categorization (Tech assistance vs R&D)

III. IDENTIFICATION OF FUNCTIONAL AREA DEFICIENCIES AND TECHNOLOGY GAPS (Defining our Opportunities)

• Functionally (Matrix)	National Teams
• Organizationally (DEH, CE)	PIs
• Technology	Industry
• Fundamental Knowledge	Academia

- Problem Deficiency Endorsement
  - Industry surveys
  - Professional organizations (ASCE, AIA, APWA)
  - National team prioritizations
- Problem area synthesis
  - Conceptual Modeling
  - Integration/Interconnection
  - Cognition

IV. DETERMINING THRUST AREA GOALS/OBJECTIVES OF RESEARCH, PRIORTIZING (Selecting What We Need to Do)

- Definition of Desired Capabilities/Time Frame
- Existing Base Support R&D Initiatives
- Mapping of Technology to Capabilities
- Define R&D Thrusts/Goals/Objectives/Time Frame
- Identification of Leap-Ahead Tech Opportunity/Probability of Success
- T^2 Opportunity
- Pre-ROI/Benefit Costs
- Leveraging Opportunities
- MAPS Scoring/Prioritization
- Opportunities for Resourcing
- Marketing Possibilities

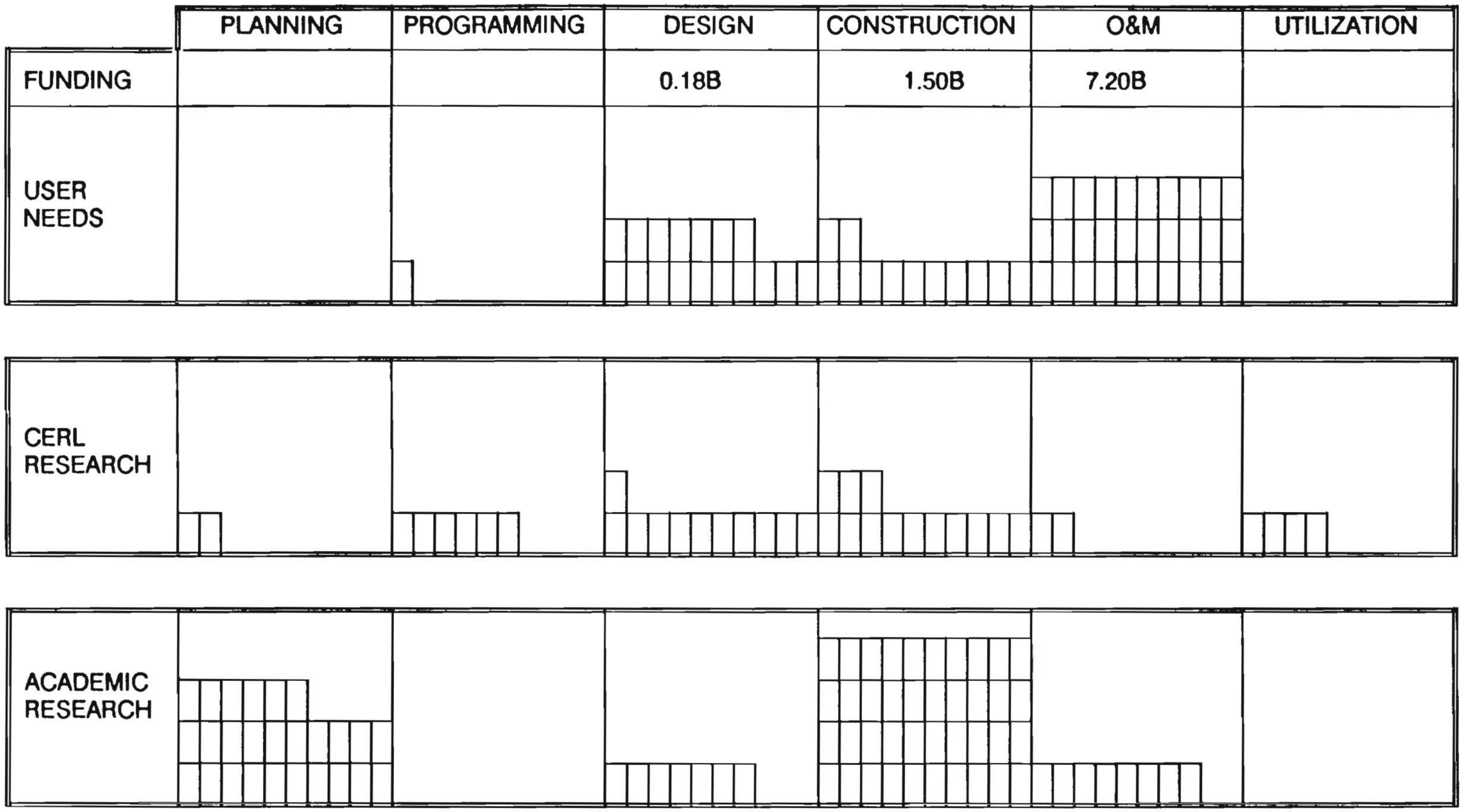
V. TECHNIQUES FOR PROJECT SELECTION/DEFENSE/PACKAGE

- Critical Success Factors Determination
- Periodic Review (IPR)
- Redirection of Thrust Areas
- Post ROI

VI. INVESTMENT STRATEGY MONITORING AND EVALUATION

- Critical success factors determination
- Periodic review (IPR)
- Post ROI
- Redirection

VII. Resourcing


PLANNING
PROGRAMMING
DESIGN
CONSTRUCTION
O&M
UTILIZATION
FUNDING
0.18B
1.50B
7.20B
USER NEEDS
CERL RESEARCH
ACADEMIC RESEARCH

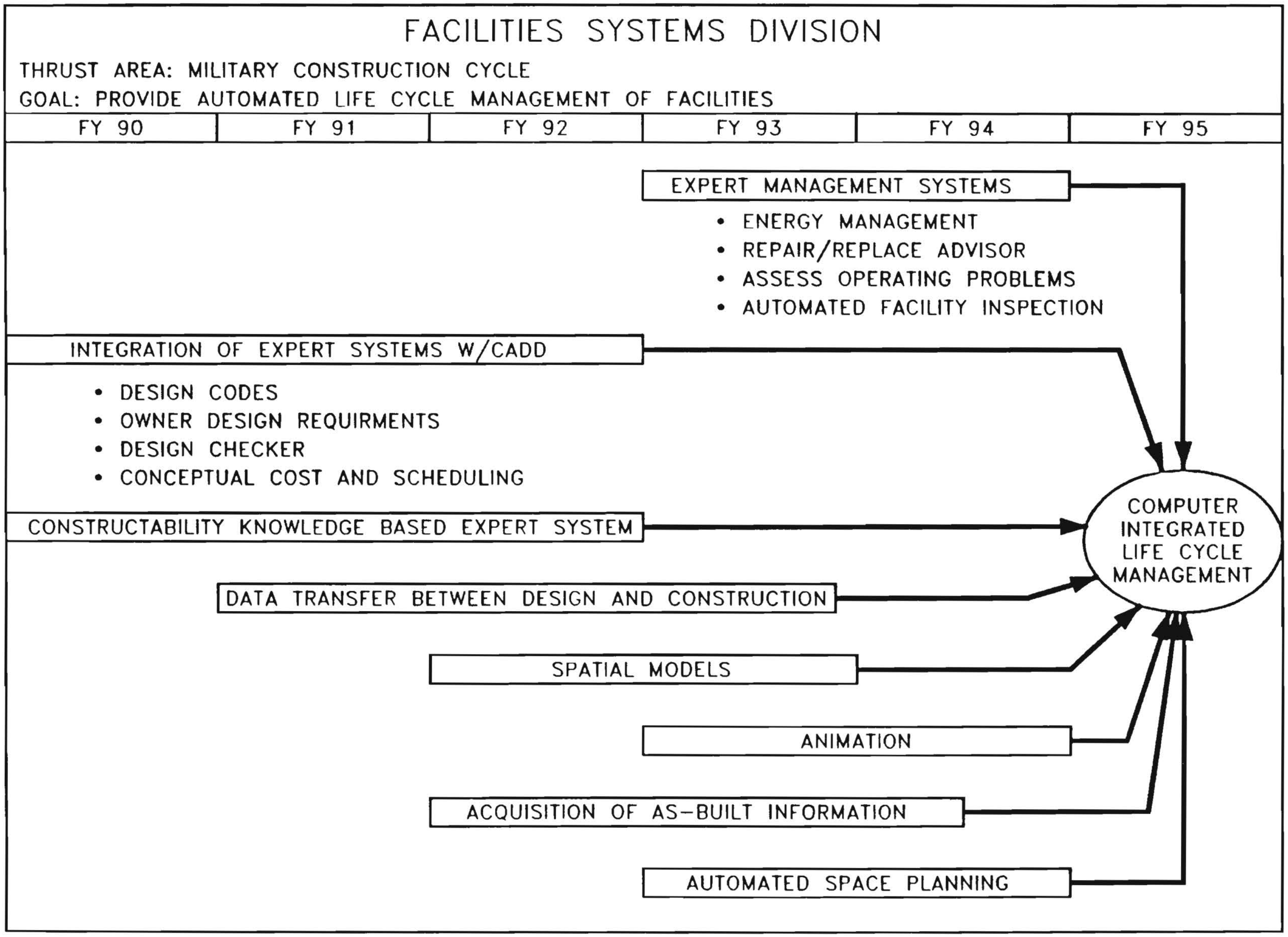
USER DEFINED NEEDS - PAGE 1					
PLANNING	PROGRAMMING	DESIGN	CONSTRUCTION	O&M	UTILIZATION
	Planning & Programming Decision Support System	Computer Aided Architectural Design	Rapid Temporary Living Shelter	Augmentation of Utility Services in Cold Regions	
		Computer Aided Engineering & Arch Sys (CAEADS)	Improved Procedures & Micro Computer Appls	Inspection of Facilities	
		Physical Security Design & Construction	Micro Computers in Military Construction	Cold Regions Effects on Physical Security Equip	
		Design Review Improvement	Techniques to Improve QC/QA Effectiveness	Water Conservation Measures	
		Computer Aided Structural Engineering	Division and District Decision Support System	Cavity/Tunnel Detection	
		Control of Snowdrifting	Automated Construction Project Management	Built Up Roof Management System	
		Updating Climatological Information on Loads	CPM for Mobilization Construction Reqts	Rail Maintenance Management System	
		Improved Munitions Storage	Engineer Troop Construction Techniques	Painting Maintenance Management System	
		Improving A/E Performance	Building Technology Forecasting & Evaluation	Corrosion Mitigation & Management System	
		Improved Value Engineering	Alternative Construction Methods	Pavement Maintenance Management System	
		Approved Standard Designs	Constructability of Facilities in Cold Wx	Installation Management	
		Innovative Performance Specifications	Improve Productivity (Synthesis Team)	Generic Maintenance Management System	
		CEAP, ISMP		DEH Decision Support System	
		Technology Transfer		Housing Management	
		Improve Planning (?)		DEH Computer Aided Design Support	
		DEH Management & Information Systems		Management of Commercial Activities Contracting	
		DEH Contract Privatization		Training QA Evaluators for Admin CA Contr	
				Operational Cost Data for Family Housing	

USER DEFINED NEEDS - PAGE 2					
PLANNING	PROGRAMMING	DESIGN	CONSTRUCTION	O&M	UTILIZATION
				DEH Management System	
				Vacuum Drying of Roof Insulation	
				Natural Drying of Wet Applied Roofing System	
				Diagnosing Blisters in Built Up Roofing	
				Effects of Re-siding of Buildings	
				Chemical Snow & Ice Control	
				Improved Military Railroad Rehab & Maint	
				Dust Palliation	
				Freeze/Thaw Prevention & Repair	
				Location of Buried Utilities	
				Rehabilitation of Pilelines	
				Moisture Control in Buildings	

CERL RESEARCH					
PLANNING	PROGRAMMING	DESIGN	CONSTRUCTION	O&M	UTILIZATION
Automated PDB	Civil Works Automated Budgeting System	Architectural Design System	Automated Review Management Systems	Fire Protection Management System	Installation Utilization Assessment
Expert System for Site Selection	Knowlege Worker	Concept Design Database	A/E Liability Management & Analysis	Fire Protection Expert System	Expert System for Facility Classification
	OORMS	Parametric Generation of Repetitive Designs	Quality Assurance Training Simulator		Facility Mapping Methods
	DEH Automated Graphics Guide	Analytical Tools for Architects	Construction Quality Knowledge Database		Enhanced Real Property Management Systems
	DTMS DEH MCA Programming Support	Criteria Retrieval System	Area Engineer Decision Support System		
	PROJ DOCS	Mechanisms for Data Integration and Sharing	Claims Guidance System		
		Integration of CEG/CADD	Expert system for MCA Cycle Analysis		
		Impact of CADD on Architectural Practice	Building Technology Forecast & Evaluation		
		Presentation Assistant	KB on Alternative Construction Methods		
		Design Management Simulation Systems	Expedient Construction Data System for Mobilization		
		Intelligent Embedded Instruction for CAD Systems	Performance Specifying Guide for Alt Cnst Meth		
			Construction Schedule Analysis System		
			Network Generation		

ACADEMIC RESEARCH - PAGE 1					
PLANNING	**PROGRAMMING**	**DESIGN**	**CONSTRUCTION**	**O&M**	**UTILIZATION**
Expert System-Based Estimating Program		Constructability During Field Operations	Flagging Safety Practices	Safe Asbestos Abatement	
Iterative Estimating		Input Variables Impacting Design Effectiveness	Field Management Control, Efficiency & Productivity	Nondestructive Evaluation of Damage in Structures	
Conceptual Cost Estimating by Expert Systems		Horizontal Construction - Improved Facility Design	Construction Equipment Management System	Steel Bridge Replacement Decks	
Pricing of Contracts Under Inflation		Automated Constructability Criteria for CAD	Concrete Curing in Cold Temperatures	Cold-Wet Weather Patching for Asphalt	
Needs for Automated Conceptual Estimating		Linking CAD Systems to Knowledge Representation	Quality Problems in Construction	Statistical Representation of Large Buildings	
Simulation Modeling for Horizontal Construction		Environment for Knowledge Based Design	System for Repetitive Unit Scheduling		
Tranforming WBS to Schedule Format		Structure of Database Management Systems	Alternate Logic Scheduling		
Preconstruction Planning System for Highway Proj			Resource Constrained Scheduling Using AI		
Site Planning & Impact on Productivity			Feasibility Model for Cold Weather Protection		
Knowledge Based Query of a Project Database			Parametric Scheduling Model		
Integrated Design/Construction Project Database			KBES for Construction Site Layout		
Interproject Productivity Comparisons			Integrated KBES Simulation System		
Emerging Innovative Building Technologies			Equipment Selection Criteria for Concrete		
Technological Structure of Construction Operations			Fabric-Reinforced Cement Laminates		
Fundamental Mechanisms for Technological Innovation			3-D Metric Vision for Engineering Construction		
Strategies for Technological Advancement in Construction			Current Modularization Practices		
Baseline Model for Productivity Measurement			Bar Code Applications in Construction		
Microcomputer Cost - Benefit Analysis System			Work Packages for Project Control		

ACADEMIC RESEARCH - PAGE 2					
PLANNING	PROGRAMMING	DESIGN	CONSTRUCTION	O&M	UTILIZATION
Objective Setting Process of Owners and Contractors			Knowledge Based Schedule Progress Reporting	Uncertainty In Management of Infrastructure Facilities	
KBES for Repeating Project Success			C/SCS Criteria in Changing Economic Environment	Level of Service Analysis for Bridge Maintenance	
Risk Analysis Practices (5)			CIMS: A Construction Information Management Sys	Building Inventory and Maintenance	
			Project Rations for Project Status and Forecasting		
			Automated Real-Time Data Acquisition		
			Microcomputer Cost Control System		
			Imaging and Vision Systems for Automated Construction		
			Automated Construction and Robotics (9)		
			Monitoring and Evaluation of Evolving Structures		
			Innovative Features of Construction Incentive Plans		
			KBES for Construction Claim Management		
			Bar Code Applications (2)		
			Linking CAD with Materials Management		


FACILITIES SYSTEMS DIVISION
THRUST AREA: MILITARY CONSTRUCTION CYCLE
GOAL: PROVIDE AUTOMATED LIFE CYCLE MANAGEMENT OF FACILITIES
FY 90
FY 91
FY 92
FY 93
FY 94
FY 95
EXPERT MANAGEMENT SYSTEMS
• ENERGY MANAGEMENT
• REPAIR/REPLACE ADVISOR
• ASSESS OPERATING PROBLEMS
• AUTOMATED FACILITY INSPECTION
INTEGRATION OF EXPERT SYSTEMS W/CADD
• DESIGN CODES
• OWNER DESIGN REQUIRMENTS
• DESIGN CHECKER
• CONCEPTUAL COST AND SCHEDULING
CONSTRUCTABILITY KNOWLEDGE BASED EXPERT SYSTEM
DATA TRANSFER BETWEEN DESIGN AND CONSTRUCTION
SPATIAL MODELS
ANIMATION
ACQUISITION OF AS-BUILT INFORMATION
AUTOMATED SPACE PLANNING
COMPUTER INTEGRATED LIFE CYCLE MANAGEMENT

F. S. BASE SUPPORT INVESTMENT STRATEGY OUTLINE

I. BASE SUPPORT DEFICIENCIES

II. R&D THRUST AREAS/EXISTING INITIATIVES/TECHNOLOGIES/BENEFITS

III. GOAL CAPABILITIES (What are we going to get from research?)

Examples:

- FULLY AUTOMATED, INTEGRATED FACILITY DESIGN BY 1994
- SMART, FULLY AUTOMATIC, SELF MONITORING/DIAGNOSTIC BUILDINGS BY 1996
- SELF-SCHEDULING, AUTOMATED DEH RE SUPPLIED WORKFORCE BY 1997

IV. INTERMEDIATE PRODUCE SYSTEMS/DELIVERABLES (How do we get there?)

• ARCH 4D • INTEGRATED DATABASE • SITE PLANNING TOOLS	Degree Leveraged	Resource Requirements

V. PROGRAM ELEMENT DISTRIBUTION

• AT23 • AT41 • T^3B/FTAT • CPAR • REIMBURSABLE	By Functional Area By Teams By Year By Proponent/Customer

I. Introduction

The purpose of this report is to develop a research and development strategy which could have an impact on reducing a DEH "cost driver". The "cost driver" we have chosen is the minor construction and alteration responsibility of the DEH. Army Management and Structure Codes show Minor Construction as a $255 million expense in fiscal year 1988. While that amount is not the largest of the DEH cost codes, it is an area where research of the type conducted by the Facilities Systems Division of CERL could have an impact. Further, the amount shown for minor construction is large enough to suggest there may be potential for worthwhile savings. For instance, improvements over a range of 5% - 10% would result in savings between $12 million and $25 million each year.

The goal of the research and development strategy in this report is an integrated system to assist the DEH in the early design phases of new construction projects as well as modification or alteration work. It is recognized that many early decisions relating to facility design are undertaken on an arbitrary basis rather than selection from a group of studied alternatives. This arbitrary approach often results in design changes much later when alternatives are more closely considered. Thus, from master planning through early design, a process should be developed which will better ensure that the impact of early design decisions on cost, scheduling, constructability, etc., are well understood and fully taken into account. This would guarantee that will ensure the most pertinent factors are considered at an early stage in the design process, minimizing the necessity for making changes at a later date.

The thrust of our argument is that if the original design is done correctly, the potential for changes will be minimized and the constructability of a project will be improved. Also, such a comprehensive approach to streamlining the early design process will result in long-term life cycle benefits and cost savings. These will translate into cost-effective improvements in similar minor construction and alteration projects.

II. The Need for an Integrated System

Changes are a major concern on any construction project. Several researchers have investigated the impact of design errors and user initiated changes on the cost of a construction project. Diekmann [1985] reports approximately half of the dollar cost of all changes are caused by design errors and user discretionary changes. Dawkins [1987] reports changes orders accounting for 6.1% of the total dollar volume of a selected set of 48 projects with a total value of $100 million. These contracts were administered by the Naval Facilities Engineering Command, Charleston, SC. Dawkins noted that 36.8% of the dollar volume of changes were the result of design errors and 22.8% of the dollar volume of changes were due to owner directed discretionary changes. A major conclusion from the Dawkins study was that especially in alteration or modification types of construction, significant savings can be achieved through improvements in design and reduction of owner changes.

These sources make it clear there is a significant dollar volume of changes which could be avoided if design errors could be reduced only slightly and if the design features could be more effectively communicated to the user. Additionally, any improvements in constructability due to better design would undoubtedly have an impact on the final cost of a project. Moreover, a recent study done for the U.S. Air Force included the observation:

> " the [military construction] system inhibits designer/construction interface early in the design stage when input is most useful. Computer networking capabilities and computer aided design/computer integrated construction (CAD/CIC) will generate increasing impetus for close integration of the design/construction process" [Technology 2000, 1988].

Constructability is also an important factor in holding the line on construction costs. Several authorities have recognized the need to inject constructability considerations early in the design process. Dr. Richard Wright, in a presentation to a workshop on America's Buildings in the 21st Century observed that much more work is needed to inform the early design decisions with intelligence about constructability and the effects of alternatives on life cycle benefits and costs [NAS Workshop, 1987]. He noted:

> "Some eminent architects tell me that they rarely find an engineer who is helpful at the early design stages. For instance, an engineer who is able to present the advantages and disadvantages of alternative structural systems or mechanical systems."

Constructability was also a major theme of a National Science Foundation workshop at Lehigh University [Wilson, 1987]. The introduction to this workshop stated that the philosophy of computer-integrated construction must take into account constructability and maintenance considerations in the design cycle. The introduction also stated that mismatches between the intentions of designers and constructors can be alleviated by using computer-integrated construction techniques.

Spatial models are recognized as a means to more accurately convey the designer's intent to the end user. It is generally accepted that many end-users not trained in the interpretation of two-dimensional drawings have difficulty visualizing the final product. Spatial models and particularly animation lets the end-user "test drive" a design before committing to an expensive but perhaps ill-conceived facility. Animation can show how the different pieces fit together and systems like Bechtel's state-of-the-art "Walkthrough" product allow the end-user to simulate views from differing perspectives inside the facility. Apart from the communication aspects of spatial models, they can have the ability to detect physical interferences such as conflicts between mechanical and electrical chases. In a report for the Office of Technology Assessment, Dr. Daniel Halpin commented:

> "The ability to utilize 3-D CADD systems will definitely yield a productivity advantage to those firms with access to this technology. Some productivity estimates ... indicate cutting required manhours to one-third of the traditional requirement for the same design related work. The list of potential advantages include better ability to determine the constructability of a design, improved plant documentation, training and maintenance support, and better planning during the conceptual design phase. The potential is unlimited." [Halpin, 1986].

Because of restricted DEH resources, computer-assisted tools should be used to the extent possible to implement research products of this integrated investment strategy. The existing DEH automation capabilities could be augmented and developed into an integrated computer-aided construction system to support all aspects of an installation's minor construction and alteration program. As will be described in this section, not only are there firm Army requirements for such a system, there are also a wide range of existing automated capabilities that can readily accommodate most DEH requirements.

The call for an integrated computer system is not new. The Mission Area Deficiency Statements of the Army Assistant Chief of Engineers, dated May 1987, contains two statements in support of the development of an enhanced computer-aided design capability, with variations, for installation support activities. The first of these statements is 2.01.018, Installation Facility Space Planning and Management. This mission area deficiency statement relates to the difficulty of properly evaluating facilities of an installation to accommodate changing mission requirements. The second deficiency statement is 2.01.023, DEH Computer-Aided Design Support. This statement calls for a computer-aided design capability for the DEH.

Further support for a computer-aided construction system comes from Facilities Engineering Management System Study, Volume I, where comments from the field personnel of Engineering Plans and Services Divisions clearly state their need for improved computer/CADD support [FEMS,].

An integrated computer-aided system, appropriately configured, offers an unusual opportunity to improve the quality of space management. With prudent planning in the development cycle, the introduction of an integrated integrated construction system to the DEH can offer real support to the Army Communities of Excellence program through significantly improved space management.

Various workshops and studies by academia and industry have noted the significance of computer-aided developments in support of all phases of the construction industry. A National Science Foundation white paper in 1985 Levitt [1985], pointed out the suitability of the construction industry to applications of artificial intelligence methodologies. The NSF and the University of Illinois jointly sponsored a workshop on future directions for computerized construction research [Ibbs, 1987]. One of the topics strongly recommended for study was project-wide data bases and communications, particularly in support of computer-aided design.

Another 1987 NSF workshop reported on the importance of research for computer-aided construction, with emphasis on the opportunities offered by knowledge-based systems for both design and construction [Wilson, 1987]. Wilson concluded that computer integration of activities can allow timely and more reliable decisions when modifications must be quickly accommodated. Additionally, Wilson observed that the development of "smart" buildings will require computer-integrated techniques.

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Of course, the challenge to CERL and the Corps of Engineers will be how to make the best use of these developments.

V. Opportunities and Gaps for CERL Research

- Profitability (Industry vs. Government)
- Evaluate Size and Value
- Evaluate Probability of Success
- Evaluate T^2 Opportunity
- Evaluate Leveraging Opportunity
- MAPS
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VI. A Facility Systems Strategy for an Integrated System

To summarize the needs developed earlier, the research strategy must address the following:

- Streamline the minor construction design process.
- Reduce change orders to the extent possible.
- Improve constructability.
- Improve the quality of space management.

The following research strategy is intended to meet the needs described above. There are five research programs which can be considered to streamline the design process.

- Evaluate the impact of master planning decisions on the design process. That is, determine what types of decisions in the master planning process have what types of effects on the design process.

- Study the appropriate regulations and directives regulating minor construction and their impact on the planning and design process. Their effect on each project should be well known and fully considered.

- Evaluate the expansion in the number of Centers of Expertise and the Strategic Support Centers to offer a more comprehensive support system for the DEH.

- Make efficient use of current and projected computer-aided design and drafting (CADD) technology. Section I of this report has identified the wide-spread recognition of an improvement of this capability for the DEH. However, as researchers at CERL have recognized, care must be taken to provide an integrated system based on existing capabilities rather than to "drop another system on the desk."

- Develop an integrated, computer-based construction system based on the minor construction design process. This effort too is one which requires a significant level of careful planning and development to insure adequate integration with existing systems as well as work done under action four above.

As discussed in section I above, the construction process can benefit significantly from the reduction of change orders. We have identified seven research programs which could reduce the volume and cost of change orders. these actions are:

- Develop new procedures and practices to get engineers involved early in the design process. Their practical understanding of the issues will contribute to constructability and communication between designers and constructors.

- Develop a set of standard designs which have been proven effective in those situations where similar tasks are repeatedly undertaken.

- Develop design databases common to minor construction disciplines.

- Develop expert systems to capture past design experience. This action must be closely integrated with, and to some extent is dependent on, the previous action.

- Develop a three-dimensional CADD system to evaluate and eliminate spatial interferences in minor construction design.

- Consider design impacts of potential mission changes. The first aspect of this action would be to develop a methodology for such reviews. The second aspect would be to perform such reviews when mission changes were contemplated. When appropriate, the design should include contingencies for mission changes.

- Develop procedures, practices and directives which will reduce mismatches between the intentions of architects, engineers and constructors.

Our investigations have shown a widespread recognition of the need to have a strategy to improve constructibility. We have identified five research programs to be taken which would contribute to improved constructability.

- Develop a methodology to coordinate the master planning process with architects, engineers and constructors. While such coordination is present in some instances, some standardization of such important communications is seen as quite important.

- Research alternate engineering approaches to determine the most cost-effective designs (structural, mechanical and electrical). Such a program should be coordinated with current on-going design efforts.

- Determine the impact of alternate designs on operations and maintenance costs.

- Evaluate the life cycle costs of design alternatives.

- Develop a set of DEH-wide data bases to exchange information on common early design problem areas. This fifth research program would be a development effort followed by a continuing program to insure adequate collection and dissemination of the information collected.

Our study has shown the importance of supporting the DEH in the pursuit of the Army Communities of Excellence program. It is clear that all programs which will result in a reduction in the cost of minor construction will contribute to COE. However, a strategy for improvement of the quality of space management is one which will clearly be seen by all as contributing to COE. We believe there are two main research programs which will support such a strategy.

- Develop a capability to visualize a completed construction project. The development of three-dimensional graphics and animation offer such a capability in the near term.

- Develop the capability to conduct a facility management study/evaluation during the design phase of all minor construction projects. Such a system would operate from within a larger, integrated computer-based system.

VII. An Action Plan to Implement the Strategy

- Resource Leveraging
  - –IPA/SFRC
  - –IDO
- Personnel Development/Training
- Recruitment
- Tools, Equipment, & technology
- Product Support
- CERL-FS Business Practices
- Define Critical Success Factors for Future Program Evaluation and Monitoring
  - –IPR (In-Progress Review)
  - –Post-ROI

I. Introduction

The purpose of this report is to develop a research and development strategy which could have an impact on reducing a DEH "cost driver". The "cost driver" we have chosen is the minor construction and alteration responsibility of the DEH. Army Management and Structure Codes show Minor Construction as a $255 million expense in fiscal year 1988. While that amount is not the largest of the DEH cost codes, it is an area where research of the type conducted by the Facilities Systems Division of CERL could have an impact. Further, the amount shown for minor construction is large enough to suggest there may be potential for worthwhile savings. For instance, improvements over a range of 5% - 10% would result in savings between $12 million and $25 million each year.

The goal of the research and development strategy in this report is an integrated system to assist the DEH in the early design phases of new construction projects as well as modification or alteration work. It is recognized that many early decisions relating to facility design are undertaken on an arbitrary basis rather than selection from a group of studied alternatives. This arbitrary approach often results in design changes much later when alternatives are more closely considered. Thus, from master planning through early design, a process should be developed which will better ensure that the impact of early design decisions on cost, scheduling, constructability, etc., are well understood and fully taken into account. This would guarantee that will ensure the most pertinent factors are considered at an early stage in the design process, minimizing the necessity for making changes at a later date.

The thrust of our argument is that if the original design is done correctly, the potential for changes will be minimized and the constructability of a project will be improved. Also, such a comprehensive approach to streamlining the early design process will result in long-term life cycle benefits and cost savings. These will translate into cost-effective improvements in similar minor construction and alteration projects.

II. The Need for an Integrated System

Changes are a major concern on any construction project. Several researchers have investigated the impact of design errors and user initiated changes on the cost of a construction project. Diekmann [1985] reports approximately half of the dollar cost of all changes are caused by design errors and user discretionary changes. Dawkins [1987] reports changes orders accounting for 6.1% of the total dollar volume of a selected set of 48 projects with a total value of $100 million. These contracts were administered by the Naval Facilities Engineering Command, Charleston, SC. Dawkins noted that 36.8% of the dollar volume of changes were the result of design errors and 22.8% of the dollar volume of changes were due to owner directed discretionary changes. A major conclusion from the Dawkins study was that especially in alteration or modification types of construction, significant savings can be achieved through improvements in design and reduction of owner changes.

These sources make it clear there is a significant dollar volume of changes which could be avoided if design errors could be reduced only slightly and if the design features could be more effectively communicated to the user. Additionally, any improvements in constructability due to better design would undoubtedly have an impact on the final cost of a project. Moreover, a recent study done for the U.S. Air Force included the observation:

> " the [military construction] system inhibits designer/construction interface early in the design stage when input is most useful. Computer networking capabilities and computer aided design/computer integrated construction (CAD/CIC) will generate increasing impetus for close integration of the design/construction process" [Technology 2000, 1988].

Constructability is also an important factor in holding the line on construction costs. Several authorities have recognized the need to inject constructability considerations early in the design process. Dr. Richard Wright, in a presentation to a workshop on America's Buildings in the 21st Century observed that much more work is needed to inform the early design decisions with intelligence about constructability and the effects of alternatives on life cycle benefits and costs [NAS Workshop, 1987]. He noted:

> "Some eminent architects tell me that they rarely find an engineer who is helpful at the early design stages. For instance, an engineer who is able to present the advantages and disadvantages of alternative structural systems or mechanical systems."

Constructability was also a major theme of a National Science Foundation workshop at Lehigh University [Wilson, 1987]. The introduction to this workshop stated that the philosophy of computer-integrated construction must take into account constructability and maintenance considerations in the design cycle. The introduction also stated that mismatches between the intentions of designers and constructors can be alleviated by using computer-integrated construction techniques.

Spatial models are recognized as a means to more accurately convey the designer's intent to the end user. It is generally accepted that many end-users not trained in the interpretation of two-dimensional drawings have difficulty visualizing the final product. Spatial models and particularly animation lets the end-user "test drive" a design before committing to an expensive but perhaps ill-conceived facility. Animation can show how the different pieces fit together and systems like Bechtel's state-of-the-art "Walkthrough" product allow the end-user to simulate views from differing perspectives inside the facility. Apart from the communication aspects of spatial models, they can have the ability to detect physical interferences such as conflicts between mechanical and electrical chases. In a report for the Office of Technology Assessment, Dr. Daniel Halpin commented:

> "The ability to utilize 3-D CADD systems will definitely yield a productivity advantage to those firms with access to this technology. Some productivity estimates ... indicate cutting required manhours to one-third of the traditional requirement for the same design related work. The list of potential advantages include better ability to determine the constructability of a design, improved plant documentation, training and maintenance support, and better planning during the conceptual design phase. The potential is unlimited." [Halpin, 1986].

Because of restricted DEH resources, computer-assisted tools should be used to the extent possible to implement research products of this integrated investment strategy. The existing DEH automation capabilities could be augmented and developed into an integrated computer-aided construction system to support all aspects of an installation's minor construction and alteration program. As will be described in this section, not only are there firm Army requirements for such a system, there are also a wide range of existing automated capabilities that can readily accommodate most DEH requirements.

The call for an integrated computer system is not new. The Mission Area Deficiency Statements of the Army Assistant Chief of Engineers, dated May 1987, contains two statements in support of the development of an enhanced computer-aided design capability, with variations, for installation support activities. The first of these statements is 2.01.018, Installation Facility Space Planning and Management. This mission area deficiency statement relates to the difficulty of properly evaluating facilities of an installation to accommodate changing • Utilization mission requirements. The second deficiency statement is 2.01.023, DEH Computer-Aided Design Support. This statement calls for a computer-aided design capability for the DEH.

Further support for a computer-aided construction system comes from Facilities Engineering Management System Study, Volume I, where comments from the field personnel of Engineering Plans and Services Divisions clearly state their need for improved computer/CADD support [FEMS,].

An integrated computer-aided system, appropriately configured, offers an unusual opportunity to improve the quality of space management. With prudent planning in the development cycle, the introduction of an integrated integrated construction system to the DEH can offer real support to the Army Communities of Excellence program through significantly improved space management.

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- Research alternate engineering approaches to determine the most cost-effective designs (structural, mechanical and electrical). Such a program should be coordinated with current on-going design efforts.

- Determine the impact of alternate designs on operations and maintenance costs.

- Evaluate the life cycle costs of design alternatives.

- Develop a set of DEH-wide data bases to exchange information on common early design problem areas. This fifth research program would be a development effort followed by a continuing program to insure adequate collection and dissemination of the information collected.

Our study has shown the importance of supporting the DEH in the pursuit of the Army Communities of Excellence program. It is clear that all programs which will result in a reduction in the cost of minor construction will contribute to COE. However, a strategy for improvement of the quality of space management is one which will clearly be seen by all as contributing to COE. We believe there are two main research programs which will support such a strategy.

- Develop a capability to visualize a completed construction project. The development of three-dimensional graphics and animation offer such a capability in the near term.

- Develop the capability to conduct a facility management study/evaluation during the design phase of all minor construction projects. Such a system would operate from within a larger, integrated computer-based system.

VII. An Action Plan to Implement the Strategy

- Resource Leveraging
  - –IPA/SFRC
  - –IDO
- Personnel Development/Training
- Recruitment
- Tools, Equipment, & technology
- Product Support
- CERL-FS Business Practices
- Define Critical Success Factors for Future Program Evaluation and Monitoring
  - –IPR (In-Progress Review)
  - –Post-ROI

Problems

- Lack of O&M and Utilization Lessons Learned Feedback
- Hard to Define Facility Requirements to Designer
- Ad Hoc Process Prevents Continuity
- Long Lead Time for MCA Process
- Difficult to Translate Mission Requirements to Facility Requirements
- Lack of Vision of the Future
- Lack of Prioritization Tools
- Multitude of Diverse/Non-Integrated Systems
- Lack of Information of Facilities Options
- Lack of Realistic Construction Cost Information

Impact

- Misallocation of Funds
- Inappropriate Facilities
- Lack of Timely Response to Mission Requirements
  - Decreased Mission Effectiveness
  - BOD ≠ IOC

Desired Capabilities

- A Coherent, Timely, Tightly-Integrated Planning and Programming Process
  - Capture Past Design, O&M, and Utilization Experience
  - A Methodology to Coordinate the Master Planning Process with the AEC Community
  - An Up-to-Date Digitized Installation Master Plan
  - A More Rigorous Evaluation of Life Cycle Costs/Alternatives
  - Accelerate the Review and Approval Process
  - A More Mission-Oriented Priortization System for Project Selection
  - An Accurate, Timely Cost Data Base
  - A Risk-Based Conceptual Cost Estimating System

Research/Technical Development Underway

- Open Information Architecture (Penn State)
- 1391 Processor (CERL)
- Automated Installation Master Planning (CERL)
- Facility Renewal/Replacement Modeling (CERL)
- Facilities Life Cycle Cost Studies (CERL)
- Facility Criteria Generator (CERL)
- Knowledge Manager (CERL)
- Expert MCA Analysis (CERL)
- Automated Mapping/Facilities Management (USAF, CERL)
- Economic Analysis of Life Cycle Costs (CERL)
- Major Trends in Army Installation Planning

Gaps

- Lack of an Integrated Planning/Programming System Incorporating:
  - Lessons Learned from Past Mistakes
  - Current Installation Master Plan Data
  - Responsive Life-Cycle Cost Methodology
  - Risk-Based Conceptual Estimates
  - Project Prioritization Methodology
- Unclouded Vision of Future Force Requirements/Technology
- Inability to Translate Mission Requirements into Facility Requirements
- Ill-Defined Facility Requirements to Designer

How CERL Can Impact Gaps

- Establish System to Incorporate Lessons Learned
- Provide Vehicle to Maintain Current, Digitized Base Master Plan
- Provide Framework and Requirements for Integrated Planning/Programming System
- Continue Development of AM/FM System
- Enhance Automated Review and Management System
- Initiate Risk-Based Conceptual Estimating Studies
- Improve MAPS
- Expedite Life Cycle Cost Data Collection Systems

Functional Area: DESIGN

Problems

- Low Initial Cost Estimates
- Lack of Accurate Project Information
- Not Enough Lessons Learned Feedback
- Inadequate Knowledge of Advanced Technology
- Not Enough Standard Designs
- No Common Design Data Base
- Design Not Responsive to Mission Requirements
- Overly Restrictive Specifications

Impact

- Non-Optimal Constructability
- Non-Functional Design } Change Orders (6% of total cost, 60% due to design errors and owner changes)
- Design Errors }
- Poor Value Engineering
- Increased Life Cycle Cost (Post-Occupancy)
- Spatial Interferences
- Arbitrary Design Decisions
- Decreased Occupant Productivity
- Increased Construction Cost

Desired Capabilities

- Better Mission-Responsive Design
- More Flexible Designs to Accomodate Mission Changes
- Increased Use of Modular Systems
- Enhanced Physical Security Systems
- Closer Management of the A/E Design Process
- Involve Contractor in Design Phase
- Knowledge Based Expert Systems
- Integrated Owner/Designer/Builder Interface
- Standardized Project-Wide Data Bases and Communications
- Spatial Models
- Interference Detection
- Animation
- Computer Aided Design/Computer-Aided Construction
- Improved Plant Documentation
- Single, Dedicated, Decision-Making Authority

Research/Technical Development Underway

- Artificial Intelligence Applications in Project Planning (Stanford, Texas A&M)
- Integrated Design and Construction (Carnegie-Mellon, Illinois, Texas A&M)
- Open Information Architecture (Penn State)
- Integration of CADD with 3-D Digitized Visual Recording of Construction (Illinois)
- Linking CAD Systems to Knowledge Representation (MIT)
- Integration of Knowledge Based Tools (Carnegie-Mellon)
- Expert System for Building Layout (Carnegie-Mellon)
- Microcomputer-Based Intelligent Computer-Aided Design System (Cal Poly)
- Knowledge-Based Design Assistant (SUNY-Buffalo)
- Structural Design Linkage with Intelligent Construction Simulator (Maryland)
- Cost Advisor for Conceptual Estimates (Colorado, Marquette)
- Automated Mapping/Facilities Management (Air Force)
- Solids Modeling Program for Installation Mapping (Air Force)
- Conceptual Design Visualization (Bechtel)
- Automated Specification Writer (Ga Tech/McGraw-Hill)
- Digital Interactive Video (Intel)
- Computer Assisted Engineering Design System (CAEDS) (CERL)
- Automated Review Management System (CERL)
- 4D Modeler (CERL)
- Automated Installation Master Planning (CERL)
- Expert Bidability, Constructability, and Operability Review Expert System (CERL)
- Design Criteria Information System (CERL)
- A/E Liability and Analysis (CERL)
- CACES (?)

Gaps

- Constructability and Maintenance Issues Not Fully Considered
- Communication Medium Between Owners/Designers/Builders Not Fully Effective
- Conceptual Cost Estimates not Realistic
- Value Engineering Not Done Early Enough or Not Thorough Enough
- Non-Standardized Data Bases
- Integration of CADD with the Construction, O&M, and Utilization Phases
- Inflexible Design
- Vulnerability to Terrorism

How CERL Can Impact Gaps

- Take Leadership Role to Establish Standards for Data Bases
- Investigate Expert Systems to Capture Past Design Experience
- Establish Methodology for Feedback System on Lessons Learned
- Develop More Standardized Drawings
- Evaluate Effect of Master Planning Decisions on the Design Process
- Study Impact of Regulations and Directives on the Design Process
- Extend Work on 4D Modeler to Incorporate Animation
- Develop Capability to Visualize Completed Project
- Develop Capability to Simulate Phases of Construction in 3D
- Improve Conceptual Estimating Capability through Simulation/Expert Systems
- Explore Innovative Contractural Approaches
- Integration of CADD with Construction Reporting Documents
- Continue to Explore Viability of Flexible, Modular Systems
- Determine Effectiveness of Current Constructability Reviews

Functional Area: CONSTRUCTION

Problems

- Inadequate Design (Plans/Specifications)
- Unrealistic Construction Budgets
- Non Cost-Effective Bid and Award Procedure
- Adversarial Environment Between Government and Contractor
- Decline in Construction Productivity
- Inability of Government to Determine Real Construction Costs
- Incompetent Contractors
- Overly Restrictive Government Contract Forms

Impact

- Schedule Delays
- Cost Overruns
- Lack of Quality Assurance
- Prolonged Claims Settlement Process
- Warranty Enforcement
- Lack of Agreement on Contract Scope

Desired Capabilities

- Innovative Contracting System Similar to Industry (Reimbursable, Shared Cost Savings)
- Minimal Change Orders
- More Effective Contractor Prequalification
- Integrated Electronic Data Management Systems
- Involve Contractor Earlier in Process
- Positive Rather than Negative Contractor Incentives
- Partnering (Ref Mobile District Dam Project)
- Improved Productivity
- Improved Quality
- More Turnkey Construction

Research/Technical Development Underway

- Efficiency and Productivity of Site Operations (U Waterloo)
- Quality Problems in Construction (Clemson)
- Constructability During Field Operations (UT Austin)
- Constructability Improvement (Stanford)
- Structure of Data Base Applications in Construction (UI)
- Bar Code Applications in Construction (U Kansas, Texas A&M, Auburn)
- Inter-Project Productivity Comparisons (UT Austin)
- Automatic Monitoring and Evaluation of Evolving Structures (Texas A&M)
- Innovative Features of Construction Incentive Plans (Cal Berkeley)
- Expert System for Construction Claim Management (UP Boulder, Ill Tech)
- Project Objective Setting by Owners and Contractors (Iowa St)
- The Determinates of Project Success (UT Austin)
- Contract Risk Allocation and Equity Analysis (UT Austin)
- Risk Analysis by Expert Systems (UT Austin, U Waterloo, Ga Tech)
- Contract Duration Estimation System (CERL)
- Alternate Construction Technologies (CERL)
- Project Management Data Exchange Systems (CERL)
- Modifications Processing System (CERL)
- Knowledge Base for Alternate Construction (CERL)
- Claims Guidance (CERL)
- Quality Assurance Management System (CERL)
- Excusable Delay Tracking System (CERL)

Gaps

- Overly Rigid Contracting System
- Lack of Incentive Plans to Improve Productivity
- Lack of Innovative Dispute Resolution Procedures
- Less-than-Thorough Quality Control
- Incomplete Construction Cost Data
- Disagreement on Project Scope

How CERL Can Impact Gaps

- Explore Alternative Contracting Methodologies to Include Reimbursable and Shared Cost Savings
- Conduct Case Studies to Evaluate Alternative Contracting Methods
- Investigate Alternative Dispute Resolution Techniques
- Take the Lead in Evaluating and Transfering Latest Construction Technology
- Explore Ways to Better Define Scope
- Revise Existing Government Contracts
- Establish Construction Cost Data Base

Problems

- Loss of Facility Knowledge
- Increasing Costs of Facility Operations
- Decreasing Funds
- Environmental Concerns
- Aging Facilities
- Changing Mission
- Decreasing Resources
- Incomplete Condition Assessment
- Overload of Data Available
- Rigid Supply Support
- Inflexible Work Assignment Rules

Impact

- Decrease in Mission Effectiveness
- Deteriorating Facilities
- Increase in BMAR
- Decrease in Quality Of Life
  Decrease in Reenlistments

Desired Capabilities

- "Smart Buildings"
- More Effective Facility Preservation/Renewal Capability
- More Cost Effective Operations of Facilities
- More Efficient Inspection and Inventory Methods
- More Flexible, Responsive Maintenance Force and Supply System
- Automated Maintenance Management
- User Friendly Decision Support Tools
- More Accurate Failure Prediction Models

Research/Technical Development Underway

- Statistical Representation of Large Buildings for Quantitative Performance (VPI&SU)
- Role of Uncertainty in Management of Infrastructure Facilities (MIT)
- Building Inventory and Maintenance (NC State)
- Voice-Activated Recognition System (CERL)
- Facility Renewal Expert System (CERL)
- Maintenance and Repair Prediction Model (CERL)
- Cost Estimating of Maintenance and Repair (CERL)
- Rental/Leasing Options (CERL)

Gaps

- Up-to-date Infrastructure Data Base
- Effective Decision Support tools
- Accurate Failure Prediction Models
- Cost Effective Inspection Systems

How CERL Can Impact Gaps

- Evaluate Consequence of Maintenance and Repair Decisions
- Identify Current and Future Information Needs
- Continue Research in M & R Prediction Models
- Develop Case Studies Comparing Various Methods of Contract M & R
- Expand Work on Automated Inspection Systems

Functional Area: UTILIZATION

Problems

- Incomplete Facility Records
- Inappropriate Facilities
- Improper Match of Space with Activity
- Inaccessible As-Built/As-Modified Information
- No Convenient Capability for Land Planning Alternatives
- Noise Impact on Surrounding Communities
- Environmental Constraints
- Ammunition Storage Constraints
- Restraints on Live Firing Exercises
- Restricted Training Areas

Impact

- Needless Construction
- Uninformed Strategic Planning
- Needless Operation and Maintenance Expense
- Decreased Readiness
- Inefficient Utilization
- Difficult to Accomodate Changing Mission Requirements

Desired Capabilities

- Computerized Real Property Inventory Data
- Automated Master Planning
- Disaster Damage Reporting
- Automated Realignment/Restationing Evaluation
- Improved Automated Mapping/Facilities Management Capability
- Better Match of Space with Activity
- Improved Physical Security

Research/Technical Development Underway

- Utilization of Facility Space (CERL)
- Facility Parameter Relationships to Command Objectives (CERL)
- Training Range Capabilities Matrix (CERL)

Gaps

- Fully Automated Master Planning/Inventory System
- Best Match of Space with Activity
- Useable Master Planning Graphics Capability
- Automatic Disaster Damage Reporting

How CERL Can Impact Gaps

- Extend Work on Automated Master Planning Systems
- Improve Master Planning Graphics Capability
- Investigate Automated Inventory Systems
- Develop Strategies to Accomodate Changing Mission Requirements
- Develop an Automated Disaster Damage Reporting System
- Explore Capabilities to Automatically Update As-Built/As-Modified Information
- Expand Work on Training Area Utilization Schemes

BASE SUPPORT RDT&E INVESTMENT STRATEGY

Report on Task 1 (Modified)

Prepared Under Contract
DACA88-88-D-0020

Submitted to:

Department of the Army
Facilities Systems Division
CONSTRUCTION ENGINEERING RESEARCH LABORATORY
Champaign, Illinois

Prepared November 7, 1989
by:

Leland S. Riggs

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Introduction

The purpose of Task 1 was to visit several U.S Army Corps of Engineers offices in order to gather information on the number, type and activities of personnel at specific locations involved in the design and construction process of military facilities. Specifically, those personnel involved in civil works is not included. Information was also to be collected on the number of contractors involved in the design and construction process. Finally, preliminary information was to be gathered on costs which can be assigned to the activities identified. The offices targeted for visits were South Atlantic Division, Savannah District and HQUSACE. This report covers the results of these visits.

Savannah District

On April 25, 1989, I visited the Savannah District along with Mike Golish of CERL. Personnel contacted during this visit include:

Bill Smith	Chief, Military Program and Management Branch
Tommy Blewett	Design Control Engineer
Ben Harrison	Chief Architectural Section
Jack Bartholet	Chief, Military Projects Section
Tom Weathers	Chief, Technical Support Section
Frank Mills	Assistant Chief, Construction Division
Gloria Gray	Program Analyst, Construction Division

Most of the discussion during the visit centered around management and budgetary issues rather than the primary purpose of the visit which was to collect information on the number, type, activities, and costs of personnel associated with the design and construction process at the District level. In fairness to our hosts, however, this information was not readily available in a useable format during the visit. Therefore, data provided at the end of the visit and later is basis of this report.

Number and type of personnel: Appendix A includes a detailed picture of this information in the form of organizational charts. Table 1 below is a summary of the information extracted from Appendix A concerning number and type of personnel. Please note that the numbers in Table 1 reflect only those personnel working in Military Construction and not those working in Civil Construction. Therefore, the totals in Table 1 may not add up to the totals shown in the lower right hand corner of the charts of Appendix A which do include personnel involved in Civil Work.

The total dollar amount for the personnel listed in Table 1 is $14,524,899. The total from the charts in Appendix A for design and construction is $15,492,614 leaving an amount of $967,715 for 52 personnel in Civil work.

Table 1. – Number & Type Personnel, Savannah District

Type	Engineering	Construction	Total
Civil Engineers	51	46	97
Electrical Engineers	16	6	22
Mechanical Engineers	21	7	28
Architects	14	1	15
Landscape Architects	2		2
Geologists	10		10
Structural Engineers	10		10
Environmental Engineers	2		2
Program Analysts	2	2	4
Interdisciplinary Engineers	1		1
Construction Representatives		20	20
Contract Negotiators	1		1
Community Planners	1		1
Technicians	43	26	69
Clerks/Stenos/Assistants/Secy's	41	20	61
Total	215	128	343

Number of Contracts: Task 1 also called for the number of contractors doing design and construction work for the Savannah District. This type data is not maintained in a form to be readily available. An attempt was made to extract the data from the AMPRS system, but the result was a printout of all contractors listed with the South Atlantic Division rather than a specific number of contractors.

Perhaps just as useful, however, is the number of current construction contracts at the Savannah District. As of 31 March, 1989, the District had a total of 82 contracts on the books for a total value of $340,893,000.

Additionally, statistics reflecting the design effort may also be of interest. Again, as of 31 March, 1989, the District had a total of 228 facilities under design with a program amount of $508,002,000.

During our discussions, a recurring topic was the comparison between in-house design effort by the Corps and A/E design effort. Table 2 is adapted from a study conducted by the Savannah District and shows the relative percentages of construction, design, and overhead related to total project funds. It is noted that the percent for design is somewhat higher than a figure of 6.9% carried by the South Atlantic Division. In the SAD tables, the percentages for design are in the 6% 8% range. However, the people at Savannah believe their analysis, which is based on COEMIS data, is an accurate depiction of the level of effort.

Table 2 – Distribution of Project Funds in Percent

	A/E	In-House
Construction Contractor	74.64	75.67
Construction Division		
Supervision and Inspection	5.50	5.50
Contingencies	5.00	5.00
Subtotal	10.50	10.50
Design		
Engineering & Design (Direct Construction)	0.50	0.50
Design Branch	2.24	6.19
Military Branch	1.30	1.00
Geotechnical Branch	1.29	1.74
Architectural/Engineering	7.90	1.02
Subtotal	13.23	10.45
Overhead		
Engineering Division	0.15	0.31
District	0.74	1.28
Travel	0.14	0.04
Reproduction	0.28	0.48
Miscellaneous	0.32	1.27
Subtotal	1.63	3.38
Total	100.00	100.00

One final table which may be of interest is Table 3 which shows the source and distribution of design funds for the Savannah District.

Table 3 – Source and Distribution of Design Funds

Source	Distribution		
Design Funds	**In-House**		**A/E**
MCA			
In-house design	4,255,335		
In-house support of A/E work		3,480,500	
A/E contract cost			6,162,761
In-house design	1,115,147		
In-house support of A/E work		1,752,147	
A/E contract cost			6,018,713
In-house design	634,703		
In-house support of A/E work		949,547	
A/E contract cost			4,133,946
Totals	6,005,185	6,182,194	16,315,420

South Atlantic Division

I visited the headquarters of the South Atlantic Division on September 19, 1989. The following personnel were contacted:

Benny Stevens	Chief, Construction Branch
Cathy Gardner	Computer Programmer Analyst

Most of the day was spent discussing the AMPRS system with Ms. Gardner. After several trial computer runs we determined that the information on contractors was not in a form which would be useable for this report. Consequently, the remainder of the visit was with Mr. Stevens.

Mr. Stevens and I discussed potential sources for the information needed for this report. He suggested several contacts for cost data, however, the people at SAD were much more sensitive to releasing cost data than were the people at Savannah. Therefore, the cost data for the charts in Appendix B represent averages for the pay grades of individuals shown on the charts. With this exception, the charts at Appendix B for SAD are similar to the charts at Appendix A for Savannah. Table 4 is a summary of SAD personnel involved in the design and construction process. Data for Table 4 has been extracted from the charts in Appendix B and is similar to Table 1.

Table 4. – Number & Type Personnel, SAD

Type	Engineering	Construction	Total
Chief	1		
Civil Engineers	22	9	31
Electrical Engineers	2	2	4
Mechanical Engineers	2		2
Architects	2		2
Landscape Architects	2		2
Geologists	4		4
Structural Engineers	4		4
Chemists	2		2
Clerks/Stenos/Assistants/Secy's	12	3	15
Total	53	14	67

Mr. Stevens was very helpful in discussing and providing a copy of the Program Review and Analysis for SAD. This is a quarterly document which includes an analysis and interpretation of trends important to the division. The tables which follow indicate the design and construction workload within the Division and are adapted from this document. Table 5 shows the total military facilities under design within SAD as of 31 March 1989.

Table 5 – Military Facilities Under Design - SAD

District	Number	Amount
Mobile	313	924,298
MEAPO	75	259,384
Savannah	228	508,002
Charleston	11	38,243
Wilmington	34	23,454
Jacksonville	18	8,109
Total	679	1,761,490

Table 6 shows the construction workload withen SAD as of 31 March, 1989.

Table 6 – Construction Contracts - SAD

District	Number	Amount
Mobile	122	23,525,000
Winchester	6	51,509,000
Savannah	84	357,287,000
Charleston	4	23,525,000
Wilmington	19	36,082,000
Jacksonville	26	280,265,000
Total	261	1,032,634,000

Logistics Management Institute Reports

Several reports were requested from the Logistics Management Institute (LMI) at the suggestion of Pete Almquist, OCE. These reports were to be used in lieu of a visit to OCE. A total of four reports were received from LMI. All were interesting, but only one was felt to be relevant to the scope of the work task of this report. This relevant report is entitled *Monitoring and Controlling Engineering and Construction Management Cost Performance within the Corps of Engineers,* dated December, 1988. Although the focus of this report is the development of cost standards mor military and civil works programs, several surveys are included which may be of interest. These surveys relate to the distribution of design and construction effort. A panel of experts were assembled from USACE and their responses are summarized in Tables 7 and 8. Table 7 shows how the experts rated the expenditure of design effort on Military Construction projects. Table 8 shows how the experts rated the expenditure of construction management effort on Military Construction projects.

Table 7 – Expert Opinion Results - MILCON

Service	Percent of Total Engineering Cost
Predesign Services	4.5%
Preliminary/Concept Design	9.8%
Design Development	48.0%
Construction Documents	8.5%
Bidding/Negotiation Services	2.5%
Construction Period Services	26.6%
Total	100.0%

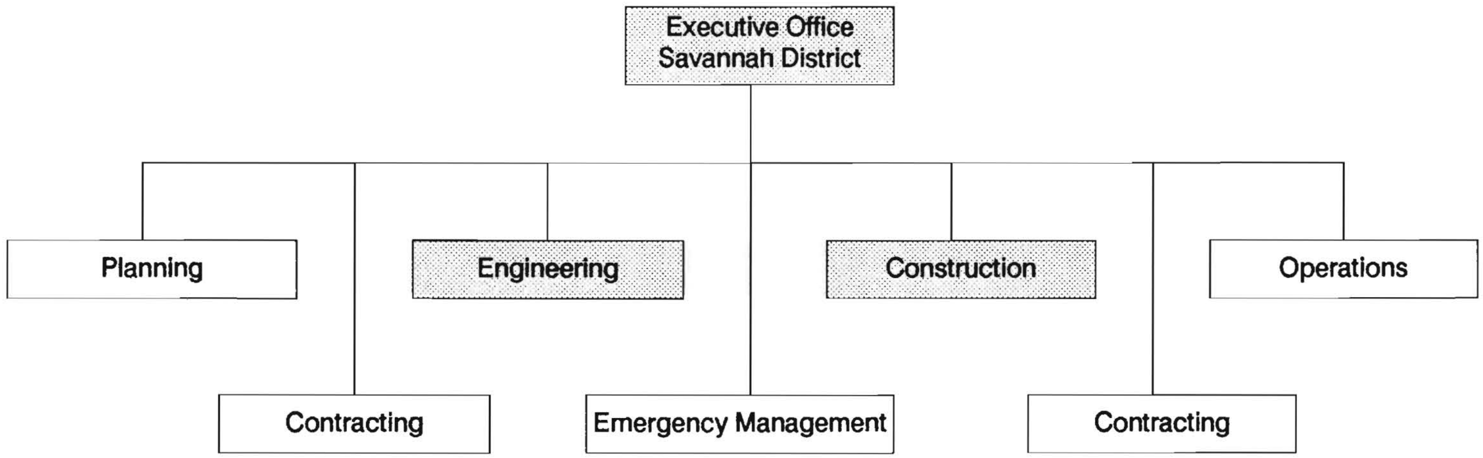
Table 8 – Expert Opinion Results - CM Effort

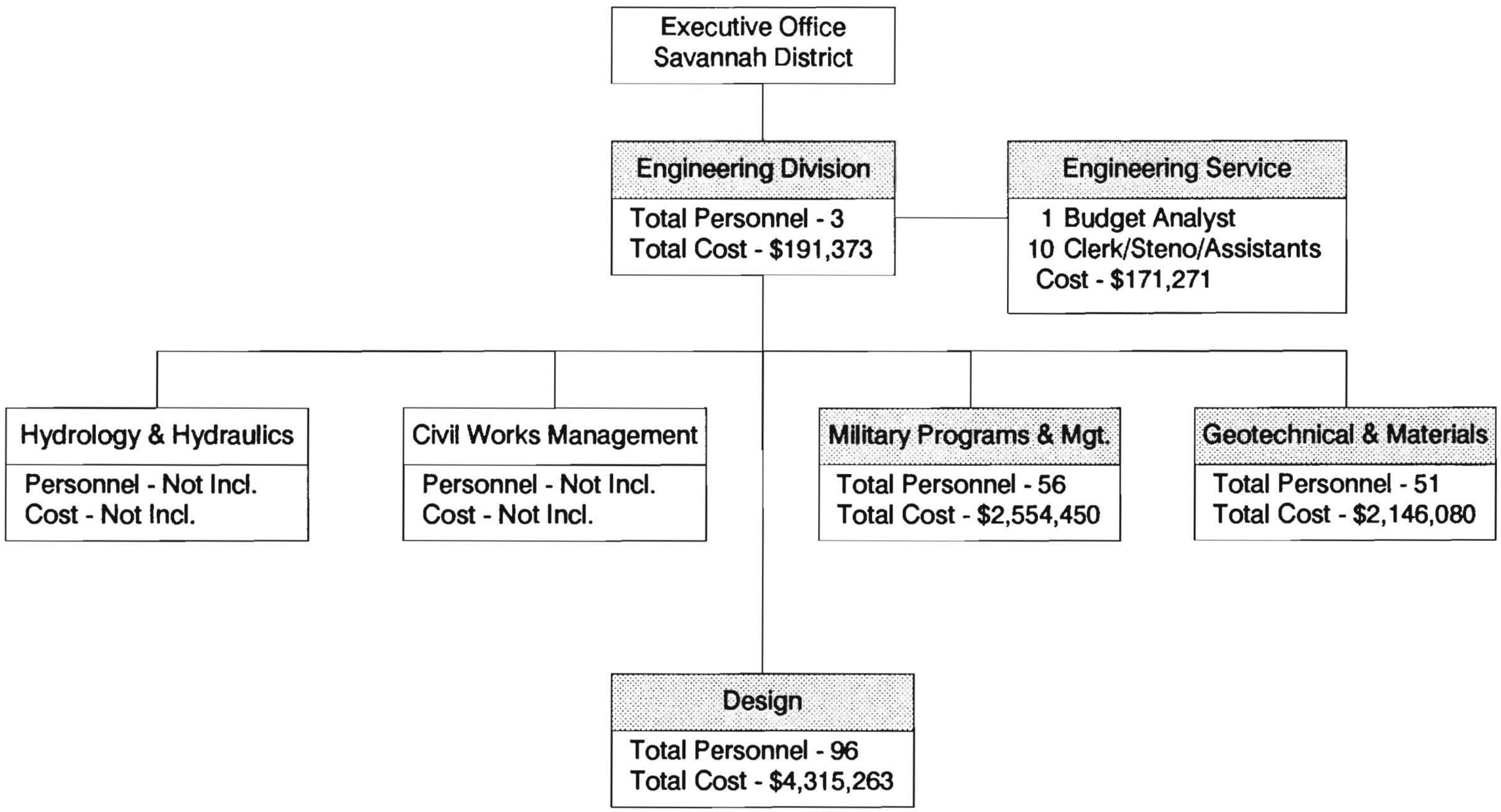
Service	Where CM Services are Performed				Percent of Construction Management Costs
	Office	District	Division	USACE	
Predesign	1.0%	95.0%	2.5%	1.5%	1.0%
Design and Bid Phase	4.0%	92.0%	3.0%	1.0%	4.6%
Construction Phase	76.0%	20.0%	2.0%	2.0%	75.6%
Additional	48.0%	49.0%	2.0%	1.0%	18.7%
				Total	100.0%

Summary

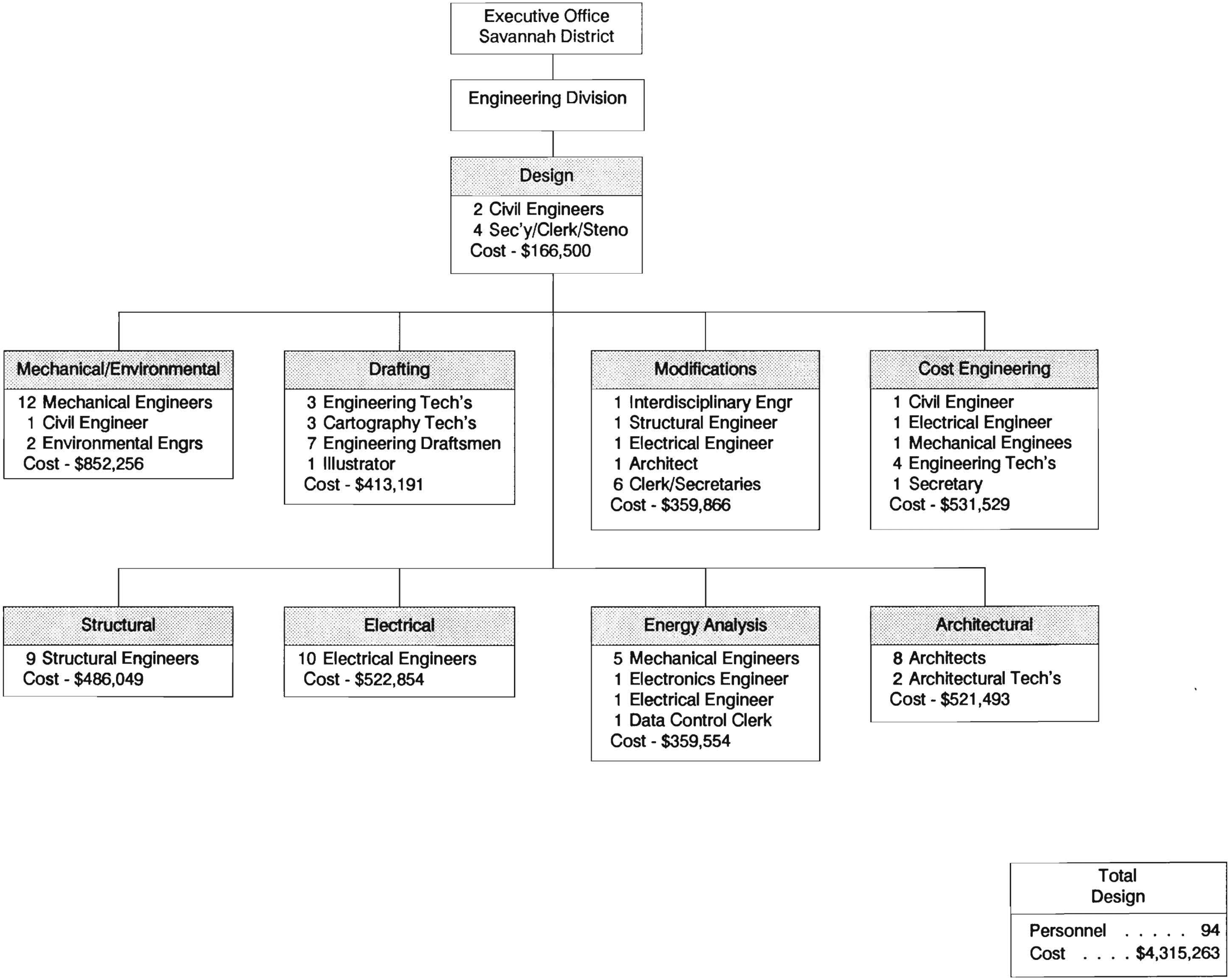
As these many tables indicate, there are numerous ways of looking at the design and construction effort within the Corps. It is noted that Districts and Divisions may not have a standardized format for analyzing the numbers. For example, the Savannah District and the South Atlantic Division do not always track the same set of numbers. This is not to suggest they need to track the same set, but rather that a large degree of caution must be used when drawing conclusions from the data.

Appendix A


Executive Office
Savannah District
Planning
Engineering
Construction
Operations
Contracting
Emergency Management
Contracting



Total Engineering	
Personnel	263
Cost . . .	$11,229,557


Executive Office
Savannah District
Engineering Division
Design
2 Civil Engineers
4 Sec'y/Clerk/Steno
Cost - $166,500
Mechanical/Environmental
12 Mechanical Engineers
1 Civil Engineer
2 Environmental Engrs
Cost - $852,256
Drafting
3 Engineering Tech's
3 Cartography Tech's
7 Engineering Draftsmen
1 Illustrator
Cost - $413,191
Modifications
1 Interdisciplinary Engr
1 Structural Engineer
1 Electrical Engineer
1 Architect
6 Clerk/Secretaries
Cost - $359,866
Cost Engineering
1 Civil Engineer
1 Electrical Engineer
1 Mechanical Enginees
4 Engineering Tech's
1 Secretary
Cost - $531,529
Structural
9 Structural Engineers
Cost - $486,049
Electrical
10 Electrical Engineers
Cost - $522,854
Energy Analysis
5 Mechanical Engineers
1 Electronics Engineer
1 Electrical Engineer
1 Data Control Clerk
Cost - $359,554
Architectural
8 Architects
2 Architectural Tech's
Cost - $521,493
Total
Design
Personnel 94
Cost $4,315,263

Executive Office
Savannah District

Military Program & Management Branch
- 3 Civil Engineers
- 1 Electrical Engineer
- 1 Steno
- Cost - $264,961

A/E Contracts
- 1 Civil Engineer
- 2 Architects
- 1 Contract Negotiator
- 1 Procurement Clerk
- Cost - $285,048

Program Management
- 1 Civil Engineer
- 1 Program Analyst
- 1 Budget Assistant
- 1 Status Clerk
- Cost - $223,079

AF & Special Projects
- 6 Civil Engineers
- 1 Mechanical Engineer
- 2 Steno/Secretaries
- Cost - $410,048

Installation Support
- 4 Civil Engineer
- 1 Steno
- Cost - $243,520

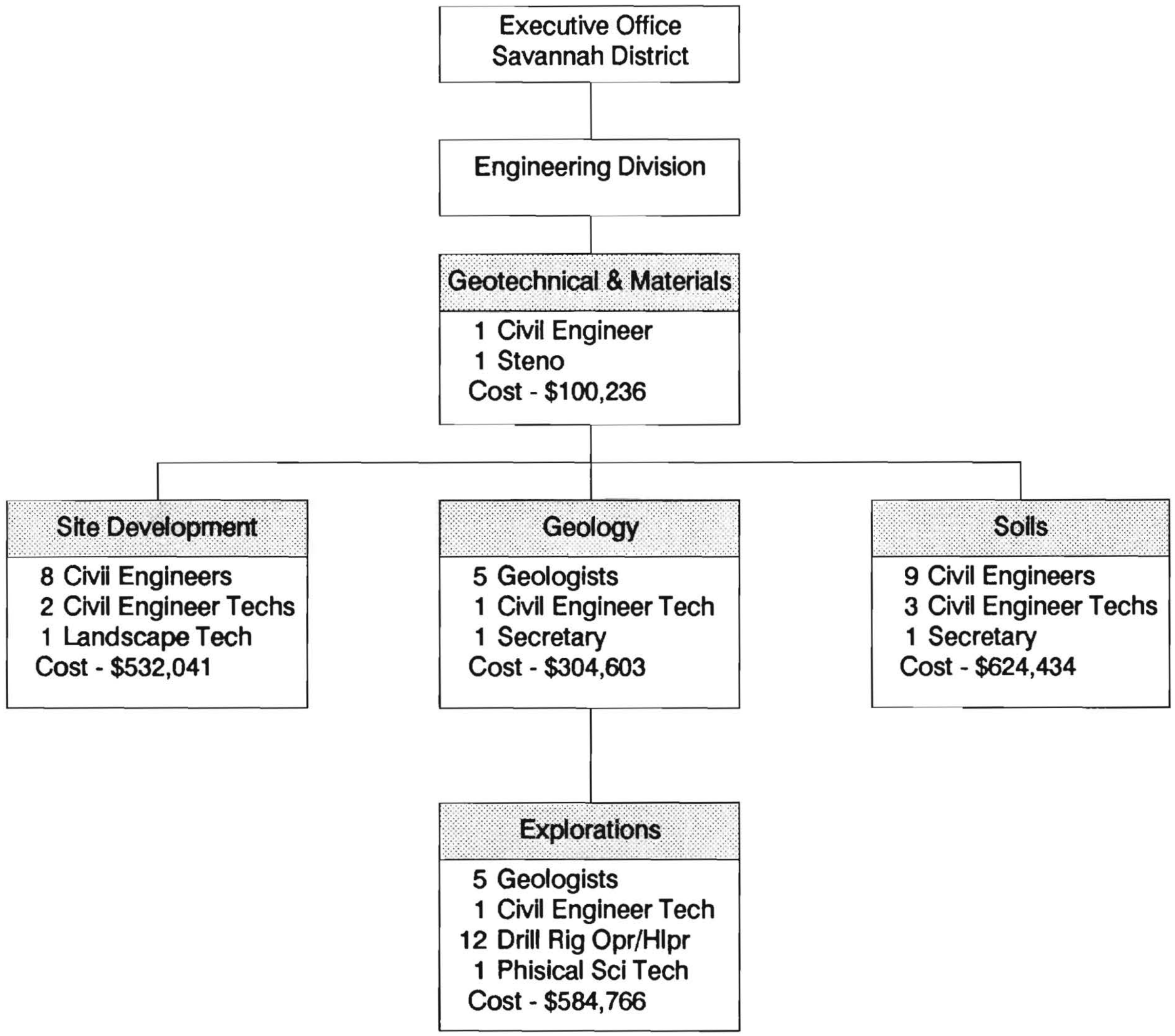
A/E Claims & Liability
- 1 Architect
- 1 Mechanical Engineer
- 1 Secretary
- Cost - $128,598

Military Planning
- 3 Civil Engineers
- 1 Architect
- 2 Landscape Architects
- 1 Community Planner
- 2 Cartography Tech's
- 2 Clerk/Steno's
- Cost - $499,058

Army Projects
- 5 Civil Engineers
- 1 Architect
- 1 Electrical Engineer
- 1 Mechanical Engineer
- 2 Clerk/Steno's
- Cost - $490,138

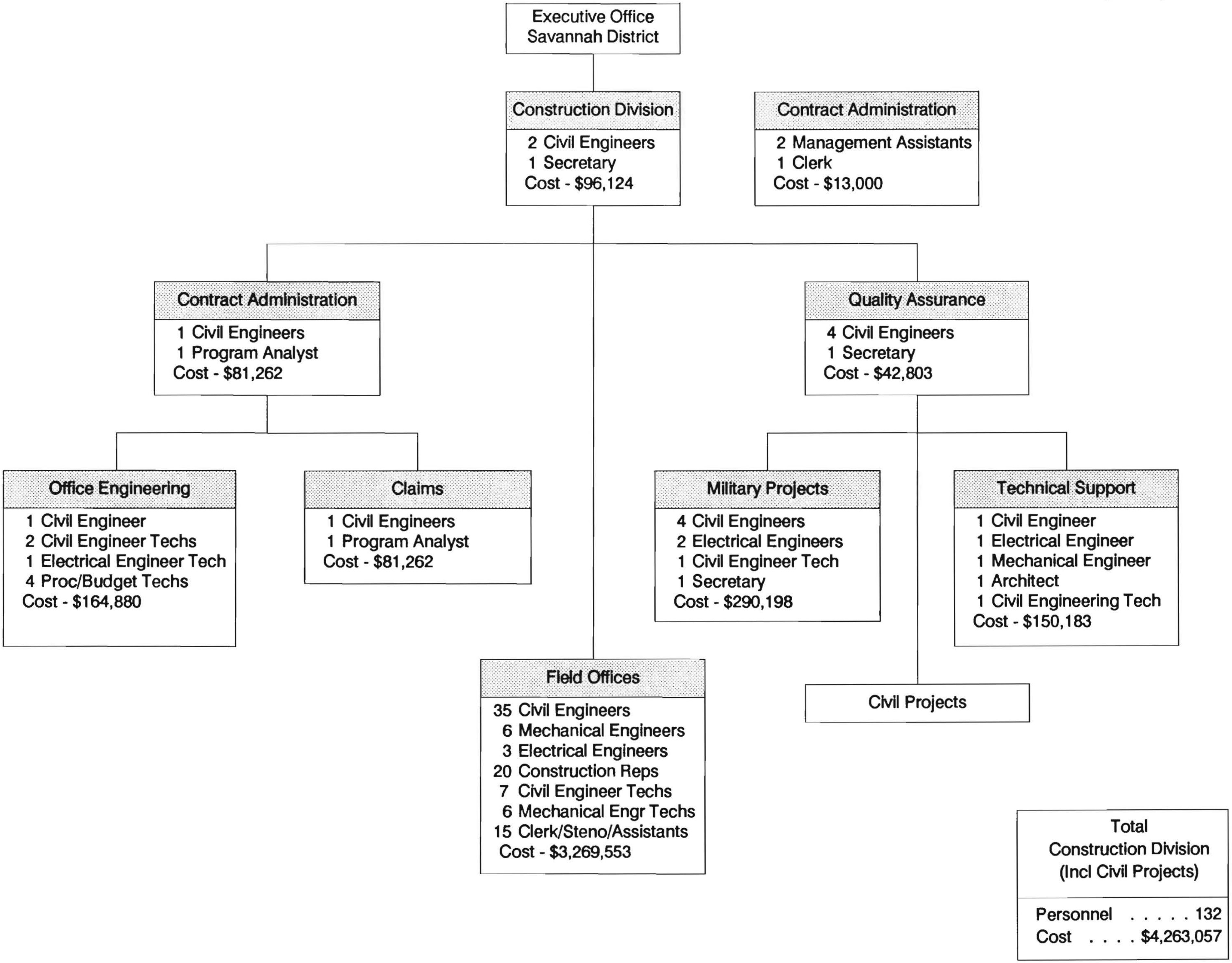
Total
Military Program & Mgt.

Personnel 56
Cost $2,554,450

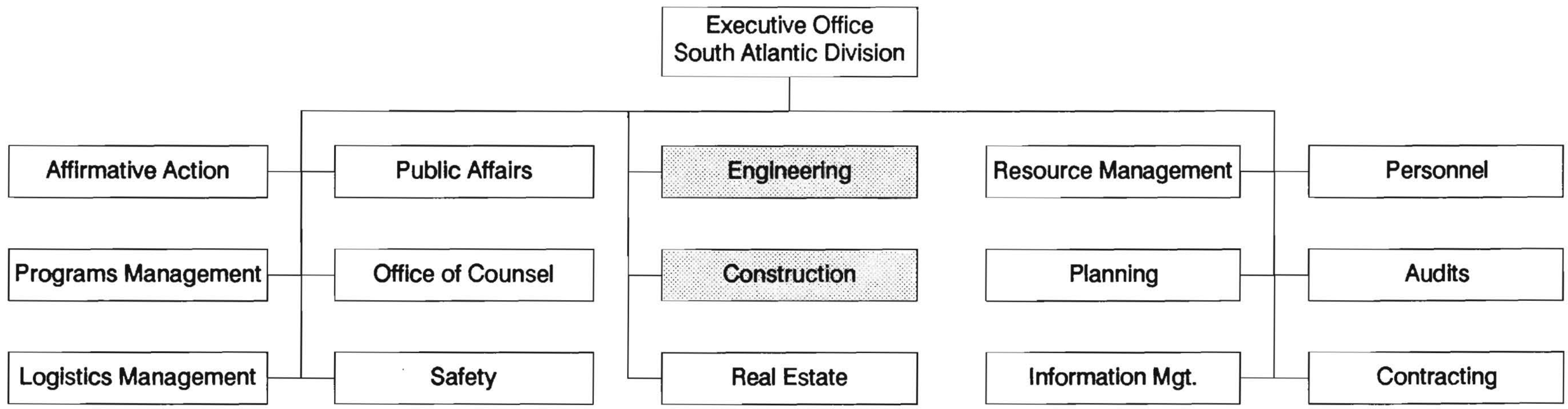


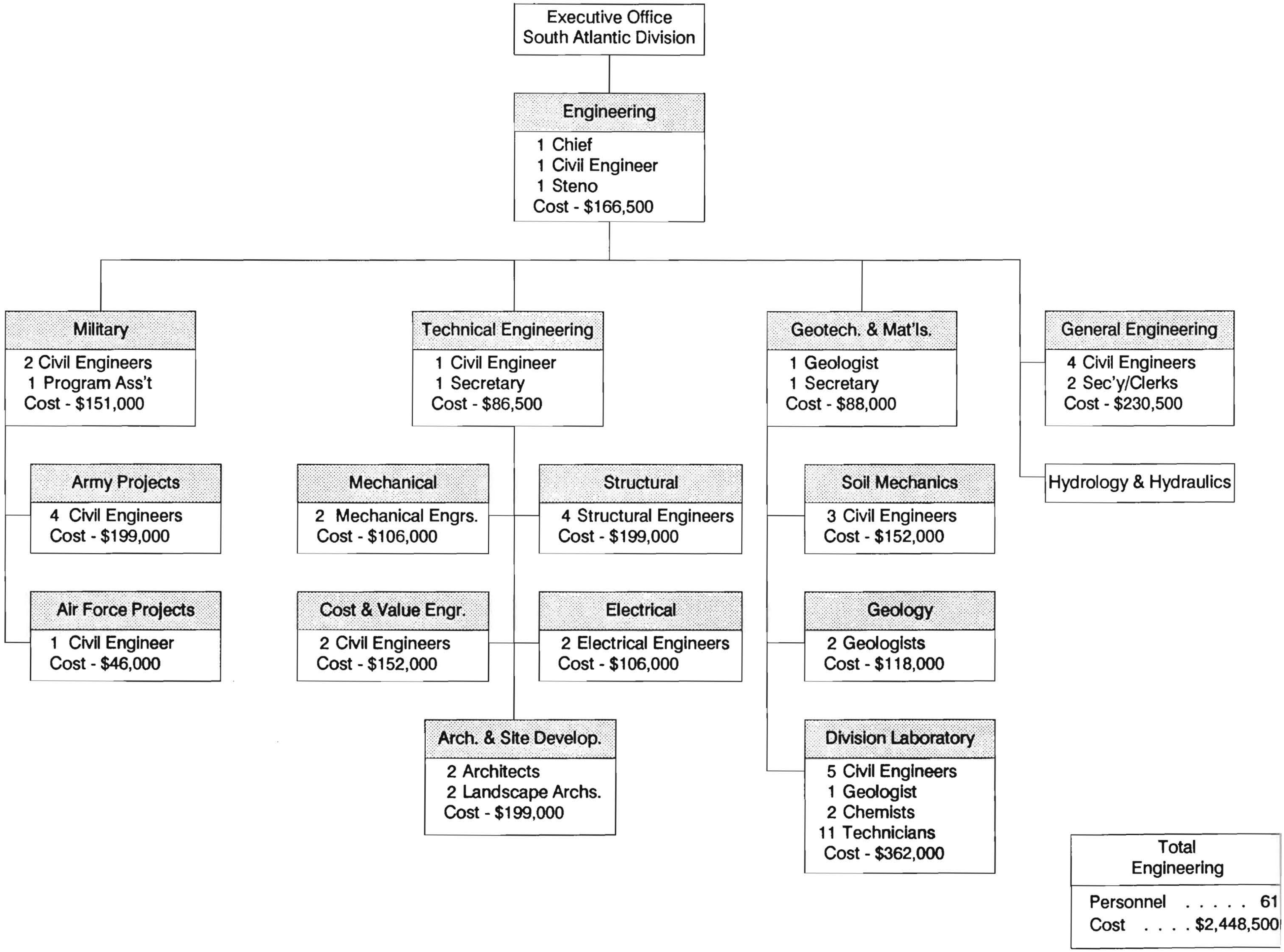
Total
Geotechnical & Materials

Personnel 51
Cost $2,146,080

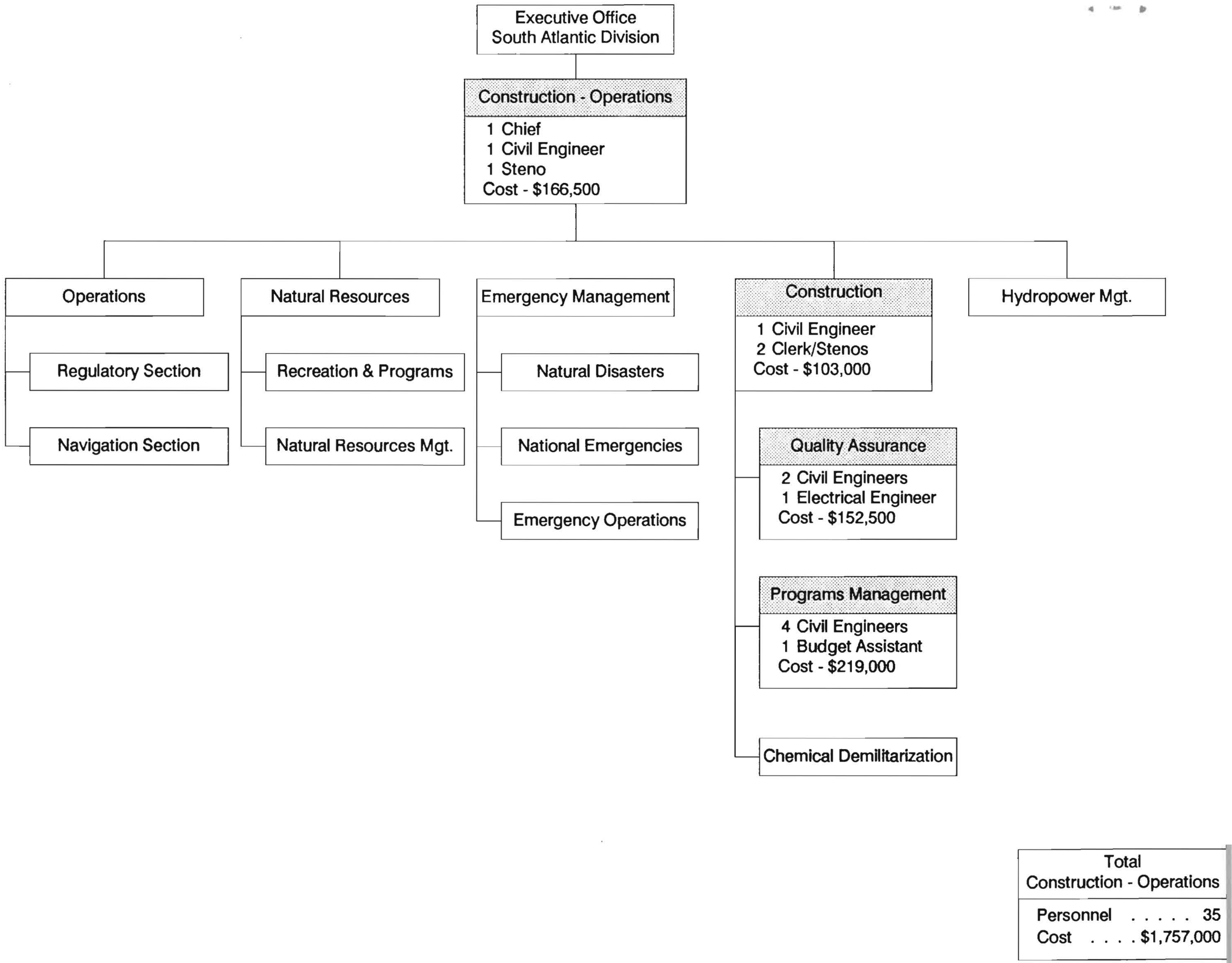

Executive Office
Savannah District
Construction Division
2 Civil Engineers
1 Secretary
Cost - $96,124
Contract Administration
2 Management Assistants
1 Clerk
Cost - $13,000
Contract Administration
1 Civil Engineers
1 Program Analyst
Cost - $81,262
Quality Assurance
4 Civil Engineers
1 Secretary
Cost - $42,803
Office Engineering
1 Civil Engineer
2 Civil Engineer Techs
1 Electrical Engineer Tech
4 Proc/Budget Techs
Cost - $164,880
Claims
1 Civil Engineers
1 Program Analyst
Cost - $81,262
Military Projects
4 Civil Engineers
2 Electrical Engineers
1 Civil Engineer Tech
1 Secretary
Cost - $290,198
Technical Support
1 Civil Engineer
1 Electrical Engineer
1 Mechanical Engineer
1 Architect
1 Civil Engineering Tech
Cost - $150,183
Field Offices
35 Civil Engineers
6 Mechanical Engineers
3 Electrical Engineers
20 Construction Reps
7 Civil Engineer Techs
6 Mechanical Engr Techs
15 Clerk/Steno/Assistants
Cost - $3,269,553
Civil Projects
Total
Construction Division
(Incl Civil Projects)
Personnel 132
Cost $4,263,057

Appendix B


Executive Office
South Atlantic Division
Affirmative Action
Programs Management
Logistics Management
Public Affairs
Office of Counsel
Safety
Engineering
Construction
Real Estate
Resource Management
Planning
Information Mgt.
Personnel
Audits
Contracting



Executive Office
South Atlantic Division
Engineering
1 Chief
1 Civil Engineer
1 Steno
Cost - $166,500
Military
2 Civil Engineers
1 Program Ass't
Cost - $151,000
Army Projects
4 Civil Engineers
Cost - $199,000
Air Force Projects
1 Civil Engineer
Cost - $46,000
Technical Engineering
1 Civil Engineer
1 Secretary
Cost - $86,500
Mechanical
2 Mechanical Engrs.
Cost - $106,000
Structural
4 Structural Engineers
Cost - $199,000
Cost & Value Engr.
2 Civil Engineers
Cost - $152,000
Electrical
2 Electrical Engineers
Cost - $106,000
Arch. & Site Develop.
2 Architects
2 Landscape Archs.
Cost - $199,000
Geotech. & Mat'ls.
1 Geologist
1 Secretary
Cost - $88,000
Soil Mechanics
3 Civil Engineers
Cost - $152,000
Geology
2 Geologists
Cost - $118,000
Division Laboratory
5 Civil Engineers
1 Geologist
2 Chemists
11 Technicians
Cost - $362,000
General Engineering
4 Civil Engineers
2 Sec'y/Clerks
Cost - $230,500
Hydrology & Hydraulics
Total Engineering
Personnel 61
Cost $2,448,500


Executive Office
South Atlantic Division
Construction - Operations
1 Chief
1 Civil Engineer
1 Steno
Cost - $166,500
Operations
Regulatory Section
Navigation Section
Natural Resources
Recreation & Programs
Natural Resources Mgt.
Emergency Management
Natural Disasters
National Emergencies
Emergency Operations
Construction
1 Civil Engineer
2 Clerk/Stenos
Cost - $103,000
Quality Assurance
2 Civil Engineers
1 Electrical Engineer
Cost - $152,500
Programs Management
4 Civil Engineers
1 Budget Assistant
Cost - $219,000
Chemical Demilitarization
Hydropower Mgt.
Total
Construction - Operations
Personnel 35
Cost $1,757,000

BASE SUPPORT RDT&E INVESTMENT STRATEGY

Report on Task 4 (Modified)

Prepared Under Contract
DACA88-88-D-0020/6

Submitted to:

Department of the Army
Facilities Systems Division
CONSTRUCTION ENGINEERING RESEARCH LABORATORY
Champaign, Illinois

Prepared December 27, 1989
by:

Leland S. Riggs

School of Civil Engineering
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Atlanta, Georgia 30332

Introduction

This is the final report of a research project entitled "Base Support RDT&E Investment Strategy." The project consists of four tasks. Tasks 1, 2 and 3 were delivered previously. Task 4 expands the work of Task 1 which was to gather information on certain U.S. Army Corps of Engineers offices engaged in the design and management of military construction. Specifically, the number, type, activities, and cost of personnel was to be collected. Additionally, information was to be collected on the number of contractors engaged in the design and construction of military facilities.

The scope of this final report is Task 4 of above referenced project. Task 1 covered Savannah District, South Atlantic Division and telephone interviews with HQUSACE. This report covers visits to Mobile and Sacramento Districts. Task 4 also includes the development of plan for a detailed follow-on cost study. This follow-on plan is provided under separate cover.

Districts Visited

On April 25, 1989, I visited the Savannah District along with Mike Golish of CERL. Personnel contacted during this visit include:

Bill Smith	Chief, Military Program and Management Branch
Tommy Blewett	Design Control Engineer
Ben Harrison	Chief Architectural Section
Jack Bartholet	Chief, Military Projects Section
Tom Weathers	Chief, Technical Support Section
Frank Mills	Assistant Chief, Construction Division
Gloria Gray	Program Analyst, Construction Division

On November 27, 1989, I visited Mobile District. Personnel contacted were

J. R. Couey	Chief, Engineering Division
Larry Mathews	Assistant Chief, Construction Division

On December 1, 1989, I visited Sacramento District. Personnel contacted were

Tom Nissen	Assistant Chief, Military Projects
Donald Dennis	Chief, Construction Division
Gene Shy	Chief, Contract Administration
Mike Sabine	Chief, Program and Reports

Summary Charts

This section also includes data from Task 1 for ease of comparison. Tables 1 and 2 below are summaries of the engineering and design personnel at all three district offices visited. The cost of these personnel is included at the bottom of these tables. Appendices A, B, and C provide detailed information on the organizational structure and personnel cost of these three district offices. Several comments are in order when reviewing Tables 1 and 2.

The first comment is that the costs shown are base salaries only. These base salaries should be multiplied by a factor to account for other personnel, indirect, and overhead costs. The formula for the multiplier is generally accepted to be

$$\text{Factor} = (\text{Base Salaries} * 1.42) * (1 + \text{Indirects} + \text{Overhead})$$

For the three districts visited this factor was observed to range from 2.28 to 2.90. Differences between districts depend on what they choose to include in indirect and overhead costs. There are even differences within districts when comparing design with construction costs. There was, however, general agreement regarding the factor of 1.42 for personnel costs.

The other comment is that, from time to time, personnel are assigned from military to civil work and therefore the personnel and costs shown in Tables 1 and 2 will fluctuate somewhat. Nonetheless, as orders of magnitude, the numbers are felt to be representative.

It is noted in Table 1 that Mobile has a large number of exploratory personnel whereas the other two districts have none. This is because Mobile supports all the other districts whenever significant drilling type work is needed. Also, it would appear in Table 1 that Sacramento has a rather large number of engineering personnel compared to the other two districts. The reason is Sacramento does all the design work for the South Pacific division.

In Table 2, the reason for the relatively large number of construction personnel at Sacramento is that the construction responsibilities for the South Pacific Division are shared between Los Angeles and Sacramento.

Table 1. – Number & Type Engineering Personnel

Type	Savannah	Mobile	Sacramento
Civil Engineers	51	63	81
Electrical Engineers	16	30	17
Mechanical Engineers	21	30	27
Architects	14	15	28
Landscape Architects	2	1	
Geologists	10	9	10
Structural Engineers	10	16	25
Environmental Engineers	2	7	3
Program Analysts	2	3	4
Interdisciplinary Engineers	1	1	
Materials Engineers			1
Contract Negotiators	1		
Community Planners	1		
Interior Designers			2
Surveyors			1
Exploratory Personnel		46	
Engineering Draftsmen		7	20
Technicians	42	43	74
Clerks/Stenos/Assistants/Secy's	41	30	44
Student Trainees		12	
Total Personnel	214	313	337
Total Cost	$9,342,437	$10,997,429	$15,007,064

Table 2. – Number & Type Construction Personnel

Type	Savannah	Mobile	Sacramento
Military Officers		3	3
Civil Engineers	46	55	70
Electrical Engineers	6	11	10
Mechanical Engineers	7	12	15
Architects	1		
Materials Engineers			1
Structural Engineers			3
Environmental Engineers			3
Program Analysts	2		5
Construction Representatives	20	35	25
Procurement Specialists			2
Technicians	26	5	30
Clerks/Stenos/Assistants/Secy's	20	31	35
Student Trainees		5	7
Total Personnel	128	160	211
Total Cost	$4,330,629	$5,645,053	$7,056,442

Tables 3 and 4 below show the number of design and construction contracts at each of the districts visited. Design information on Sacramento was not available in time for this report. As this information is received it will be forwarded as an addendum.

Table 3. – Design Effort

Type	Number	Amount	A/E	In-House
Savannah	228	$508,002,000	48%	52%
Mobile	313	$924,298,000	82%	18%
Sacramento				

Table 4. – Construction Effort

Type	Number	Amount
Savannah	84	$357,387,000
Mobile	122	$283,966,000
Sacramento	115	$148,782,244

Several topics included in the report for Task 1 are felt to be worthy of repeating. As noted previously, a recurring topic during our discussions at Savannah was the comparison between in-house design effort by the Corps and A/E design effort. Table 5[1] is adapted from a study conducted by the Savannah District and shows the relative percentages of construction, design, and overhead related to total project funds. It was noted in the report for Task 4 that the percent for design is somewhat higher than a figure of 6.9% carried by the South Atlantic Division for the Savannah District. Data from the South Atlantic Division shows the percentages for design in the 6% – 8% range for all their districts. However, the people at Savannah believe their analysis, which is based on COEMIS data, is an accurate depiction of the level of effort.

1 Tables 5 and 6 are repeated from the previous report.

Table 5.– Distribution of Project Funds in Percent
Savannah District

Savannah District	A/E	In-House
Construction Contractor	74.64	75.67
Construction Division		
Supervision and Inspection	5.50	5.50
Contingencies	5.00	5.00
Subtotal	10.50	10.50
Design		
Engineering & Design (Direct Construction)	0.50	0.50
Design Branch	2.24	6.19
Military Branch	1.30	1.00
Geotechnical Branch	1.29	1.74
Architectural/Engineering	7.90	1.02
Subtotal	13.23	10.45
Overhead		
Engineering Division	0.15	0.31
District	0.74	1.28
Travel	0.14	0.04
Reproduction	0.28	0.48
Miscellaneous	0.32	1.27
Subtotal	1.63	3.38
Total	100.00	100.00

Table 6 is again presented which shows the source and distribution of design funds for the Savannah District.

Table 6. – Source and Distribution of Design Funds
Savannah District

Source	Distribution		
Design Funds	In-House		A/E
In-house design	4,255,335		
In-house support of A/E work		3,480,500	
A/E contract cost			6,162,761
In-house design	1,115,147		
In-house support of A/E work		1,752,147	
A/E contract cost			6,018,713
In-house design	634,703		
In-house support of A/E work		949,547	
A/E contract cost			4,133,946
Totals	6,005,185	6,182,194	16,315,420

South Atlantic Division

I visited the headquarters of the South Atlantic Division on September 19, 1989. The following personnel were contacted:

Benny Stevens	Chief, Construction Branch
Cathy Gardner	Computer Programmer Analyst

Table 7 below shows the number and type personnel at South Atlantic Division engaged in the engineering and construction process. This table as well as Tables 8 and 9 were included in the previous report for Task 1. Appendix D is a detailed organizational listing of the engineering and construction personnel for South Atlantic Division.

Table 7. – Number & Type Personnel, SAD

Type	Engineering	Construction	Total
Chief	1		
Civil Engineers	22	9	31
Electrical Engineers	2	2	4
Mechanical Engineers	2		2
Architects	2		2
Landscape Architects	2		2
Geologists	4		4
Structural Engineers	4		4
Chemists	2		2
Clerks/Stenos/Assistants/Secy's	12	3	15
Total	53	14	67

Tables 8 and 9 were extracted from a document titled "Program Review and Analysis - South Atlantic Division." This is a quarterly document which includes an analysis and interpretation of trends important to the division. Table 8 shows the total military facilities under design within SAD as of 31 March 1989. Table 9 shows the construction workload within SAD as of 31 March, 1989.

Table 8. – Military Facilities Under Design - SAD

District	Number	Amount
Mobile	313	924,298,000
MEAPO	75	259,384,000
Savannah	228	508,002,000
Charleston	11	38,243,000
Wilmington	34	23,454,000
Jacksonville	18	8,109,000
Total	679	1,761,490

Table 9. – Construction Contracts - SAD

District	Number	Amount
Mobile	122	283,966,000
Winchester	6	51,509,000
Savannah	84	357,287,000
Charleston	4	23,525,000
Wilmington	19	36,082,000
Jacksonville	26	280,265,000
Total	261	1,032,634,000

Logistics Management Institute Reports

Tables 10 and 11 were included in the report for Task 1, but they are also interesting in the context of this report. These tables were taken from a Logistics Management Institute report entitled "Monitoring and Controlling Engineering and Construction Management Cost Performance within the Corps of Engineers," dated December, 1988. A panel of experts were assembled from USACE and their responses were summarized in the LMI report. Table 10 shows how the experts rated the expenditure of design effort on Military Construction projects. Table 11 shows how the experts rated the expenditure of construction management effort on Military Construction projects. The information in these tables is useful when examining the information from the three districts covered in this report.

Table 10 – Expert Opinion Results - MILCON

Service	Percent of Total Engineering Cost
Predesign Services	4.5%
Preliminary/Concept Design	9.8%
Design Development	48.0%
Construction Documents	8.5%
Bidding/Negotiation Services	2.5%
Construction Period Services	26.6%
Total	100.0%

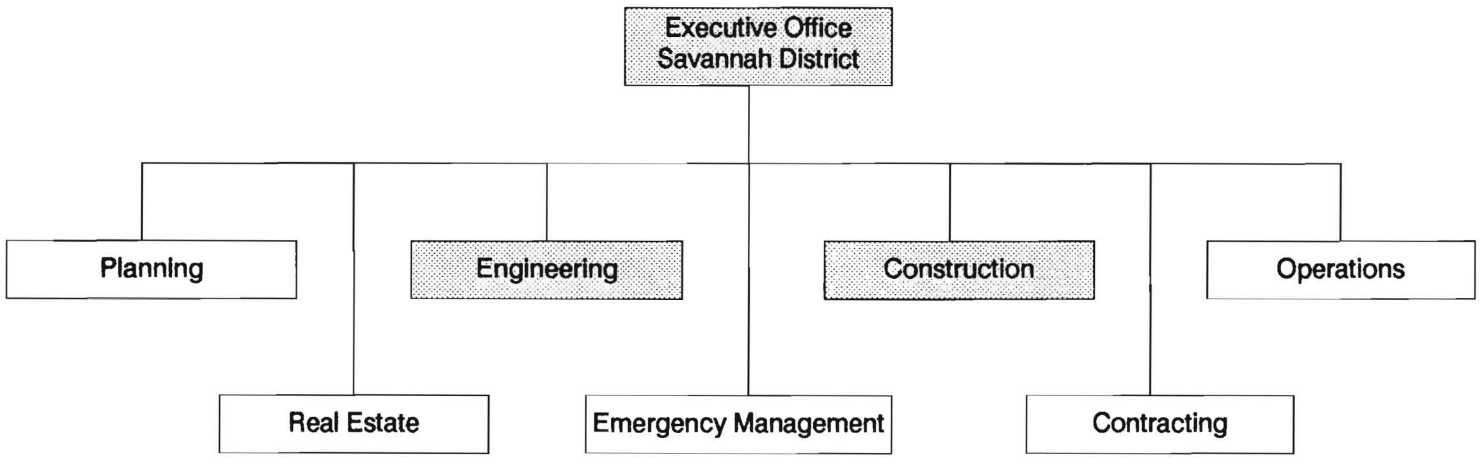
Table 11 – Expert Opinion Results - CM Effort

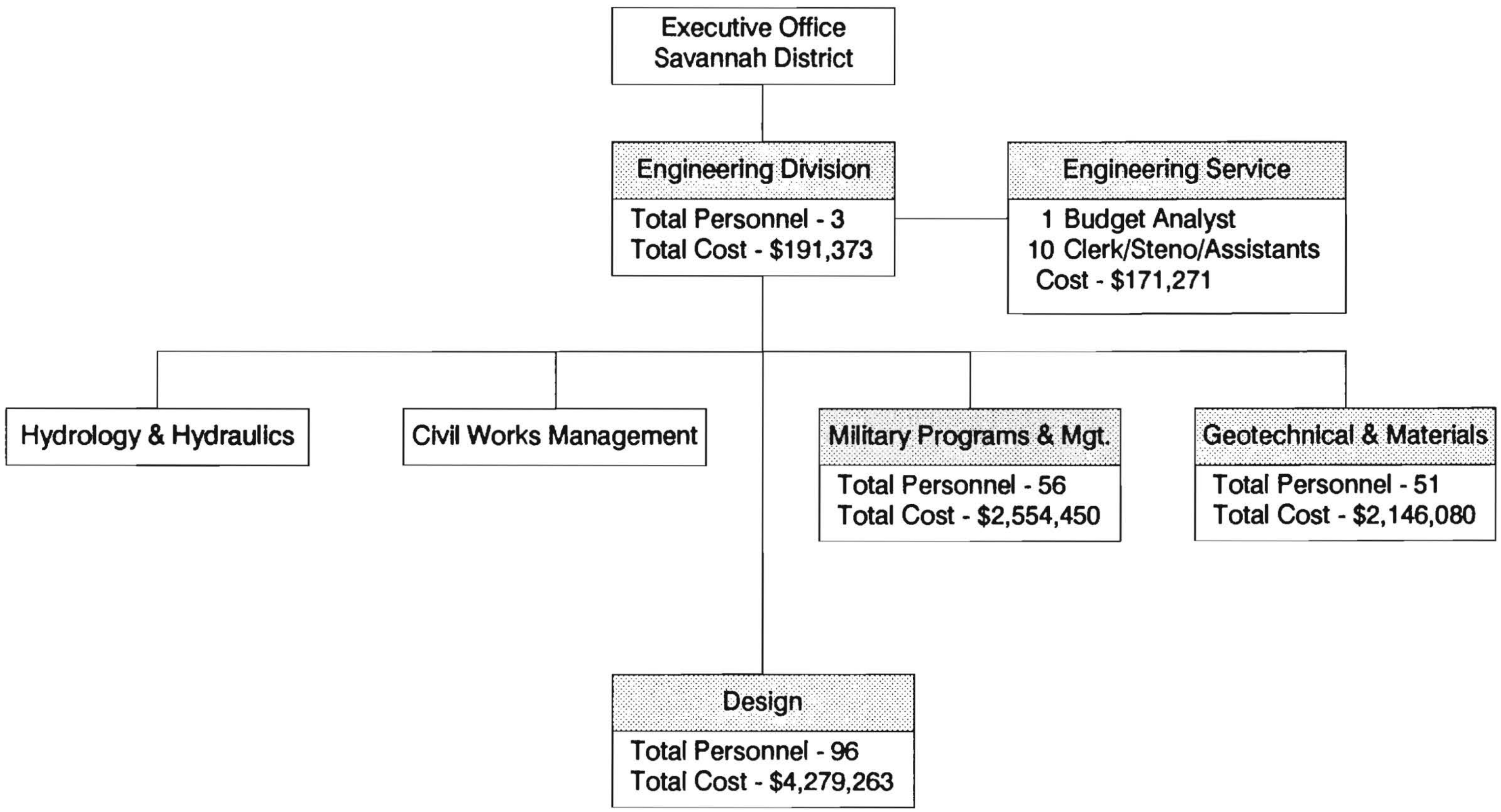
	Where CM Services are Performed				Percent of Construction Management Costs
Service	Office	District	Division	USACE	
Predesign	1.0%	95.0%	2.5%	1.5%	1.0%
Design and Bid Phase	4.0%	92.0%	3.0%	1.0%	4.6%
Construction Phase	76.0%	20.0%	2.0%	2.0%	75.6%
Additional	48.0%	49.0%	2.0%	1.0%	18.7%
				Total	100.0%

Summary

There has been no attempt to draw any major conclusions in this report because the effort was essentially one of data collection. However, it is again noted, as in the previous report, the various divisions use considerably different overhead and indirect rates. Additionally, the missions of the districts visited are somewhat different. Therefore, direct comparisons of the personnel numbers in this report could be misleading without taking the individual mission into account.

Appendix A
Savannah District


Executive Office
Savannah District
Planning
Engineering
Construction
Operations
Real Estate
Emergency Management
Contracting



Total Engineering (Incl Civil)

Personnel 263
Cost . . . $11,183,557

- **Executive Office Savannah District**
  - **Engineering Division**
    - **Design**
      - 2 Civil Engineers
      - 4 Sec'y/Clerk/Steno
      - Cost - $232,471

Mechanical/Environmental
- 12 Mechanical Engineers
- 1 Civil Engineer
- 2 Environmental Engrs
- Cost - $852,256

Drafting
- 3 Engineering Tech's
- 3 Cartography Tech's
- 7 Engineering Draftsmen
- 1 Illustrator
- Cost - $413,191

Modifications
- 1 Interdisciplinary Engr
- 1 Structural Engineer
- 1 Electrical Engineer
- 1 Architect
- 6 Clerk/Secretaries
- Cost - $359,866

Cost Engineering
- 1 Civil Engineer
- 1 Electrical Engineer
- 1 Mechanical Engineer
- 4 Engineering Tech's
- 1 Secretary
- Cost - $531,529

Structural
- 9 Structural Engineers
- Cost - $486,049

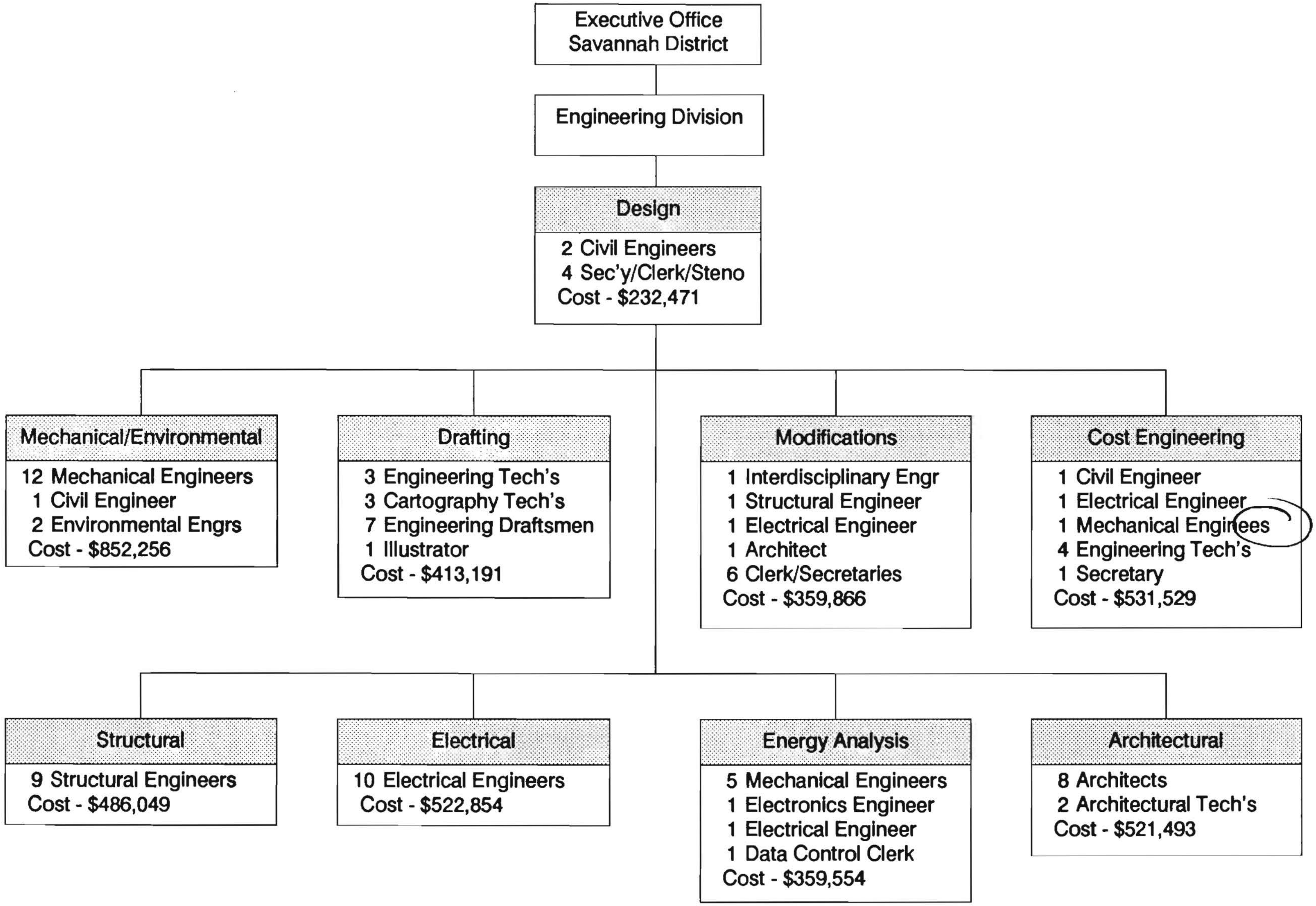
Electrical
- 10 Electrical Engineers
- Cost - $522,854

Energy Analysis
- 5 Mechanical Engineers
- 1 Electronics Engineer
- 1 Electrical Engineer
- 1 Data Control Clerk
- Cost - $359,554

Architectural
- 8 Architects
- 2 Architectural Tech's
- Cost - $521,493

Total Design

Personnel 94
Cost $4,279,263



Total Design	
Personnel	94
Cost	$4,279,263

Executive Office
Savannah District

- **Military Program & Management Branch**
  - 3 Civil Engineers
  - 1 Electrical Engineer
  - 1 Steno
  - Cost - $264,961

  - **A/E Contracts**
    - 1 Civil Engineer
    - 2 Architects
    - 1 Contract Negotiator
    - 1 Procurement Clerk
    - Cost - $285,048

  - **Program Management**
    - 1 Civil Engineer
    - 1 Program Analyst
    - 1 Budget Assistant
    - 1 Status Clerk
    - Cost - $223,079

  - **AF & Special Projects**
    - 6 Civil Engineers
    - 1 Mechanical Engineer
    - 2 Steno/Secretaries
    - Cost - $410,048

  - **Installation Support**
    - 4 Civil Engineer
    - 1 Steno
    - Cost - $243,520

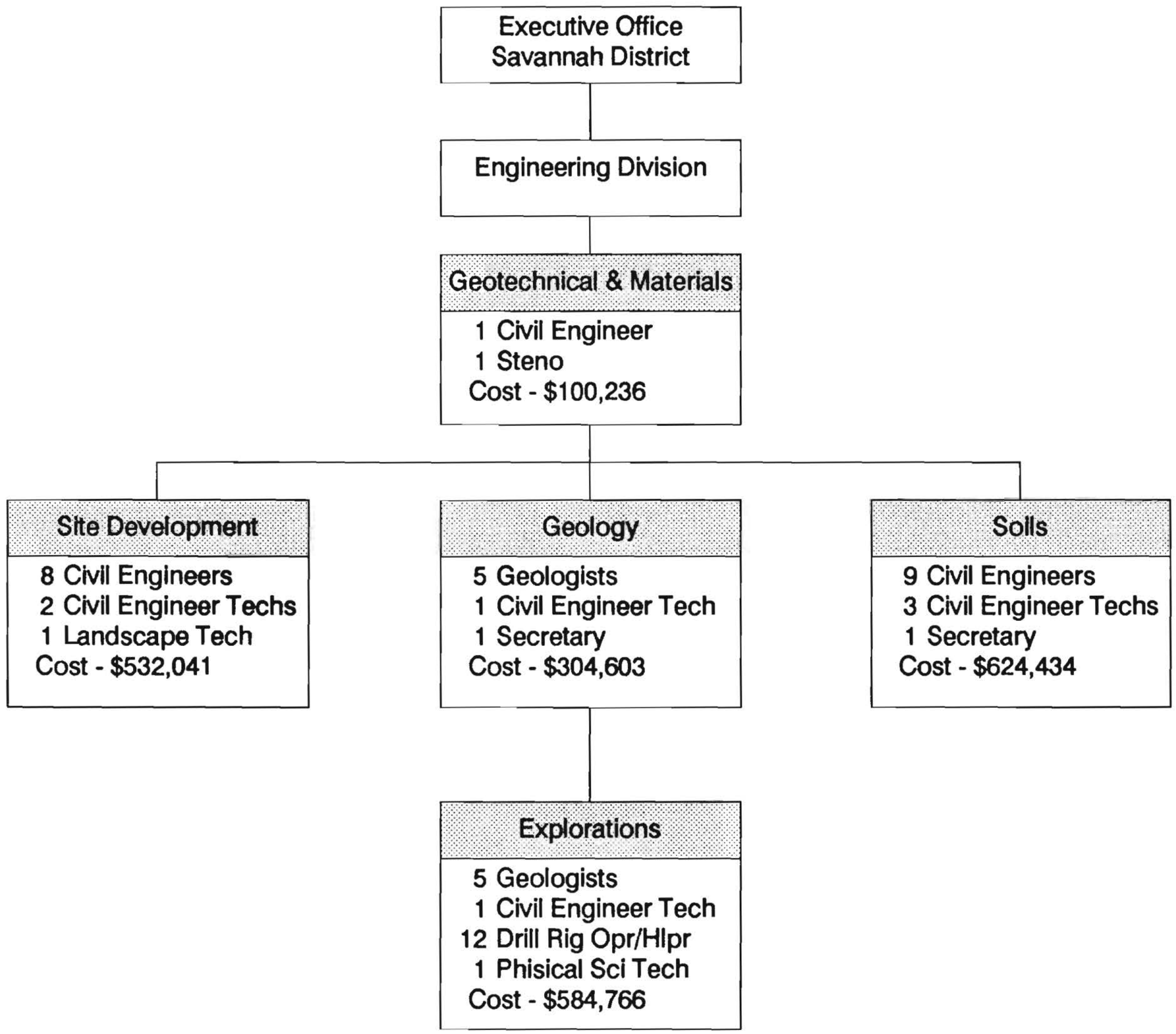
    - **A/E Claims & Liability**
      - 1 Architect
      - 1 Mechanical Engineer
      - 1 Secretary
      - Cost - $128,598

  - **Military Planning**
    - 3 Civil Engineers
    - 1 Architect
    - 2 Landscape Architects
    - 1 Community Planner
    - 2 Cartography Tech's
    - 2 Clerk/Steno's
    - Cost - $499,058

  - **Army Projects**
    - 5 Civil Engineers
    - 1 Architect
    - 1 Electrical Engineer
    - 1 Mechanical Engineer
    - 2 Clerk/Steno's
    - Cost - $490,138

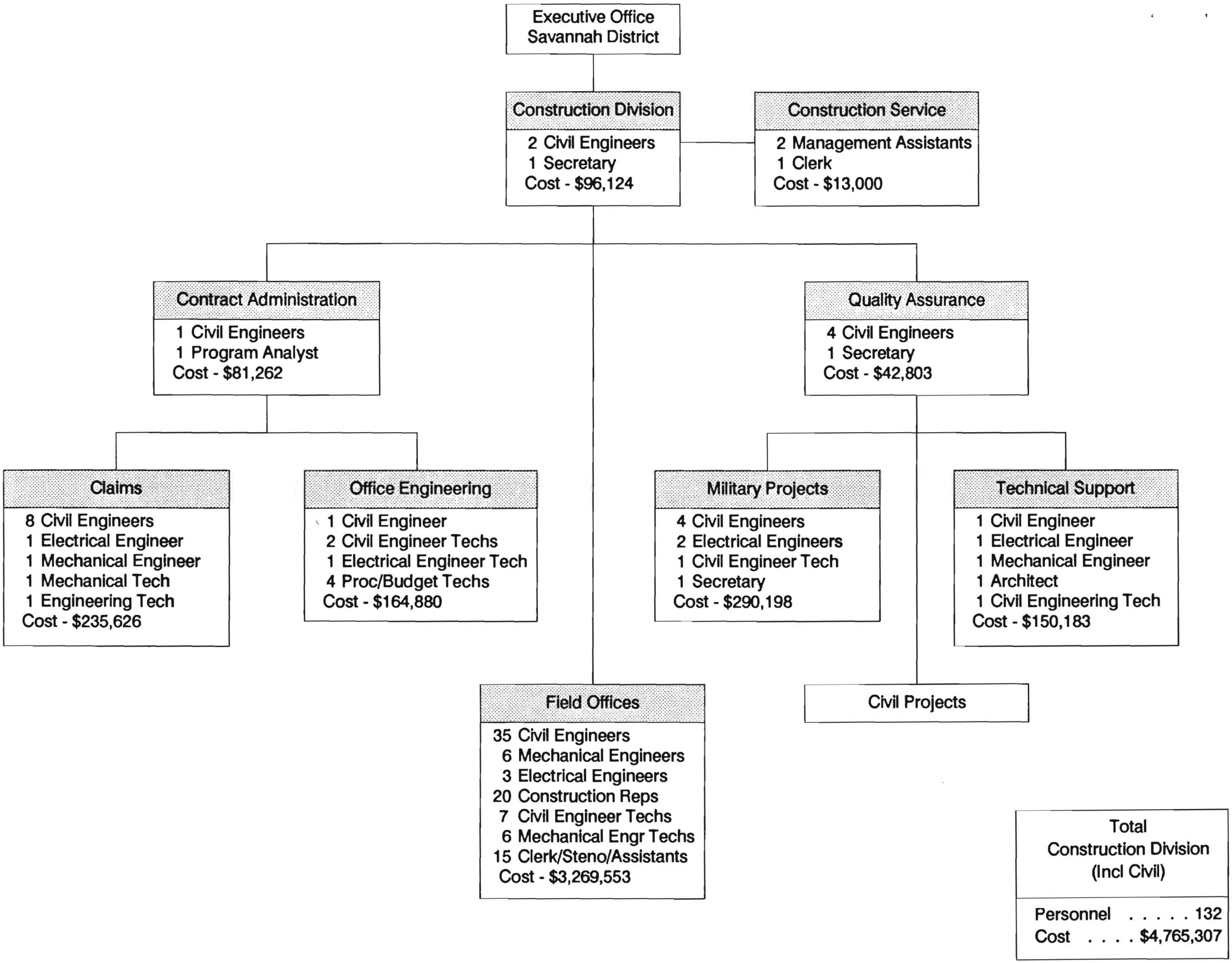
Total
Military Program & Mgt.

Personnel 56
Cost $2,554,450



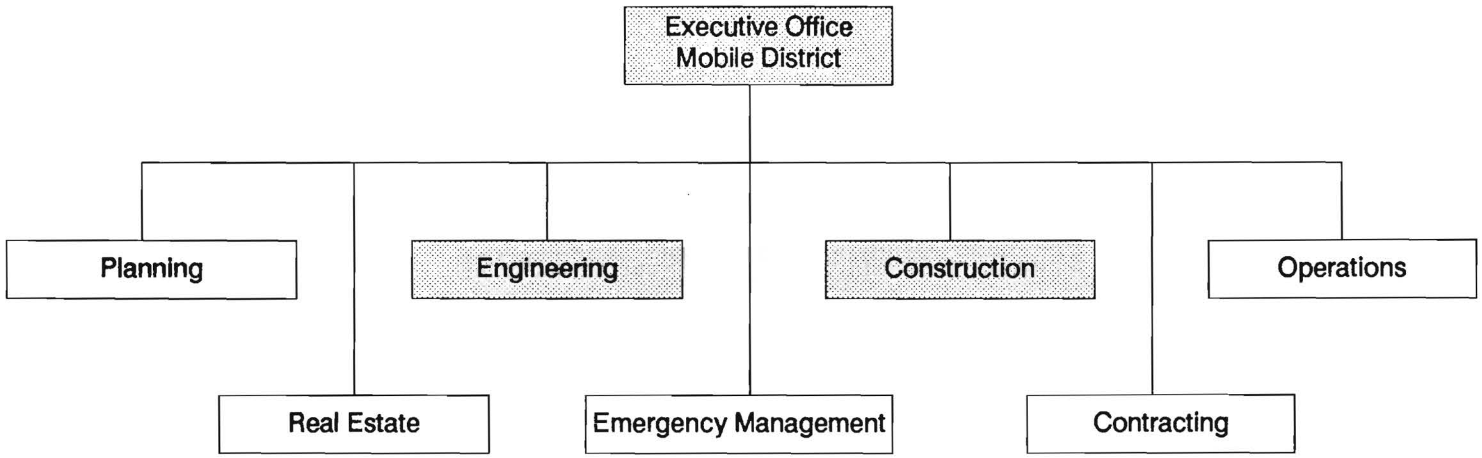
Total
Geotechnical & Materials

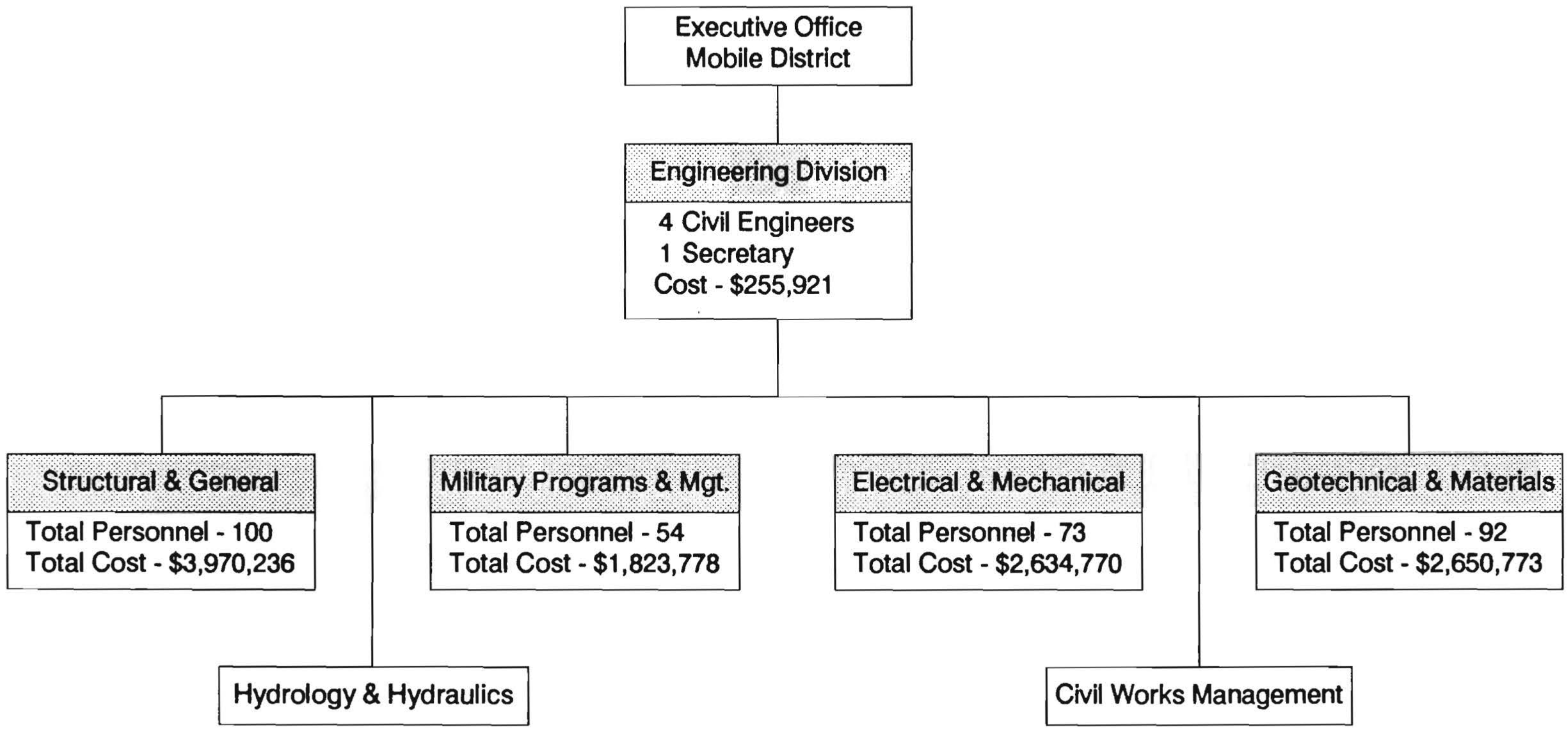
Personnel 51
Cost $2,146,080



Executive Office Savannah District
Construction Division
2 Civil Engineers
1 Secretary
Cost - $96,124
Construction Service
2 Management Assistants
1 Clerk
Cost - $13,000
Contract Administration
1 Civil Engineers
1 Program Analyst
Cost - $81,262
Quality Assurance
4 Civil Engineers
1 Secretary
Cost - $42,803
Claims
8 Civil Engineers
1 Electrical Engineer
1 Mechanical Engineer
1 Mechanical Tech
1 Engineering Tech
Cost - $235,626
Office Engineering
1 Civil Engineer
2 Civil Engineer Techs
1 Electrical Engineer Tech
4 Proc/Budget Techs
Cost - $164,880
Military Projects
4 Civil Engineers
2 Electrical Engineers
1 Civil Engineer Tech
1 Secretary
Cost - $290,198
Technical Support
1 Civil Engineer
1 Electrical Engineer
1 Mechanical Engineer
1 Architect
1 Civil Engineering Tech
Cost - $150,183
Field Offices
35 Civil Engineers
6 Mechanical Engineers
3 Electrical Engineers
20 Construction Reps
7 Civil Engineer Techs
6 Mechanical Engineer Techs
15 Clerk/Steno/Assistants
Cost - $3,269,553
Civil Projects
Total Construction Division (Incl Civil)
Personnel 132
Cost $4,765,307

Appendix B
Mobile District


Executive Office
Mobile District
Planning
Engineering
Construction
Operations
Real Estate
Emergency Management
Contracting



Total Engineering
(Incl Hyd & Civil)

Personnel 393
Cost . . . $13,691,214

Executive Office
Mobile District

Military Program Dev. & Management Branch
- 1 Civil Engineer
- 1 Secretary

Cost - $83,635

AF & Special Projects
- 8 Civil Engineers
- 2 Electrical Engineers
- 2 Steno/Secretaries
- 2 CE Aides

Cost - $494,284

Army & FE Projects
- 5 Civil Engineers
- 1 Architect
- 1 Mechanical Engineer
- 1 Engineering Tech
- 2 Clerk/Steno's

Cost - $366,268

Contracts, Plng. & Prog.
- 7 Civil Engineers
- 2 Electrical Engineers
- 2 Mechanical Engineers
- 1 CE Tech
- 5 Clerks

Cost - $587,448

Military Master Planning
- 2 Civil Engineers
- 1 CE Tech
- 1 Program Analyst
- 4 Engineering Draftsmen
- 2 Budget Analysts
- 1 Secretary

Cost - $292,143

Total
Military Program & Mgt.

Personnel 54
Cost $1,823,778

Executive Office
Mobile District

Engineering Division

Geotechnical & Materials

1 Geologist
1 Secretary
Cost - $80,984

Soils Design

9 Civil Engineers
6 Civil Engineer Techs
1 Secretary
2 Trainees
Cost - $562,752

Geology

6 Geologists
3 CE Tech
Cost - $308,710

Paving, Grading & Drain.

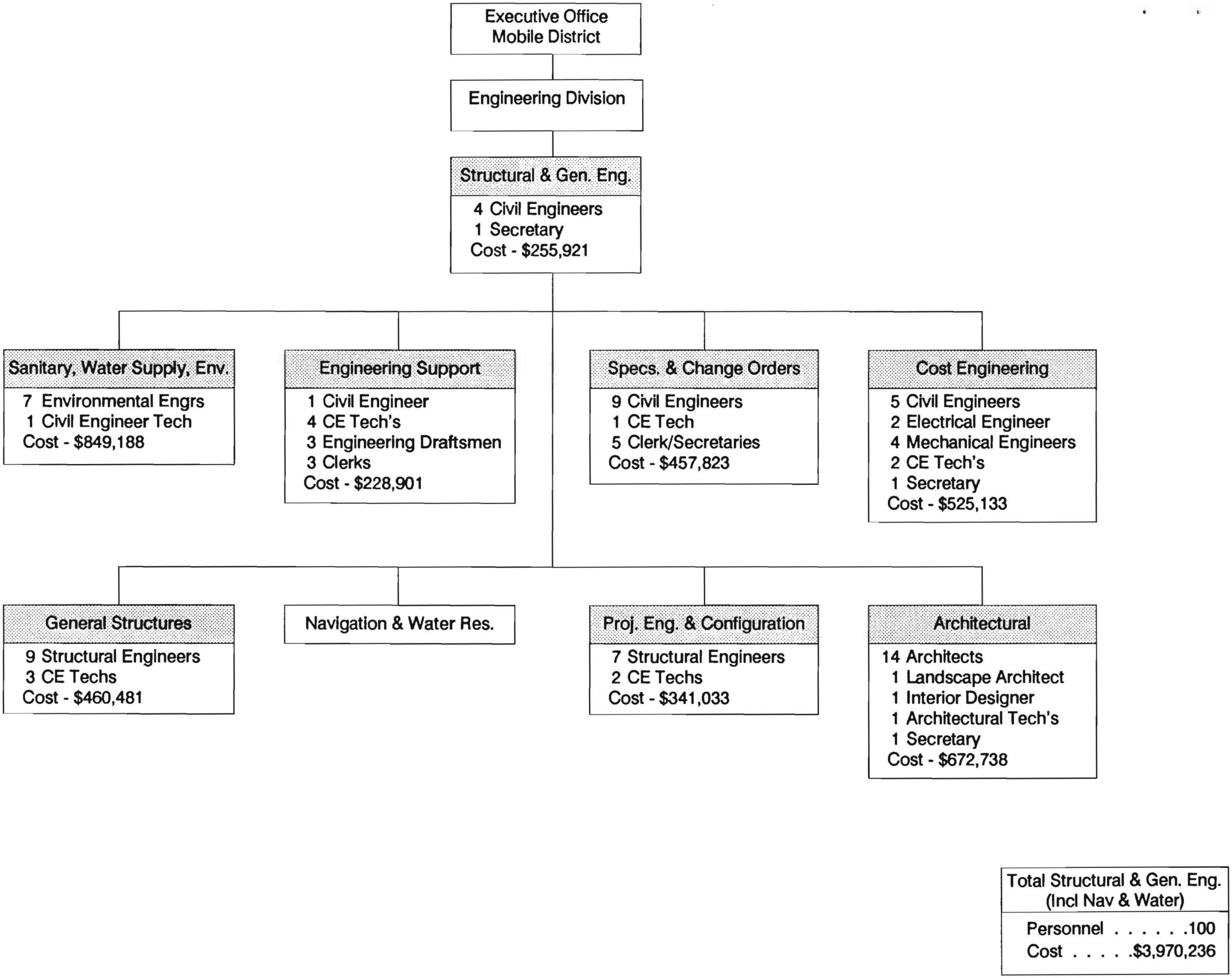
11 Civil Engineers
3 Civil Engineer Techs
1 Clerk
Cost - $572,012

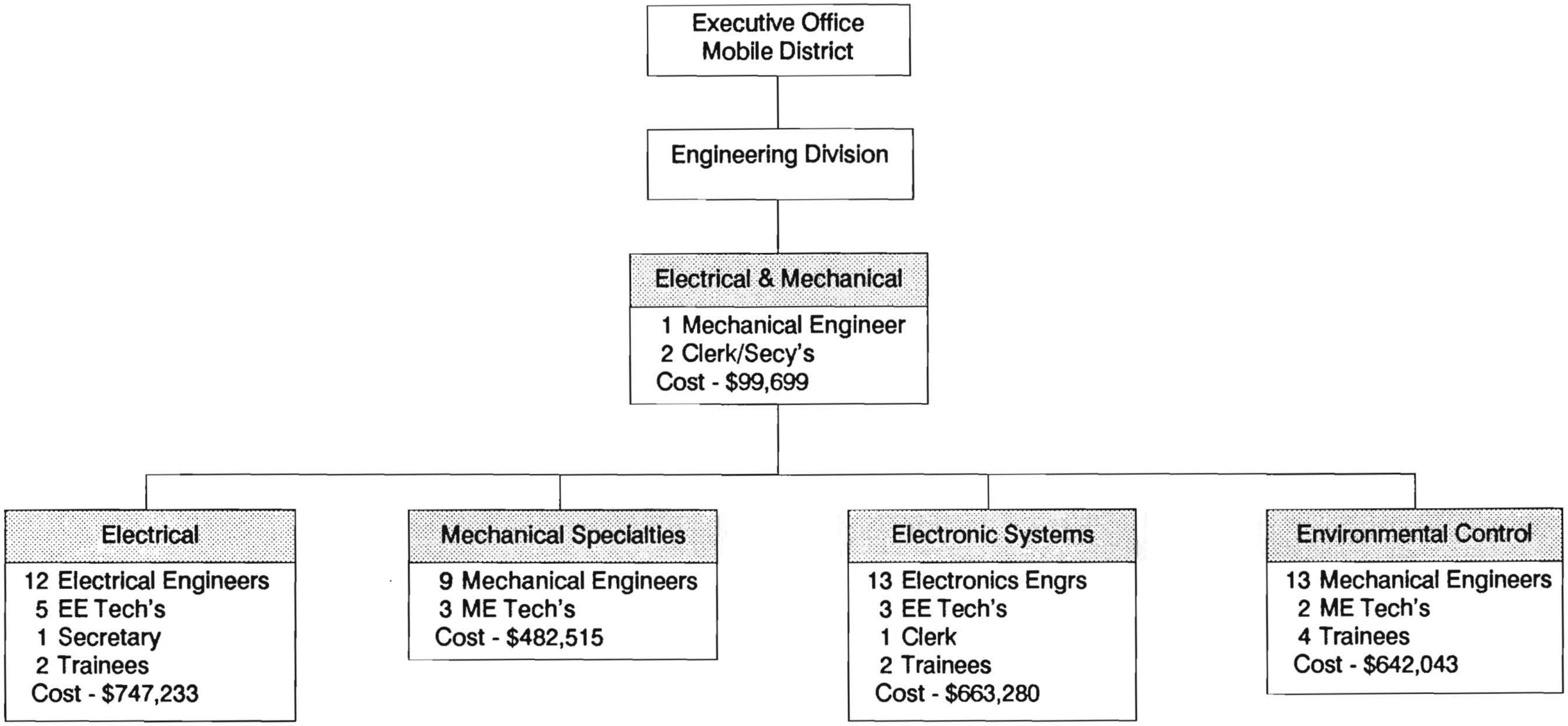
Exploration & Support

2 Geologists
26 Drill Rig Operators
6 Laborers
4 Hvy Mobile Eq Opr
1 Supply Techs
1 Machinist
1 Motor Vehicle Opr
2 Clerk/Secretaries
5 Student Aides
Cost - $1,126,315

Total
Geotechnical & Materials

Personnel 92
Cost $2,650,773


Executive Office
Mobile District
Engineering Division
Structural & Gen. Eng.
4 Civil Engineers
1 Secretary
Cost - $255,921
Sanitary, Water Supply, Env.
7 Environmental Engrs
1 Civil Engineer Tech
Cost - $849,188
Engineering Support
1 Civil Engineer
4 CE Tech's
3 Engineering Draftsmen
3 Clerks
Cost - $228,901
Specs. & Change Orders
9 Civil Engineers
1 CE Tech
5 Clerk/Secretaries
Cost - $457,823
Cost Engineering
5 Civil Engineers
2 Electrical Engineer
4 Mechanical Engineers
2 CE Tech's
1 Secretary
Cost - $525,133
General Structures
9 Structural Engineers
3 CE Techs
Cost - $460,481
Navigation & Water Res.
Proj. Eng. & Configuration
7 Structural Engineers
2 CE Techs
Cost - $341,033
Architectural
14 Architects
1 Landscape Architect
1 Interior Designer
1 Architectural Tech's
1 Secretary
Cost - $672,738
Total Structural & Gen. Eng.
(Incl Nav & Water)
Personnel 100
Cost $3,970,236



Total
Electrical & Mechanical

Personnel 73
Cost $2,634,770

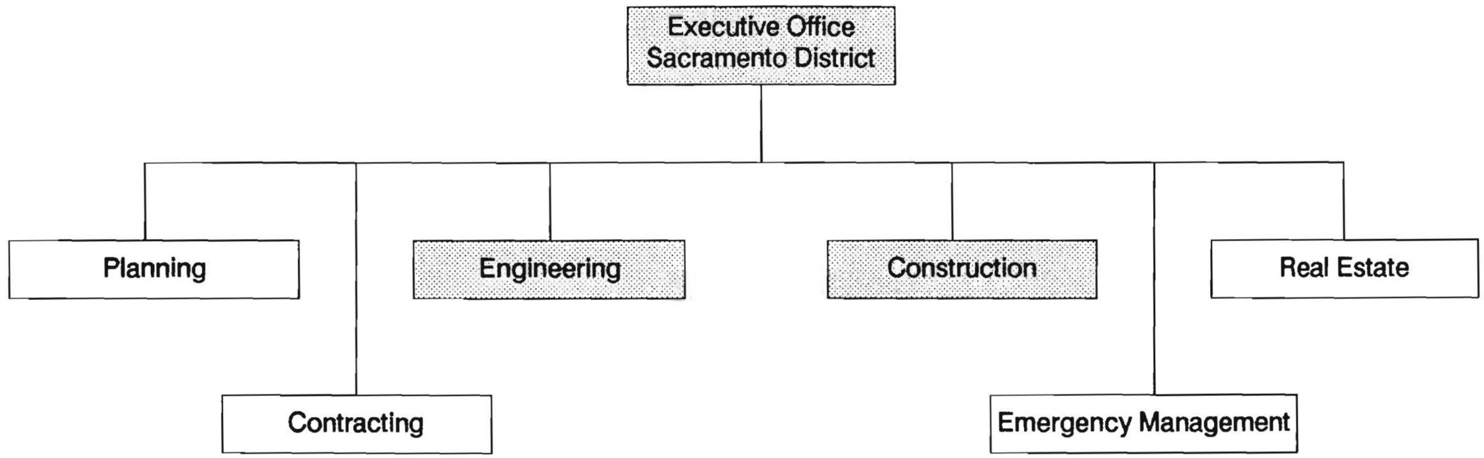
Executive Office Mobile District

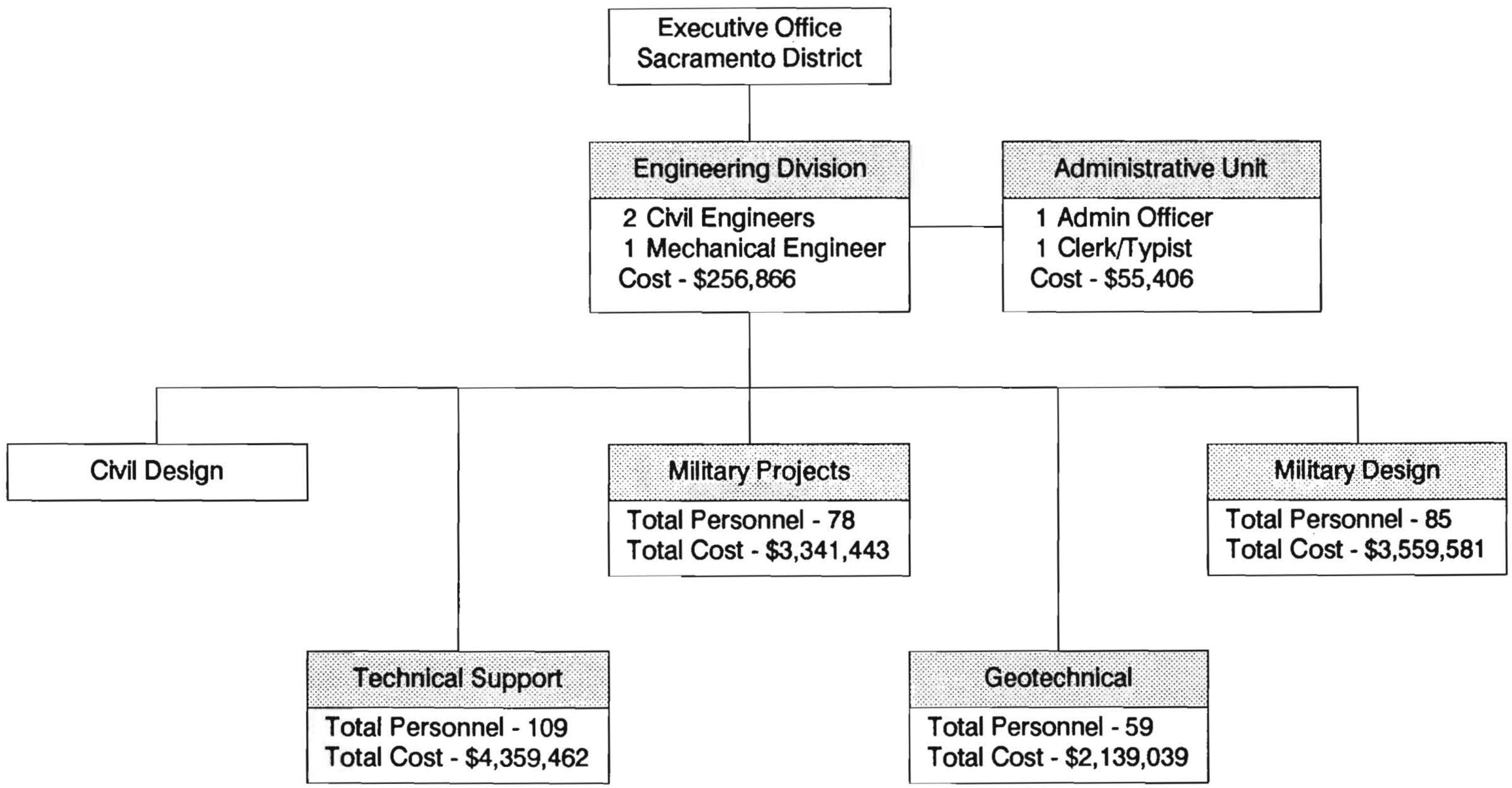
- **Construction Division**
  - 2 Civil Engineers
  - 1 Secretary
  - Cost - $155,895
  - **Contract Administration**
    - 1 Civil Engineer
    - 1 Clerk Steno
    - Cost - $86,635
    - **Modification & Admin**
      - 5 Civil Engineers
      - 1 Civil Engineer Techs
      - 2 Proc/Asst's
      - 2 Clerk Typists
      - Cost - $307,431
    - **Claims & Negotiating**
      - 2 Civil Engineers
      - 1 Mechanical Engineer
      - 1 Civil Engineer Tech
      - 2 Clerk Typist
      - Cost - $230,032
  - **Construction Programs**
    - Vacant
    - Cost - $0
    - **Military Management**
      - 1 Civil Engineer
      - 1 Construction Rep
      - 1 Computer Assistant
      - 1 Electrical Engineer (DA)
      - 1 Project Manager Asst
      - 1 Clerk/Stenos
      - Cost - $142,203
    - **Civil Management**
  - **Quality Assurance**
    - 1 Mechanical Engineer
    - 2 Secretary
    - Cost - $130,615
    - **Field Support**
      - 1 Civil Engineers
      - 1 Electrical Engineer
      - 1 Mechanical Engineer
      - 1 Architect
      - 1 Construction Rep
      - 1 Civil Engineer Tech
      - Cost - $239,935
    - **Technical Support**
      - 1 Civil Engineer
      - 1 Electrical Engineer
      - 1 Mechanical Engineer
      - 1 Architect
      - 1 Civil Engineering Tech
      - 2 Clerk/Steno's
      - Cost - $190,561
  - **Field Offices**
    - 3 Military Officers
    - 37 Civil Engineers
    - 9 Mechanical Engineers
    - 8 Electrical Engineers
    - 2 Architect
    - 33 Construction Reps
    - 2 Civil Engineer Techs
    - 6 Field Office Asst's
    - 9 Clerk/Steno/Assistants
    - 3 Student Trainees
    - Cost - $3,969,254
  - **Civil Field**

Total Construction Division (Incl Civil Projects)

Personnel	189
Cost	$6,612,873

Appendix C
Sacramento District


Executive Office
Sacramento District
Planning
Contracting
Engineering
Construction
Emergency Management
Real Estate



Total Engineering (Incl Civil)	
Personnel	365
Cost . . .	$15,007,064

Executive Office
Sacramento District

Engineering Division

Technical Support
- 1 Civil Engineer
- 1 Electrical Engineer
- 4 Comp Prog Analysts
- 3 Clerk/Typist/Asst's

Cost - $316,996

Drafting & Map File
- 9 Eng Draftsmen
- 3 Clerk/Typists

Cost - $271,036

Specifications
- 2 Civil Engineers
- 1 Architect
- 4 Civil Engineer Techs
- 4 Clerk/Typist

Cost - $363,682

DQA Air Force
- 3 Civil Engineers
- 3 Electrical Engineers
- 4 Mechanical Engineers
- 2 Structural Engineers
- 4 Architects
- 1 Engineer Tech
- 1 Clerk

Cost - $624,434

Construction Support
- 4 Civil Engineers
- 2 Architects
- 1 Electrical Engineer
- 3 Mechanical Engineers
- 2 Structural Engineers
- 1 Environmental Engr
- 1 Materials Engineer
- 4 Engineer Tech's
- 1 Engineer Aid
- 1 Clerk

Cost - $899,577

DQA Army
- 2 Civil Engineers
- 2 Electrical Engineers
- 2 Mechanical Engineers
- 2 Structural Engineers
- 1 Environmental Engr
- 2 Architects
- 2 Engineer Tech's
- 2 Clerk/Typists

Cost - $635,263

Cost Engineering
- 2 Civil Engineers
- 1 Electrical Engineer
- 19 Engineer Tech's
- 1 Engineer Trainee
- 1 Clerk

Cost - $1,038,547

Total Technical Support

Personnel 109
Cost $4,359,462

Executive Office
Sacramento District

Engineering Division

Military Projects
- 2 Civil Engineers
- 1 Engineer Tech
- 3 Clerk/Secy's

Cost - $224,531

Project Mgmt. – Air Force
- 10 Civil Engineers
- 3 Architects
- 1 Structural Engineer
- 1 Engineer Tech
- 1 Clerk/Steno's

Cost - $770,236

Project Mgmt. – Army
- 6 Civil Engineers
- 1 Architect
- 1 Mechanical Engineer
- 1 Environmental Engr
- 1 Engineer Tech
- 2 Clerk/Steno's

Cost - $522,089

Special Projects
- 7 Civil Engineers
- 1 Mechanical Engineer
- 1 Structural Engineer
- 2 Architects
- 2 Engineer Tech's
- 3 Steno/Secretaries

Cost - $659,605

Installation Support
- 7 Civil Engineers
- 1 Mechanical Engineer
- 1 Architect
- 1 Engineer Tech
- 1 Engineer Aid

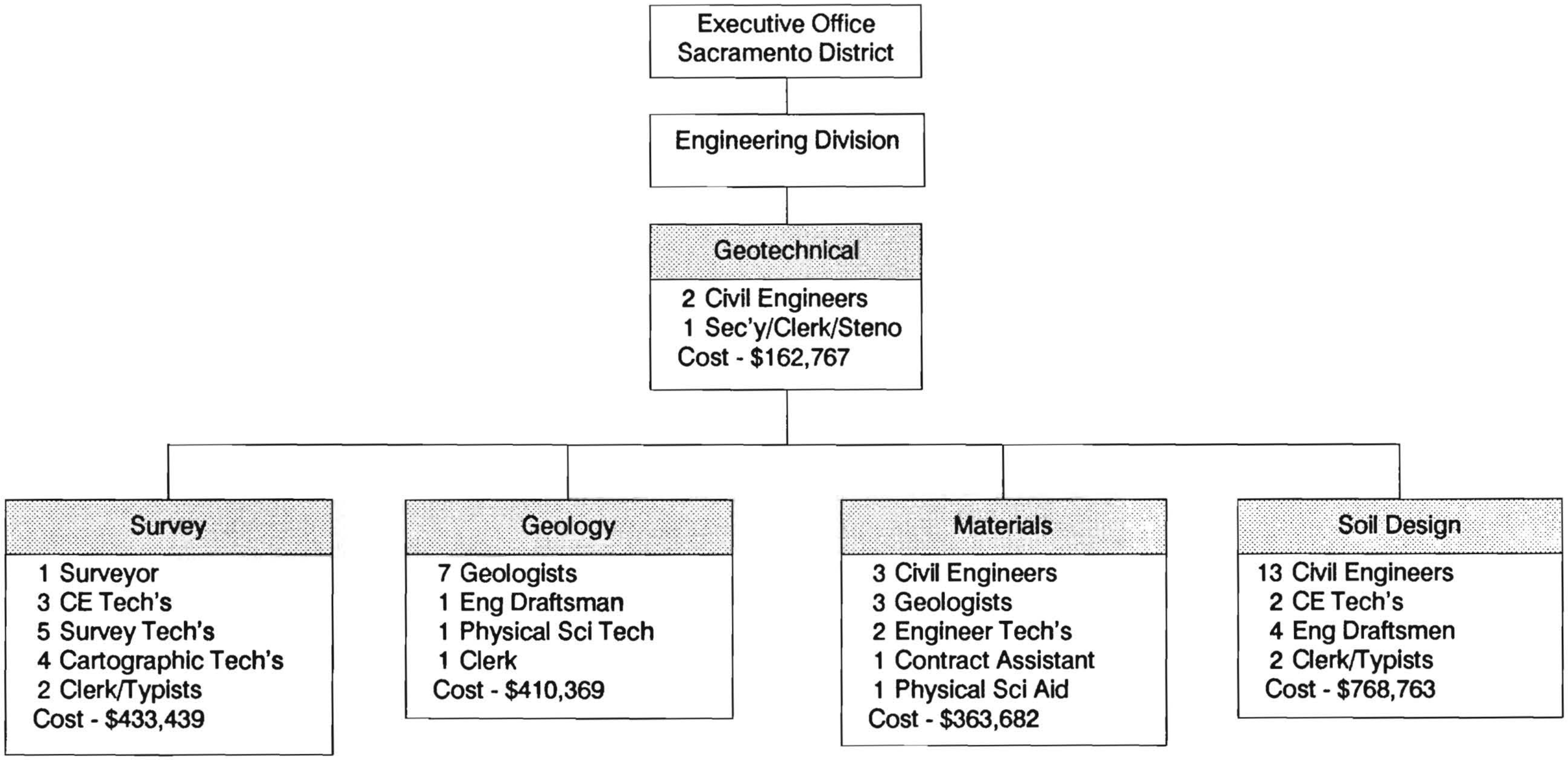
Cost - $544,070

A-E Negotiations
- 3 Civil Engineers
- 1 Structural Engineer
- 1 Architect
- 5 Engineer Tech's
- 6 Clerk/Steno/Asst's

Cost - $620,912

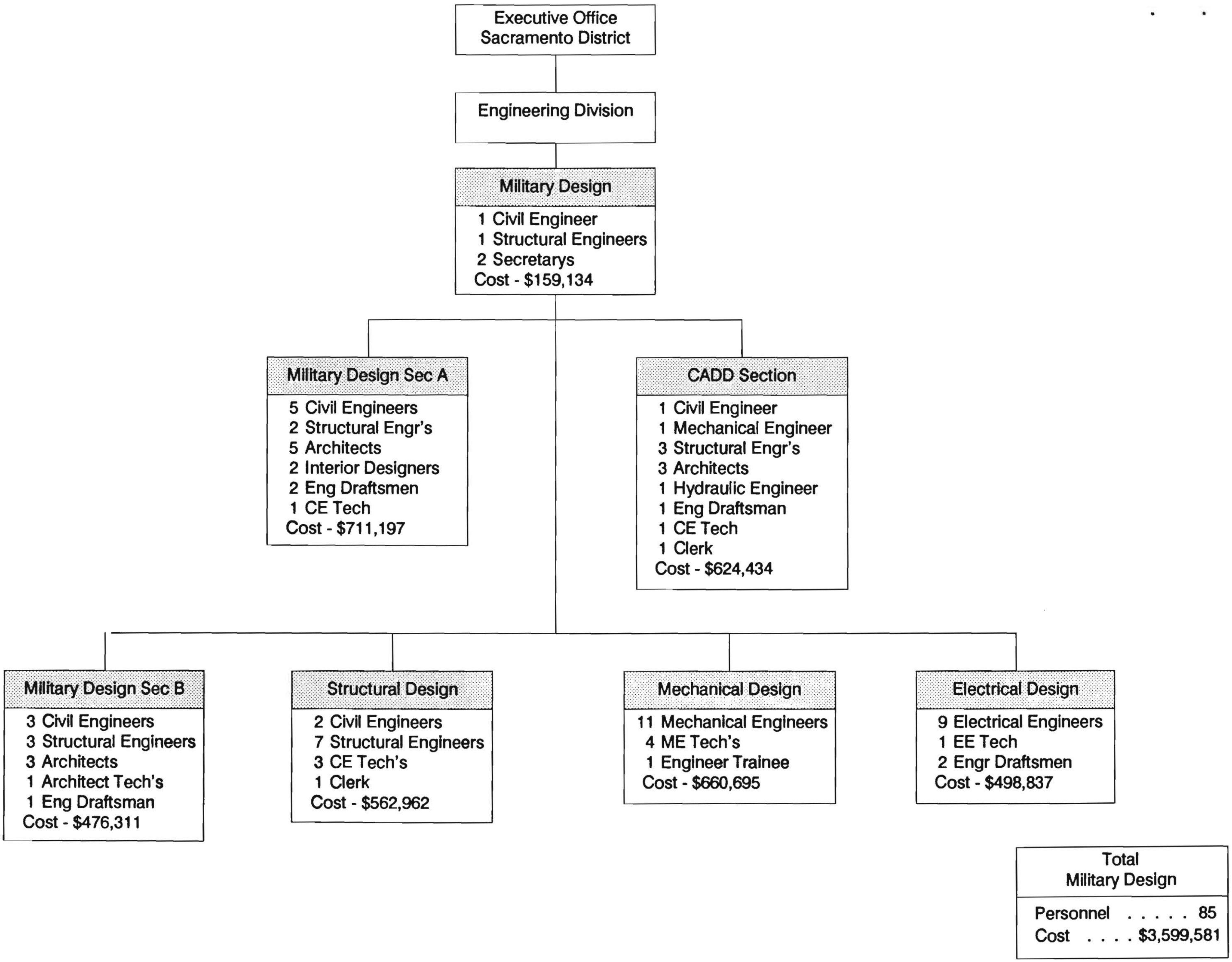
Total Military Projects

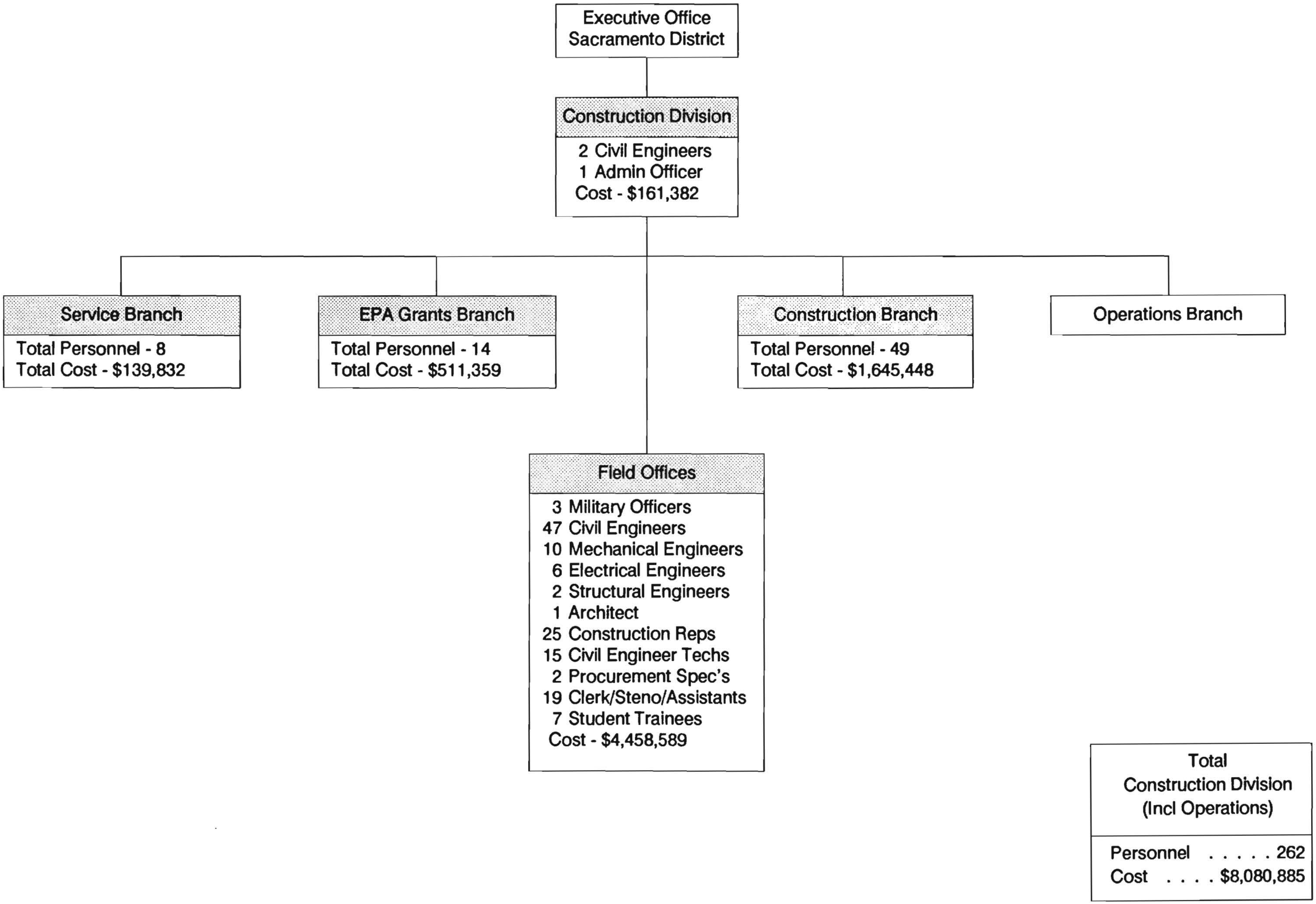
Personnel 78
Cost $3,341,443



Total Geotechnical

Personnel 59
Cost $2,139,039


Executive Office
Sacramento District
Engineering Division
Military Design
1 Civil Engineer
1 Structural Engineers
2 Secretarys
Cost - $159,134
Military Design Sec A
5 Civil Engineers
2 Structural Engr's
5 Architects
2 Interior Designers
2 Eng Draftsmen
1 CE Tech
Cost - $711,197
CADD Section
1 Civil Engineer
1 Mechanical Engineer
3 Structural Engr's
3 Architects
1 Hydraulic Engineer
1 Eng Draftsman
1 CE Tech
1 Clerk
Cost - $624,434
Military Design Sec B
3 Civil Engineers
3 Structural Engineers
3 Architects
1 Architect Tech's
1 Eng Draftsman
Cost - $476,311
Structural Design
2 Civil Engineers
7 Structural Engineers
3 CE Tech's
1 Clerk
Cost - $562,962
Mechanical Design
11 Mechanical Engineers
4 ME Tech's
1 Engineer Trainee
Cost - $660,695
Electrical Design
9 Electrical Engineers
1 EE Tech
2 Engr Draftsmen
Cost - $498,837
Total
Military Design
Personnel 85
Cost $3,599,581


Executive Office
Sacramento District
Construction Division
2 Civil Engineers
1 Admin Officer
Cost - $161,382
Service Branch
Total Personnel - 8
Total Cost - $139,832
EPA Grants Branch
Total Personnel - 14
Total Cost - $511,359
Construction Branch
Total Personnel - 49
Total Cost - $1,645,448
Operations Branch
Field Offices
3 Military Officers
47 Civil Engineers
10 Mechanical Engineers
6 Electrical Engineers
2 Structural Engineers
1 Architect
25 Construction Reps
15 Civil Engineer Techs
2 Procurement Spec's
19 Clerk/Steno/Assistants
7 Student Trainees
Cost - $4,458,589
Total
Construction Division
(Incl Operations)
Personnel 262
Cost $8,080,885

Executive Office
Sacramento District

Construction Division

Construction Branch
- 1 Civil Engineer
- 1 Secretary

Cost - $78,910

Program & Reports
- 5 Program Analysts
- 2 Program Assistants
- 1 Clerk

Cost - $207,468

Quality Assurance
- 2 Civil Engineers
- 4 Electrical Engineers
- 2 Mechanical Engineers
- 1 Architect
- 1 Material Engineer
- 1 Structural Engineer
- 7 Material Engr Tech's

Cost - $576,853

Project Management
- 8 Civil Engineers

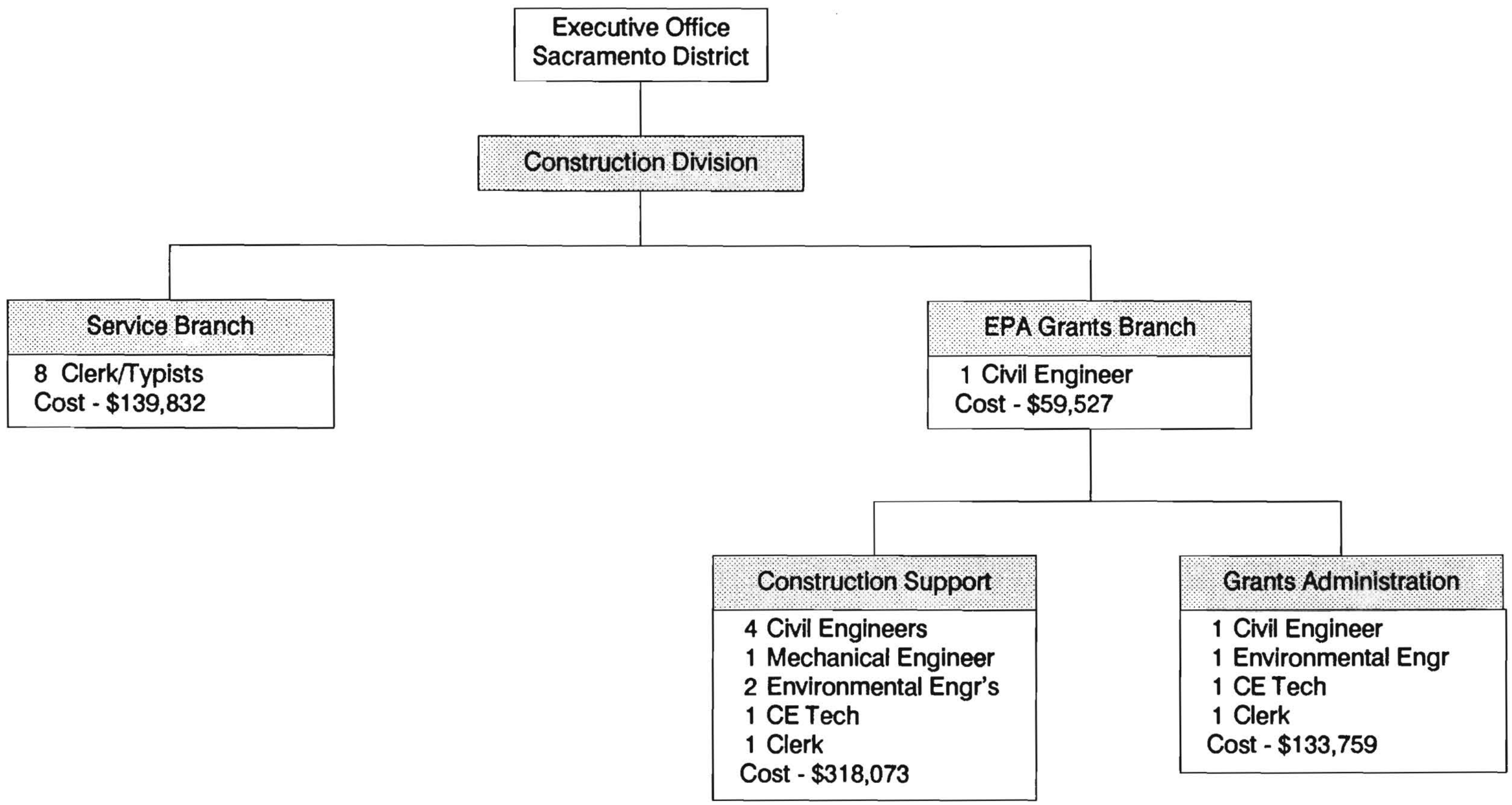
Cost - $330,629

Contract Administration
- 4 Civil Engineers
- 2 Mechanical Engineers
- 6 CE Tech's
- 1 Procurement Assistant

Cost - $451,588

Total
Construction Branch

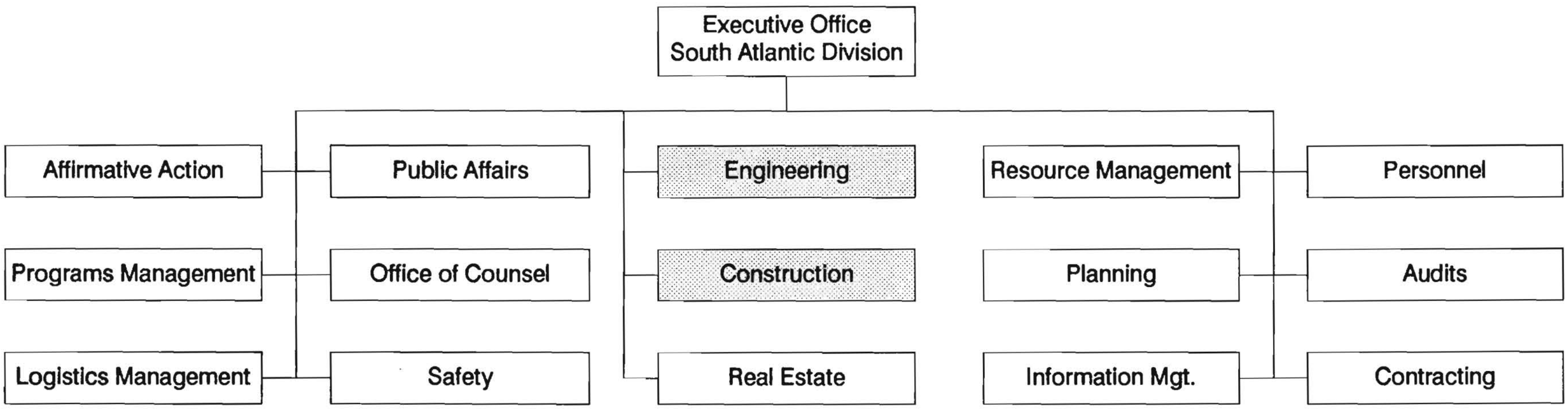
Personnel 49
Cost $1,645,448

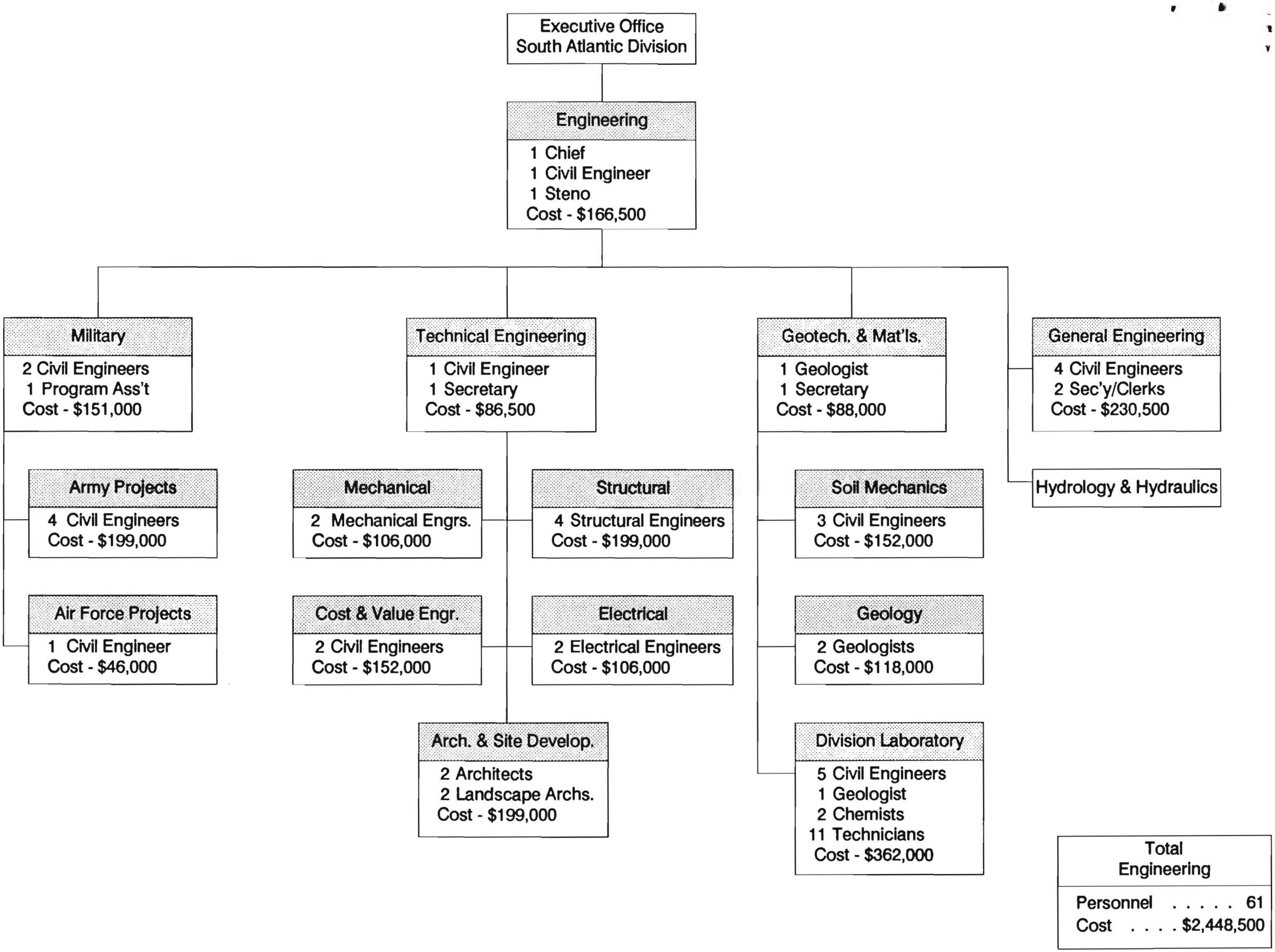


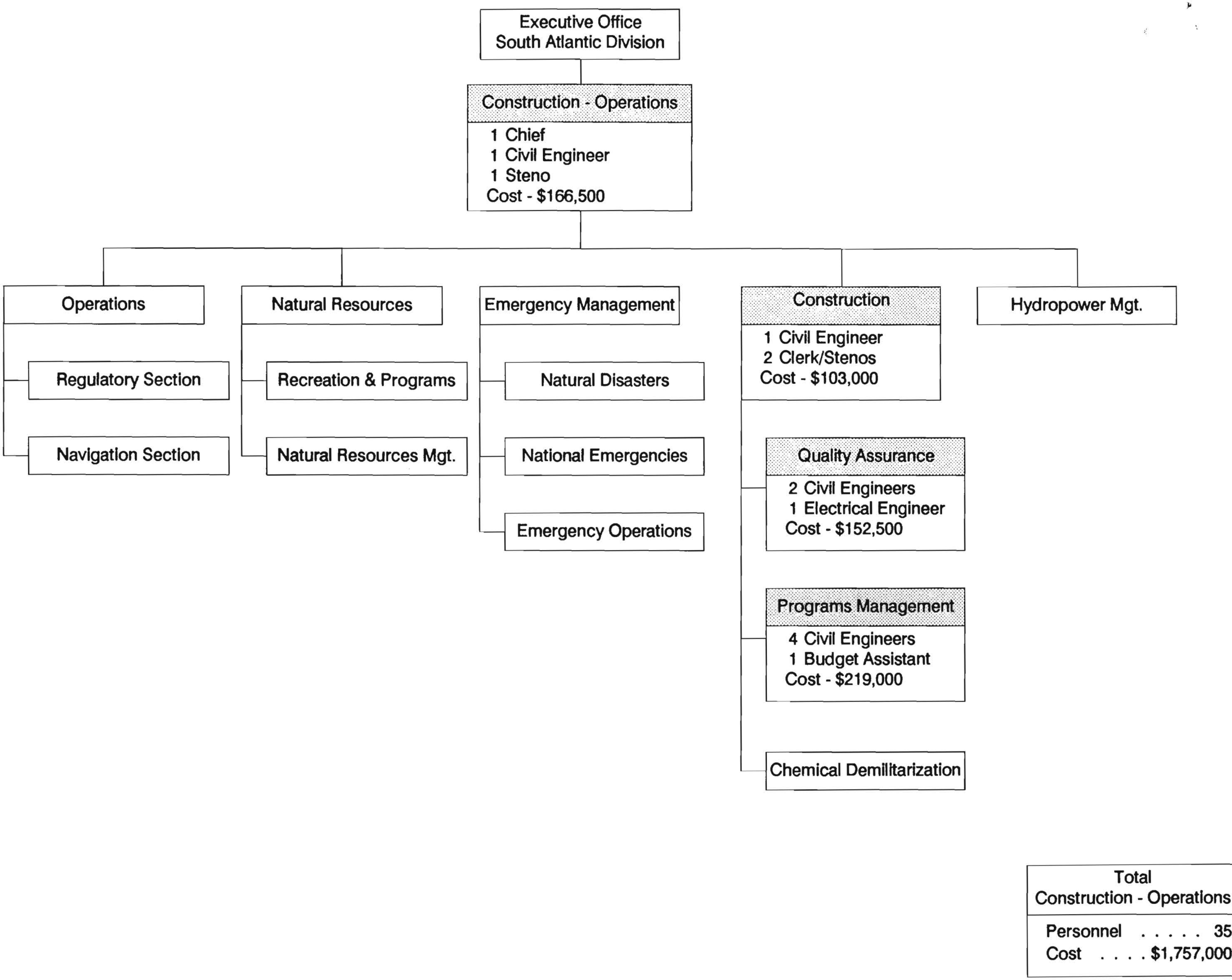
Total
Service & EPA Grants

Personnel 22
Cost $651,191

Appendix D
South Atlantic Division


Executive Office
South Atlantic Division
Affirmative Action
Public Affairs
Engineering
Resource Management
Personnel
Programs Management
Office of Counsel
Construction
Planning
Audits
Logistics Management
Safety
Real Estate
Information Mgt.
Contracting


Executive Office
South Atlantic Division
Engineering
1 Chief
1 Civil Engineer
1 Steno
Cost - $166,500
Military
2 Civil Engineers
1 Program Ass't
Cost - $151,000
Technical Engineering
1 Civil Engineer
1 Secretary
Cost - $86,500
Geotech. & Mat'ls.
1 Geologist
1 Secretary
Cost - $88,000
General Engineering
4 Civil Engineers
2 Sec'y/Clerks
Cost - $230,500
Army Projects
4 Civil Engineers
Cost - $199,000
Air Force Projects
1 Civil Engineer
Cost - $46,000
Mechanical
2 Mechanical Engrs.
Cost - $106,000
Structural
4 Structural Engineers
Cost - $199,000
Cost & Value Engr.
2 Civil Engineers
Cost - $152,000
Electrical
2 Electrical Engineers
Cost - $106,000
Arch. & Site Develop.
2 Architects
2 Landscape Archs.
Cost - $199,000
Soil Mechanics
3 Civil Engineers
Cost - $152,000
Geology
2 Geologists
Cost - $118,000
Division Laboratory
5 Civil Engineers
1 Geologist
2 Chemists
11 Technicians
Cost - $362,000
Hydrology & Hydraulics
Total
Engineering
Personnel 61
Cost $2,448,500


Executive Office
South Atlantic Division
Construction - Operations
1 Chief
1 Civil Engineer
1 Steno
Cost - $166,500
Operations
Regulatory Section
Navigation Section
Natural Resources
Recreation & Programs
Natural Resources Mgt.
Emergency Management
Natural Disasters
National Emergencies
Emergency Operations
Construction
1 Civil Engineer
2 Clerk/Stenos
Cost - $103,000
Quality Assurance
2 Civil Engineers
1 Electrical Engineer
Cost - $152,500
Programs Management
4 Civil Engineers
1 Budget Assistant
Cost - $219,000
Chemical Demilitarization
Hydropower Mgt.
Total
Construction - Operations
Personnel 35
Cost $1,757,000