1 of 1

**Workforce Planning for DOE/EM:
Assessing Workforce Demand and Supply**

R.E. Lewis
C. A. Ulibarri

October 1993

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

MASTER

RP

Abstract

The U.S. Department of Energy (DOE) has committed to bringing its facilities into regulatory compliance and restoring the environment of sites under its control by the year 2019. Responsibility for accomplishing this goal is vested with the Office of Environmental Restoration and Waste Management (EM). Concerns regarding the availability of workers with the necessary technical skills and the prospect of retraining workers from other programs within DOE or other industries are addressed in this report in several ways. First, various workforce projections relevant to EM occupations are compared to determine common findings and resolve inconsistencies. Second, case studies, interviews, and published data are used to examine the potential availability of workers for these occupations via occupational mobility, training/retraining options, and salary adjustments. Third, demand and supply factors are integrated in a framework useful for structuring workforce analyses. The analyses demonstrate that workforce skills are not anticipated to change due to the change in mission; science, engineering, and technician occupations tend to be mobile within and across occupational categories; experience and on-the-job training are more crucial to issues of worker supply than education; and, the clarity of an organization's mission, budget allocation process, work implementation and task assignment systems are critical determinants of both workforce need and supply. DOE is encouraged to create a more stable platform for workforce planning by resolving organizational and institutional hindrances to accomplishing work and capitalizing on workforce characteristics besides labor "supply" and demographics.

Summary

The U.S. Department of Energy (DOE) Office of Environmental Restoration and Waste Management (DOE-EM) has experienced concerns over several aspects of the workforce it will need to accomplish its mission. There are many apparently contradictory reports regarding the size and skill mix of the workforce that will be needed; the likely availability of workers with the appropriate knowledge, skills, and abilities; and the ease with which the DOE and its prime contractors can attract, recruit, and retain personnel.

These issues are addressed in this report in several ways. The workforce "needs" of EM are examined by comparing five studies sponsored or co-sponsored by DOE to determine general conclusions, inconsistencies, and potentially troublesome occupational needs. Worker availability is assessed by characterizing occupational mobility, career paths, and occupational salary structure for the occupations most relevant to EM. Data for this assessment are derived from published reports, contractor human resources databases, and interviews with trainers and managers. Finally, a framework is developed as a management tool for investigating personnel recruitment and retention difficulties and assessing workforce interventions. The framework is applied to workforce planning in EM by drawing data from published reports and case studies.

S.1 EM's Need for Workers

Managers and planners within EM see the need for a growing workforce, as do private contractors and subcontractors. They do not, however, find that the skills mix needed to accomplish EM's goals will change markedly from that needed to support the defense production mission. Most workers have, in the view of managers, adjusted to program changes in the past and have developed the in-depth knowledge of DOE facilities and procedures that will be needed to restore the environments at DOE sites. Though they may perform different tasks, the good basic training in science and engineering that characterizes the DOE workforce will be usefully applied to the EM mission. Staffing difficulties are perceived primarily for the "niche" occupations that are largely homegrown within DOE, such as radiological chemist, safety engineer, and program manager.

Projections of the skills mix needed to accomplish EM goals are likely to be more robust than predictions of total headcount. Overall employment is sensitive to complex interactions among funding, work scope, work schedule, and landlord status. The way the workforce is allocated over occupations, however, remains roughly constant over most headcount changes since landlord, administrative, and other activities must be accomplished regardless of fluctuations in employment. The failure to provide clear work schedule, scope, and budget parameters has unnecessarily reduced the utility of the workforce projections completed to date. Thus, the mix of occupations EM "needs" seems clear even if total headcount does not.

S.2 The Availability of Workers with EM-Relevant Skills

Based on occupational mobility data for scientists, engineers, and technicians, workers employed within DOE programs outside EM are likely to be able to transition to EM relatively quickly as long as their previous positions entailed some technical skill. Thus within DOE itself, there is a sizeable pool of workers who may meet EM's needs. This pool is supplemented by well-educated (though not DOE-experienced) scientists, engineers, and technicians who are available because of current economic conditions. EM needs in the short run, therefore, are likely to be met with the current "supply" of workers for the vast majority of occupations.

In the past, the range of occupations (or number of workers) considered suitable for DOE employment depended on college majors and graduation rates. Though helpful predictors, these are not sufficient. Managers indicate that the supply of workers who could meet EM's needs is built not from the graduation pool only, but from workers who have experience in similar occupations and industries or from within DOE itself. In fact, managers regard experience as a more valid predictor of on-the-job success than educational background. If this perception is true, the availability of workers in the future will depend more heavily on how workers are developed within organizations than macroeconomics-based programs that attempt to influence worker supply. Many occupations within the DOE complex lack clear career ladders, fail to capitalize on the background of incumbents, or are not described adequately to candidates. Internships, co-op education, and structured mentoring and development plans may be the preferred method for developing an internal pool of candidates, especially for "niche" occupations. By investing minimally in marketing-based approaches such as these, EM can expand the pool of potential workers and obtain status as an employer of choice. These "grow and nurture" approaches are especially relevant since DOE and its prime contractors tend to compensate workers less than their competitors in rival industries or geographic regions.

S.3 Integrating Workforce Needs and Availability

Workforce planning is usually the domain of economics. The framework for evaluating labor shortages and excesses has quite naturally emphasized supply and demand, salaries, and graduation rates. However, unclear missions and goals, fluctuating budgets, uncoordinated technology development and use, and outmoded or inappropriate organizational characteristics account for a far greater portion of workforce planning and management difficulties than macroeconomic factors. The DOE complex, for example, will not get the quality workforce it desires if it pays less than competitors and offers poorer work conditions, burdensome administrative requirements, work that fails to capitalize on a candidate's training, and few career options, regardless of the number of scholarships or fellowships it offers. Focusing efforts on resolving the organizational and institutional barriers which detract from the quality of work life in the DOE complex is the first step to securing a stable workforce.

Acknowledgments

The authors gratefully acknowledge the support of many individuals who contributed to the quality of this report. Jim Foushee of the Foushee Group, Inc. graciously permitted us to use his compensation survey data. Frank reviews and valued advice were contributed by Nora Buel, Pacific Northwest Laboratory; Larry Bundy, Westinghouse Hanford Company; Cheryl Dobbins, Basic Technologies, Inc.; Joe Finch, Coleman Research; Mike Finn, Oak Ridge Institute for Science and Education; Powell Hutton, DBD; Lou Middleman, Waste Policy Institute; Ed Stahlman, Pacific Northwest Laboratory; and, Molly Wankel, Coleman Research. The document was formatted by Margie Hutchings, Erica Brown and Marlene Hale, Pacific Northwest Laboratory.

Strong management support was received from the U.S. Department of Energy (DOE) project field managers, June Ollero, Dom Sansotta, and Joyce Gilbert (all DOE-Richland Operations Office), and the project sponsor, Ike Sewell (EM-522).

Finally, we thank all the individuals who lent us their knowledge and experience during the many interviews and phone calls made to obtain the information we report.

Contents

Abstract	iii
Summary	v
Acknowledgments	vii
1.0 Demand: Comparing Workforce Projection Studies for DOE/EM Activities	1.1
1.1 Summary of the Studies	1.6
1.2 Results of the Studies	1.8
1.2.1 Comparing Results Within Studies	1.8
1.2.2 Comparing Projections Across Studies	1.18
1.3 Discussion of the Studies	1.21
1.4 Chapter Summary	1.23
2.0 Supply: Occupational Mobility and the Availability of Workers	2.1
2.1 Changes in the Conduct of R&D	2.2
2.2 National Trends in Occupational Mobility	2.3
2.3 Mobility Patterns in Science and Engineering	2.4
2.4 Occupational Mobility in the DOE Complex	2.5
2.5 Conclusions Relevant to Occupational Mobility	2.6
2.6 Occupational Transition Sequences	2.6
2.6.1 Specific Training and Experience Requirements	2.7
2.6.2 Critical Occupations	2.13
2.7 Salary Compensation in EM-Relevant Occupations	2.17
2.8 EM Salary Differentials Across Industry and Regions	2.19
2.9 Lessons Learned	2.22

2.9.1	Shortages Come and Shortages Go	2.22
2.9.2	Interdisciplinary Research and Majors Are Rising	2.22
2.9.3	Engineers Are Made, Not Graduated	2.22
2.9.4	The DOE Has Options, But Must Act	2.23
2.10	Chapter Summary	2.23
3.0	A Framework for Assessing Workforce Transitions	3.1
3.1	Components of the Framework	3.2
3.1.1	Mission	3.2
3.1.2	Technology/Products	3.2
3.1.3	Budget	3.3
3.1.4	Skills	3.3
3.1.5	Workforce	3.3
3.1.6	Organizational and Institutional Characteristics	3.3
3.1.7	Labor Market Supply	3.3
3.2	The “Ideal” Scenario	3.4
3.3	“Non-ideal” Scenarios	3.6
3.3.1	An Exogenous Shock to the Organization Mission	3.6
3.3.2	An Exogenous Shock to the Budget	3.8
3.4	Time Constraints on Scenario Changes	3.10
3.5	Applying the Framework to DOE	3.12
3.5.1	Mission	3.13
3.5.2	Budget	3.15
3.5.3	Technology/Products	3.15
3.5.4	Schedules	3.16

3.5.5 Organizational and Institutional Characteristics	3.17
3.5.6 Skills and Workforce Needs	3.19
3.5.7 Labor Supply	3.19
3.6 Chapter Summary	3.20
4.0 Notes	4.1
5.0 References	5.1
Appendix A - ANOVA Methodology	A.1

Figures

3.1 A Typical Workforce Needs and Availability Comparison	3.1
3.2 The "Ideal" Scenario	3.2
3.3 Structuring Questions for an "Ideal Scenario Workforce Change	3.6
3.4 Mission Change Scenario	3.7
3.5 Scenario Depicting an Exogenous Shock to the Budget	3.8
3.6 Structuring Questions for a Budget Shock Scenario	3.9
3.7 An Example Time Scenario	3.11
3.8 Applying the Framework by Structuring Workforce-Related Questions	3.14

Tables

1.1	Aggregated Roadmap Human Resource Projections from 14 DOE Sites	1.3
1.2	Rank Demand and Criticality, Anticipated Supply and Required Degree for Selected Scientific, Engineering, and Technical Occupations Drawn from the MNAS	1.5
1.3	Characteristics of the Workforce Projection Studies Examined in this Report	1.7
1.4	Projected Percentage of Site Employment Accounted for by Occupational Families by Site and Year Drawn from Roadmap Data	1.9
1.5	Occupations Not Needed by Site, 1993-1997, Based on Roadmap Data	1.10
1.6	Change Factors (FY 1993-1997) for Scientist, Engineer, and Technician Occupation Families Based on Data from the MNAS	1.12
1.7	Occupational Family as a Percentage of Total Site Employment Across Activity Phases at the Hanford Site Drawn from the Hanford 30-Year Study	1.15
1.8	Activity Phases Assumed for the 200 Area Plateau Option for the Hanford 30-Year Study	1.16
1.9	Most Populous Occupations in Each Family Based on Hanford 30-Year Projections . . .	1.17
1.10	Projected Growth (decline) by Site and Study FY 1993 - FY 1997	1.18
1.11	Projected Growth by Occupation Family and Study for Scientists, Engineers, and Technicians, FY 1993 - FY 1997	1.19
2.1	Differences Between Science Knowledge Creation and Application	2.3
2.2	Characteristics of Occupations of Concern to DOE-EM	2.8
2.3	Preliminary Formal Training Costs and Times for Occupational Families	2.12
2.4	Median Salaries for Environmental Occupations by Industry and Region	2.18
2.5	Salary Differences Across Industry	2.20
2.6	Salary Differences Across Regions	2.21
3.1	Shippingport Station Decommissioning Project Schedule	3.17

1.0 Demand: Comparing Workforce Projection Studies for DOE-EM Activities

The U.S. Department of Energy Office of Environmental Restoration and Waste Management (DOE-EM) continues to face several major uncertainties as it plans its environmental restoration and waste management mission. Two of these are a specification of the mix of occupations needed to achieve EM goals and the likely demand/supply of those occupations. Several organizations within DOE have recently sponsored or co-sponsored studies to address these questions, and those contractors have successfully completed their analyses. As a result, a databank now exists to facilitate EM's planning.

These data, however, are not directly comparable. Because the sponsoring organizations had different concerns, missions, and options available to them, workforce studies varied considerably in terms of the occupations they studied, the timeframes they examined, and the questions each was to answer. In this chapter, these data are examined in order to determine general conclusions, points of contention, and directions for future research.

The following studies, including both unpublished (see Notes at the end of this document) and published (see References) matter, are examined in this report:

- DOE-EM Roadmap Human Resource Projections (Roadmap; Notes 1 and 2)
- Environmental Restoration and Waste Management Manpower Needs Assessment Study (MNAS; Holmes, Lewis, Hunt, and Finn, 1992)^(a) sponsored by DOE-EM-52
- Educational Needs and Employment Trends of Environmental Hazardous Materials Technicians and Related Workers (EHM Tech; Hudis, Garland, Matlof, and Vork, 1992) study co-sponsored by the Department of Education Office of Vocational and Adult Education and the DOE Office of Contractor Human Resources
- Long-Term Workforce Projections at the Hanford Site (Hanford 30-Year; Note 3)
- Environmental Restoration and Waste Management: An Occupational Assessment for the Oak Ridge Area (ORAA; Note 4).

Each study is summarized below.

(a) This will be referred to simply as MNAS, 1992, in the remainder of this document.

Roadmap. Data for the DOE-EM Roadmap Human Resource Projections were collected to expand the EM Roadmap planning process from one that solely examines technical options to one that includes human resources, transportation, and safety needs as well. Sites were to estimate the "personnel required to support all EM managed projects" (Note 1), including all DOE Field Office, prime contractor (Management & Operations [M&O] and Environmental Restoration Management Contractor [ERMC]), and subcontractor personnel. Estimates were generated for the FY 1993 to FY 2019 time-span in three phases. Near-term projections (FY 1993-1997) were made each year for 87 occupations. Mid-range projections (FY 2002, 2007, and 2012) were made every five years for nine occupational families. For the final projection (FY 2019), the nine occupational families were collapsed to four. Each site collected its data independently under the general guidance of the Roadmap Steering Committee. Fourteen sites responded to the request for data; they generally employed surveys or interviews to collect anticipated employment data using the Common Occupational Classification System (Holmes, Lewis, Hunt, and Finn, 1993, MNAS, Addendum 1). Aggregated data from the 14 sites are presented in Table 1.1.

MNAS. Faced with the need to allocate its education and training dollars with little information regarding the anticipated EM workforce, EM-52 sponsored the Environmental Restoration and Waste Management Manpower Needs Assessment Study (MNAS). Researchers assessed the need for workers based on two inputs: 1) the judgments of managers throughout the complex and 2) budget projections. The anticipated availability of workers was inferred from managers' recruiting experiences and from science and engineering graduation rates. Data were obtained via surveys, teleconferences, and focus groups from 121 program and project managers and 54 human resources professionals who rated their current (FY 1993) and anticipated (FY 1997) needs and recruiting experiences for 53 science, engineering, technician, and selected other occupations based on the ER/WM 1993-1997 Five Year Plan (1991). The study covered all ten DOE Field Offices, which include 19 DOE sites and 53 contractors and subcontractors. Labor force and demographic data were obtained from the U.S. Department of Labor and the National Science Foundation (NSF)/DOE-sponsored Survey of Natural and Social Sciences and Engineering Graduates. Selected occupational needs compared with supply and degree levels cited by the study are presented in Table 1.2.

EHM Tech. The goals of the Educational Needs and Employment Trends of Environmental Hazardous Materials Technicians and Related Workers study are to examine in detail the need and utilization of environmental hazardous material (EHM) workers and to recommend the educational programs which will most effectively train individuals for such positions. Interview data were collected from 144 managers and technicians at 11 DOE and 10 private organizations to guide the development of a job analysis survey. This survey was then distributed to 128 managers and supervisors of EHM technicians, who also provided employment needs data. In contrast to the previous studies which required estimates of the number of positions employers anticipated filling, the EHM Tech study simply asked employers if they planned to hire EHM technicians over the next one to three years. Of the 128 surveyed, 98 anticipated hiring for new positions, 10 did not, and 20 failed to respond.

Table 1.1. Aggregated Roadmap Human Resource Projections from 14 DOE Sites

	1993	1994	1995	1996	1997	2002	2007	2012	2019
Chemical Engineers	882.5	1053.7	1144.3	1197.4	1261.3				
Civil Engineers	693.9	768.8	846.5	836.2	924.1				
Computer Engineers	787.8	884.8	886.0	907.7	921.1				
Electrical Engineer	799.6	886.1	938.7	976.9	972.3				
Environmental Engineers	611.3	694.5	740.5	751.0	795.5				
Industrial Engineers	154.3	176.4	174.6	161.4	160.7				
Mechanical Engineers	1244.4	1419.9	1526.3	1562.5	1577.7				
Nuclear Engineer	300.4	345.7	372.4	386.8	410.7				
Petroleum/Mining Engineers	34.7	33.0	37.7	58.7	59.7				
Plant Engineers	817.9	883.1	924.6	934.8	966.4				
Quality Control Engineers	446.3	446.2	407.7	388.6	382.3				
Safety Engineers	349.2	379.7	387.0	377.1	375.3				
Other Engineers	1702.2	1765.9	1729.5	1661.2	1674.5				
Engineers	8824.5	9737.8	10115.8	10200.3	10481.6	9940.2	11912.3	11749.4	
Chemists	437.7	503.1	535.1	558.9	618.0				
Environmental Scientists	292.2	326.4	365.9	374.2	425.8				
Geologists	225.6	263.4	287.7	312.9	375.9				
Life Scientists	70.5	78.4	100.1	89.8	109.9				
Materials Scientists	75.5	80.3	83.3	82.9	83.3				
Mathematicians	85.4	94.2	100.2	101.1	102.5				
Physicists	141.2	154.3	170.4	171.8	201.3				
Social Scientists	44.2	51.2	56.2	52.2	54.2				
Other Scientists	134.8	147.8	150.0	150.4	151.6				
Scientists	1507.1	1699.1	1848.9	1894.2	2122.5	2273.9	2692.2	2471.0	
Computer Operators/Coders	222.9	254.7	277.7	279.0	303.6				
Drafters	414.0	457.9	498.0	508.1	515.8				
Engineering Technicians	693.7	711.8	715.6	739.2	730.2				
Environmental Sciences Technicians	185.9	202.1	201.3	200.7	209.7				
Health Physics Technicians	1485.7	1556.8	1375.3	1326.7	1368.9				
Industrial Safety and Health Technicians	91.9	91.1	89.3	90.9	91.5				
Instrument and Control Technicians	466.6	480.6	478.8	466.3	478.5				
Laboratory Technicians	794.1	865.5	876.9	874.1	918.8				
Media Technician	129.9	136.4	140.6	145.4	145.2				
Survey and Mapping Technician	20.2	18.2	18.2	19.2	20.2				
Other Technicians	288.2	286.8	278.0	297.2	292.4				
Technicians	4793.1	5061.9	4949.7	4946.8	5074.8	4590.6	5153.0	5154.4	
Technical	15124.7	16498.8	16914.4	17041.3	17678.9	16804.7	19757.5	19374.8	16173.5
First Line Supervisors	2942.6	3203.5	3231.8	3171.7	3057.5				
General Managers and Executives	755.1	744.3	744.3	753.2	749.6				
Project and Program Managers	1076.6	1192.9	1254.0	1312.8	1357.0				
Other Managers	974.7	996.3	1038.8	1043.0	1035.4				
General Managers, Executives and First Line Supervisors	5749.0	6137.0	6268.9	6280.7	6199.5	6028.0	6733.8	6724.9	
Management	5749.0	6137.0	6268.9	6280.7	6199.5	6028.0	6733.8	6724.9	6192.1
Accountants and Auditors	698.3	727.7	773.1	776.6	813.3				
Architects	39.6	44.7	49.7	57.1	59.1				
Buyers, Procurement and Contracting Specialists	512.2	520.7	544.1	570.1	599.6				
Communication Specialists	135.5	135.4	135.1	139.7	140.9				
Compliance Inspectors	306.2	329.7	339.3	351.6	356.3				
Computer Systems Analysts	380.1	403.3	429.8	436.2	469.7				
Cost Estimators and Planners and Schedulers	1387.7	1499.1	1493.8	1501.5	1498.5				
Health Physicists	333.1	355.3	349.0	351.1	382.5				
Industrial Hygienists	164.9	170.3	180.0	165.0	187.2				

Table 1.1. (contd)

Lawyers	51.0	54.7	60.7	56.7	61.7			
Personnel and Labor Relations Specialists	323.6	328.4	331.2	337.4	343.9			
Physicians	32.6	34.7	33.9	33.7	33.8			
Physician Assistants, Nurses and Other Medical Support	99.6	102.0	101.1	101.8	107.9			
Safeguards and Other Security Specialists	417.1	407.6	388.9	397.5	395.8			
Trainers	655.3	671.4	605.7	620.5	607.6			
Technical Writers and Editors	396.7	417.7	424.9	429.7	421.6			
Other Administrative and Professional Other Occupations	802.5	779.2	736.1	745.5	747.9			
Administrative and Other Professional Occupations	6736.0	6981.9	6976.4	7071.7	7227.3	7463.9	8525.9	8288.8
Administrative Assistants	535.8	598.5	638.7	651.5	677.6			
Office Clerks (general)	1284.4	1322.5	1347.6	1372.1	1370.1			
Office Clerks (specialized)	1038.8	999.4	963.9	947.9	950.3			
Secretaries	1381.7	1470.3	1511.3	1515.1	1540.2			
Typists and Word Processors	659.0	714.7	741.7	746.1	728.0			
Other General Administrative, Secretarial and Clerical Support	50.9	51.8	54.2	54.0	56.2			
General Administrative, Secretarial and Clerical Support Staff	4950.6	5157.2	5257.4	5286.7	5322.4	5188.0	6020.2	5845.5
Administrative	11686.6	12139.1	12233.8	12358.4	12549.7	12651.9	14546.1	14134.3
						11871.0		
Carpenters	352.5	363.8	346.0	344.3	324.8			
Electricians	1063.8	1133.1	1129.6	1106.1	1063.2			
Heating Air-Conditioning and Refrigeration Mechanics (HVAC)	90.0	102.0	103.0	110.0	109.0			
Machinists	318.1	258.7	163.5	164.3	158.4			
Masons	339.0	396.0	409.0	426.0	396.0			
Millwrights	598.0	645.0	625.0	619.0	588.0			
Painters	235.0	250.9	235.5	241.2	233.4			
Plumbers and Pipefitters	408.3	421.8	425.3	411.8	423.4			
Structural and Metal Workers	251.2	250.4	228.4	230.8	223.8			
Vehicle and Mobile Equipment Mechanics	183.6	144.0	151.8	150.7	145.3			
Welders	220.2	233.3	230.2	236.2	218.7			
Other Crafts	212.3	240.8	270.4	281.3	373.4			
Crafts	4272.0	4439.8	4317.7	4321.7	4257.4	4846.9	5903.3	6069.4
Chemical System Operators	560.4	601.6	509.7	498.7	486.7			
Drillers	49.0	75.0	99.0	112.0	188.0			
Light Vehicle Drivers	590.7	597.8	551.9	452.6	432.0			
Material Moving Equipment Operators	692.8	670.0	521.8	396.7	357.3			
Nuclear Plant Operators	526.8	631.4	676.3	694.4	748.6			
Nuclear Waste Process Operators	1138.1	1260.2	1259.8	1246.5	1144.0			
Utilities Systems Operators	382.7	358.6	401.6	413.6	423.4			
Other Operators	287.0	278.0	197.0	190.0	220.0			
Operators	4227.5	4472.6	4217.1	4004.5	4000.0	4793.0	5590.8	5249.8
Firefighters	142.0	141.0	135.0	135.0	135.0			
Food Service Workers	178.4	169.6	181.6	180.0	178.0			
Janitors and Cleaners	522.0	516.6	552.4	541.7	525.4			
Laundry Workers	160.8	133.1	136.1	135.9	136.0			
Material Handlers, Helpers and Laborers (general)	394.0	405.7	414.6	432.2	440.0			
Material Handlers, Helpers and Laborers (specialized)	312.1	237.1	159.1	91.1	76.1			
Security Guards	722.0	717.0	723.0	729.0	734.0			
Other Laborers and General Services Workers	183.2	194.9	187.0	185.9	175.5			
Laborers	2614.5	2515.0	2488.8	2430.8	2400.0	2047.8	3472.6	3632.2
Crafts	11114.0	11427.4	11023.6	10757.0	10657.4	12687.7	14966.7	14951.4
						12965.2		
TOTALS	43674.3	46202.3	46440.7	46437.4	47085.5	48172.3	56004.1	55185.4
						47201.8		

Table 1.2. Rank Demand and Criticality, Anticipated Supply and Required Degree for Selected Scientific, Engineering, and Technical Occupations Drawn from the MNAS

Occupation	Demand	Supply	Degree
Environmental Engineer	1	V. Low	Mix of BS and Advanced
Administrative Clerical	2	-- *	Mostly Associate
Chemical Engineer	3	V. Low	Mix of BS and Advanced
Project Manager	4	--	Mostly Bachelor
Mechanical Engineer	5	Low	Mix of BS and Advanced
Material Handler	6	--	HS or less
Nuclear Waste Process Operator	7	--	Mostly Associate
Chemist	8	Low	Mix of BS and Advanced
Hazardous Waste Mgmt Specialist	9	--	Mix of AS and BS
Environmental Scientist	10	--	Mix of BS and Advanced
Health Physics Technician	11	V. Low	Mostly Associate
Safety Engineer	12	--	Mostly Bachelor
Waste Management Engineer	16	--	Mix of BS and Advanced
Health Physicist	19	V. Low	Mix of BS and Advanced
Hydrogeologist	20	Low	Mix of BS and Advanced
Industrial Hygienist	29	V. Low	Mostly Bachelor
Risk Assessment Manager	33	--	Mostly Bachelor
Driller	53	--	Mostly Associate

* Dashes indicate occupations for which supply data were not available.

Note: Bold type indicates high priority occupations.

The EHM Tech study reported on two neglected sources of training for technicians: corporate courses and community colleges. EHM technicians are found in many organizational departments performing a variety of tasks with a common core of knowledge and skill sets. Many organizations have established their own EHM training curriculum by collaborating with community colleges. The study recommends that these trends be encouraged; specifically, that corporate (in-house) courses be regarded as a valid educational/training experience and that greater use of the community college network be made to address technician training needs.

Hanford 30-Year. In an effort to determine the feasibility of collecting long-range employment projections based on well-crafted technical plans, data were collected from five top executives of the Hanford prime contractor. They were chosen for this preliminary effort for their broad responsibility for and knowledge of the Hanford Site. Each executive estimated site-wide employment needs for nine occupational families during four environmental restoration activity phases over the period, 1992-2023+. The executives also listed the three occupations they felt would be the most populous within each family. Unlike the Roadmap study, participants in this exercise did not give point values (a head-count or full-time equivalent [FTE] number) for each estimate. Instead, they projected the percentage of total site employment each family would occupy in each activity phase. Employment numbers were generated on the basis of these percentage distributions by applying a cost-per-FTE figure to the anticipated site budget for each phase and allocating the resulting total site employment figure across the percentage assigned to each family. Consequently, this was a more explicitly budget-related exercise than the previous three.

ORAA. The Environmental Restoration and Waste Management: An Occupational Assessment for the Oak Ridge Area (ORAA) study (Note 4) was conducted to clarify results from the MNAS for the Oak Ridge site. One Oak Ridge respondent to the MNAS listed occupational needs only for technicians, scientists, and engineers in general. That is, this respondent did not distinguish between occupational specialties within these families. Unfortunately, this respondent managed a large program at Oak Ridge and as a result, a significant portion (approximately 40%) of the needs reported at this site are in this summary form.

The authors of the ORAA surveyed senior managers of six subcontractors in the Oak Ridge area in order to define site needs more specifically. The authors did not use the 53 occupations survey used in the MNAS. Instead they relied on a subset of 27 occupations listed in Table 4.4 of that study which are representative of ER/WM needs. Managers were contacted individually and were interviewed as well as surveyed by the authors. No employment projections were made by these managers. Instead, they assessed their qualitative need for individuals in the 27 occupations and discussed the recruiting and staffing difficulties they encountered.

1.1 Summary of the Studies

Although these studies used substantially common methods for collecting data, they varied, sometimes significantly, on other characteristics (see Table 1.3). For instance, the timeframes examined varied from three to 30 years, the number of occupations that were examined ranged from 1 to 83, and the breadth of the projections ranged from workforce needs across the EM complex to those exclusively at one site. Although nearly all studies were published within a year's time, the data collection periods differed. Data for the Roadmap study, for example, were collected from October to December 1992, a year after much of the data for the MNAS had been collected.

Table 1.3. Characteristics of the Workforce Projection Studies Examined in this Report

Study	Topic	Timeframe	Occupations/families	Methods
Roadmap HR Projections January, 1993	complex-wide needs for the comprehensive workforce	30 years (FY 1993- FY 2019)	83 occupations 9 families	varied
MNAS June, 1992	complex-wide technical workforce needs	5 years (FY 1993- FY 1997)	53 occupations 4 families	survey/ focus groups
EHM Tech December, 1992	DOE and private needs for hazardous material technicians	3 years 1992-1994	1 family	survey/ interviews
Hanford 30-year February, 1992	comprehensive needs at Hanford	30 years FY 1993- FY 2023	9 families	survey/ focus group
ORAA 1992	Oak Ridge technical workforce needs	5 years (FY 1993- FY 1997)	27 occupations	survey/ interviews

Several steps are needed to accommodate these differences for the purposes of this report. Because the specific occupations examined varied widely across studies, comparisons among projections are aggregated at the occupational family level. Definitions at the family level are more consistent than those at the occupational level and, therefore, will result in more reliable comparisons. They are illustrated with breakdowns by occupation when possible. The years (points in time) for which projections are made can be aggregated only at multi-year intervals since none of the studies attempted year-by-year projections over the timeframe each examined. However, several did report projections for multi-year intervals, and comparisons of both short- and long-term projections are possible by

aggregating across these studies. Consequently, the time periods illustrated in this report are for the years 1993, 1997, and 2012. Finally, data for this report are not presented in the form they were originally collected or presented; that is, in point estimate or summation form. Instead, percentages for occupations or occupational families are used to illustrate workforce changes over time. This approach is necessary because summing employment needs, say, for engineers, across several studies is not warranted when the studies differ inconsistently in terms of the project managers sampled, the timeframes estimated, and the period during which data were collected. An analysis based on percentages permits a better examination of personnel needs due to work plans by eliminating effects due to double counting, site size, and budget assumptions.

1.2 Results of the Studies

1.2.1 Comparing Results Within Studies

Roadmap. Several of the sites responding to the Roadmap effort did not respond as requested. Sites reporting to the Albuquerque Field Office estimated employment needs for waste management activities but not environmental restoration. In addition, it is not clear that every site accounted for subcontractors and federal employees as well as prime contractors. The data provided by the sites reporting to Albuquerque are definitely not comparable with data from the remaining sites and are not included in subsequent comparisons. The comparability of data provided by the remaining sites (Fernald, Hanford, Idaho, Rocky Flats, and Savannah River) is suspect. For instance, sites were to base their projections on the most feasible ER/WM option available. Some sites interpreted this to mean the most feasible technical solution, given current technology and anticipated regulatory developments; whereas others interpreted it to mean the work that could be accomplished, given the most likely budget that would be allowed. As a result, some sites made out-year (beyond FY 1997) projections by fitting budget to work scope (Hanford, Fernald); others fit work scope to assumed budget increases; and others failed to report their interpretation. Data from these five sites are compared with the knowledge that each may not have estimated needs using the same criteria or planning assumptions.

The projected percentage of site employment accounted for by each occupational family at the Fernald, Hanford, Idaho, Rocky Flats, and Savannah River sites are presented for the years 1993, 1997, and 2012 in Table 1.4. Each occupational family's percentage of total site employment changes relatively little over the 20-year period considered. Hanford, which reports that 22% of its workforce is currently engineers, projects that engineers will account for 21.4% of the workforce in 2012. Similarly, Idaho projects that 18% of its workforce in 2012 will be professionals, equal to its current workforce percentage.

There are, however, a few occupations subject to large changes. Large percentage increases in site employment occur at Hanford for the operator (7.5% to 10.7%) and craft (6.7% to 11.8%) occupations; for laborers at Savannah River (4.5% to 8%); technicians, professionals managers, and crafts

Table 1.4. Projected Percentage of Site Employment Accounted for by Occupational Families by Site and Year Drawn from Roadmap Data

	Fernald			Hanford			INEL			Rocky Flats			Savannah River			Average		
	'93	'97	'12	'93	'97	'12	'93	'97	'12	'93	'97	'12	'93	'97	'12	'93	'97	'12
Engineers	19	20.4	16	22	24.1	21.4	19	19.8	21	15.7	16.7	16.7	21	21.8	22.4	19.34	20.56	19.5
Scientists	3	4.6	5	4.2	5.4	5.4	7.3	6.1	6	2.8	3.5	3.5	2	2.5	2.6	3.86	4.42	4.5
Technicians	18	16	21	10.8	10.8	8.3	11	12	12	13.5	13.8	13.8	6.7	6.9	6.2	12	11.9	12.26
Manager/Sup	13	16.2	17	12	11.2	9	14	14.8	15	12	14.5	14.5	15.9	15	14.4	13.38	14.34	13.98
Professional	13	15.6	21	16	16.1	15	18	17.5	18	18	16	16	13.4	13	13	15.68	15.64	16.6
Clerical	6	5.4		15	14	12	11	10.5	11	11	11	11	9	9.5	9.5	10.4	10.08	10.88
Crafts	5.7	5.8	9.7	6.7	6.8	11.8	5.3	5.1	5	11	7.3	7.3	16.5	16.7	14	9.04	8.34	9.56
Operators	14	11	8.6	7.5	7.9	10.7	9.3	8.7	8	7.1	6.5	6.5	11	10.3	9.5	9.78	8.88	8.66
Laborers	6	5		4.5	3.6	5.5	3	5.5	2.5	7.8	9.7	9.7	4.5	4.4	8	5.16	5.64	6.425
Change Factor '93 to year	1.1	0.57		1.29	1.6	1.6	1.48	1.7		0.75	0.75	0.75	1.07	1.4		1.11	1.31	

workers at Fernald; and laborers at Rocky Flats. Large percentage decreases are projected for technicians, managers, and administrative occupations at Hanford; operators and engineers at Fernald; craftworkers and professionals at Rocky Flats; and operators at Idaho.

The stability of the overall projections (illustrated in the final three columns of Table 1.4) appears quite strong given the projected changes in employment levels at the sites. A change factor (using 1993 as a base) is calculated for each site for 1997 and 2012 and illustrated in the last row of Table 1.4. (Change factors greater than one indicate an increase in the workforce, those less than one indicate a decrease. A change factor of one indicates no change in the size of the workforce.) Hanford and Idaho project 60% and 70% increases, respectively, in their workforces between 1993 and 2012. Their occupational change factors in 1997 indicate they expect continued growth throughout the 20-year time period. Savannah River expects somewhat slower, though continued growth as well. Fernald and Rocky Flats both project long-term decreases in their workforces. Fernald anticipates that its decrease will occur after a shorter-term increase (indicated by a change factor greater than one in 1997) whereas Rocky Flats projects a one-time decrease which is maintained at that level thereafter.

Examining the projections for FY 1993 to FY 1997 reveals that each of the five sites projected no employment needs for certain occupations. Fernald, for instance, reports no need for electrical engineers, typists, or firefighters, among others, in its ER/WM program. The "missing" occupations for the other sites are presented in Table 1.5.

A few of these occupations appear across sites: heating, ventilation, and air-conditioning (HVAC) workers; masons, and firefighters. Many, however, differ with no explanation in the Roadmap report. Sites may report no need for an occupation because site characteristics are such that some occupations are not needed. For example, if a site plans no capital construction projects there would be little need for masons and HVAC workers. In other cases, sites may report no need for an occupation because of the way occupational estimates were generated. A few sites estimated indirect employees via ratios based on the estimates given for direct; i.e., one indirect support for every direct. For these sites the overall employment projection will be accurate but the distribution across occupations (the occupational mix) may not. Consequently, some occupations may have been overlooked. As mentioned earlier,

Table 1.5. Occupations Not Needed by Site, FY 1993-1997, Based on Roadmap Data

Fernald	Hanford	Idaho	Rocky Flats	Savannah River
Lab Technician	Nuclear Waste Process	Mason	Architect	Safeguards and
Instrument Technician	Operator	HVAC Worker	Typist	Security
Electrical Engineer	Food Service Worker	Millwright	Mason	Specialist
Nuclear Engineer		Driller	HVAC Worker	Vehicle
Typist		Firefighter	Janitor	Mechanic
Metal Worker		Security Guards	Special Material	Nuclear Process
HVAC Worker		Special Material	Handlers	Operator
Firefighter		Handlers		General Laborers

some sites did not account for subcontractors, which may explain the anticipated lack of need for lab technicians at Fernald and architects at Rocky Flats. And differences in how certain occupations are used at sites may affect "needs." For instance, it may be that chemical system operators and nuclear operators also perform nuclear waste process operations at Hanford; thus the report that there is no need for nuclear process waste operators. Finally, sites differ based on the percentage of their budget derived from the EM organization. The lack of need for firefighters, security guards, and typists at some sites may indicate that other programs (such as Defense Programs [DP]) are supporting the land-lord budgets which typically pay for fire and security protection and central services. It is likely that these sources of support are being accounted for differently across the complex, thereby distorting EM versus DP versus other program needs.

The Roadmap study concludes that a reasonable assessment of growth trends and skills needs is available. Although supply data are needed, the report notes that filling chemical engineer positions is expected to be difficult.

MNAS. Sites which responded to the MNAS data collection effort and matched the Roadmap sample illustrated above were included in this analysis. (Savannah River did not provide employment projections data for the MNAS.) Since the MNAS concentrated on the employment needs for scientists, engineers, and technicians, data for those specific occupational families are presented below. Other occupations examined in the MNAS (professional and clerical occupations, for instance) are too few in number to compare with the Roadmap data at the occupation family level.

A 45% growth in the workforce over the period, FY 1993-1997, was projected by program and project managers. Budget calculations for the constrained and unconstrained cases project 49% and 87% growth, respectively. The MNAS subset of data for the Fernald, Hanford, Idaho, and Rocky Flats sites is presented in Table 1.6.

Economic and demographic supply data included in the MNAS suggest that certain occupations will receive low numbers of new graduates/employees for the near term. Low anticipated availability and high demand resulted in predictions of extreme needs for the following occupations: environmental engineer, project manager, and health physics technician among others (see Table 1.2).

Focus groups were included as part of the MNAS to determine the qualitative factors underlying the need for personnel. Specifically, managers were asked to describe the methods they use to recruit and hire staff, the problems they encounter, skills and knowledge they seek, and successes they have experienced. They reported that hindrances to workforce readiness were to be found in organizational and institutional barriers which limit occupational mobility, retention, and hiring. These include head-count restrictions, poorly coordinated recruiting and hiring policies within and across sites, and security restrictions, among others. They also experienced difficulties getting the appropriate regulatory training for their technicians, regulatory analysts, scientists, engineers, and managers.

Table 1.6. Change Factors (FY 1993-1997) for Scientist, Engineer, and Technician Occupation Families Based on Data from the MNAS

Occupation Family	Site				Weighted Average
	Fernald	Hanford	Idaho	Rocky Flats	
Scientist	1.61	1.57	1.48	.98	1.45
Engineer	2.65	1.68	1.45	.94	1.61
Technician	2.5	1.20	1.66	1.05	1.46
Average	2.38	1.45	1.52	1.00	

Note: Change factors greater than one indicate a projected increase in the workforce whereas growth factors less than one indicate a decrease. A change factor of one signifies no change in the size of the workforce.

Managers reported having success when they are able to recruit from a variety of disciplines and factor experience into the hiring decision. In fact, they find experience to be a much greater predictor of on-the-job success than academic background. Prime contractors have been relatively more successful at recruiting for science, engineering, and technician positions precisely because they have greater flexibility to substitute experience for an academic degree. Not surprisingly, contractors find their in-house workforce to be equally flexible. Individuals with strong basic science and technical skills, managers say, are able to apply their skills to a variety of projects.

The MNAS concludes that "there is little need for large changes in the workforce skills mix" (p. ix). Certain occupations, however, will be difficult to staff. These primarily are highly skilled occupational classes unique to the DOE environment, such as health physics technicians and chemists with radiological experience. These "niche" occupations should command the most attention and are, according to managers, most effectively addressed via on-the-job experience, mentoring, and short training courses. The report also concludes that many perceived occupational shortages are not the result of a lack of qualified workers. Instead, shortages more often result from organizational and institutional restrictions, barriers, and policies which make it more difficult for the DOE complex to recruit, staff, and retain technical personnel.

EHM Tech. No projections for environmental hazardous materials technicians were gathered. However, the survey and interview data indicate that "an adequate supply of trained technician-level personnel in the environmental management industry is not readily available" (p. vi). The managers surveyed expect the need for these individuals to increase moderately to substantially over the next one

to three years. Managers report no lack of people willing to accept technician jobs. Instead they find themselves paying higher salaries for overqualified personnel or paying training costs for under-qualified candidates.

The study also reports that "the skills required of technician-level environmental personnel are remarkably consistent across a broad range of specific occupations in both private-sector and DOE employment" (p. vii). Technical skills consist of relatively basic knowledge of math, chemistry, geology, and physics whereas non-technical skills include communication, teamwork, and problem-solving skills. Specialized regulatory knowledge is often required as well.

More important than education, however, is experience. Managers report that experience gained outside EHM jobs, such as that derived via co-op internships or technician jobs outside the DOE complex, is valuable. Education, they note, is valuable only to the extent that related work experiences are included.

Of the 128 managers who provided data, 98 anticipated hiring EHM technicians during the next one to three years. Over half of these managers indicated that a high school degree plus some on-the-job or community college training is sufficient to meet the knowledge and skill demands of technician-level positions. Relatively few (14%) indicated the need for technicians with four-year college degrees. Educators also expected that employers in their local area would demand more EHM technicians. Nearly 70% felt that industry in general would increase its demand for these occupations.

The study did not gather any economic or demographic data characterizing the availability of EHM technicians. However, a surrogate "supply" question regarding the difficulty managers experienced when recruiting technicians was included. Nearly two-thirds of the employers surveyed anticipated that it would be slightly difficult or difficult to recruit qualified individuals for these positions. A similar assessment of students indicates that students in general found it "somewhat easy" to obtain employment (p. 118). This experience, however, differed by education level. More than half the students who completed one- or two-year certificates or two-year AA degrees found it somewhat easy to obtain employment; on average, only 27% of students with this background found it somewhat difficult to obtain a job. A much higher percentage of students who possessed less background--that is, those who attended individual semester classes or public short courses--experienced some difficulty finding work.

The EHM Tech study concludes that the demand for EHM technicians is increasing and that, during the near term, an adequate supply of trained technicians will not exist. Although enrollment in community college technician programs is increasing and these programs meet the needs of local industry, the authors suggest consideration should be given to expanding them further.

Hanford 30-Year. The Hanford Site contractor used its own occupational classifications for this exercise. As a result, the technician family of occupations defined in this study is not directly comparable to the previous three. The contractor at the Hanford Site distinguishes occupations on the basis of whether they are represented by a bargaining unit. As defined here, technician includes those

occupations involving technician-level work that are not represented by a union. Certain occupations which would normally be included in this family are classed as operatives because of their representation.

Data were collected for Hanford based on an intermediate planning case, the 200 Area Plateau Option. This is considered the most likely remediation scenario wherein certain wastes are consolidated onsite for permanent disposal (and permanent site control by the U.S. government), and other wastes are cleaned from the soil and groundwater and shipped offsite for disposal. Land outside the permanent disposal site would be certified for public use. (This is the same scenario used by Hanford for its Roadmap exercise.)

Managers at Hanford balked at projecting specific numbers for the occupational families under consideration. They argued that technologies were still to be developed and that unforeseen events would likely make long-term projections obsolete. They felt that better and more useful data would result from assessing the percentage of site employment each family would assume and how that percentage would change over time. Projections for all occupational families are presented in Table 1.7. Time was marked not in years but in activity phases, which are defined in Table 1.8.

For each activity phase, the managers were given detailed cost estimates, technical plans and schedules, and material balance sheets for the 200 Area Plateau Option. Managers discussed their assumptions, defined the activity phases more precisely, and then made their projections. The exercise took nearly two-and-one-half hours. Shortly after they made their projections, managers were given the opportunity to comment on the summarized projections and report on the exercise. No substantive changes were offered.

The percentage of site employment accounted for by the administrator, clerical, services, and technician families remains roughly constant (see Table 1.7). The largest relative increases in percentage of site employment are projected for the crafts and operative families. Scientists, engineers, and managers are projected to assume fewer positions over time relative to the other families. The drop in the engineer family is especially dramatic. Managers, on average, predicted that engineers would remain a consistent 22% to 23% of site employment over the first three phases. In Phase 4, however, the number of engineers would decrease to just over 16%. Their explanation was that the final phase would largely involve monitoring, testing, and evaluation activities for which engineering skills are less appropriate. Although the relative percentage of employment by occupational family will change over time, the occupations employed at the Site will not. The most populous occupations across activity phases change quite little, indicating that managers feel the skills possessed by the workforce now are the same skills which will be needed in the future.

Table 1.9 highlights the three occupations with the largest number of incumbents for each family. They are quite consistent across activity phases. For all families, two of the three top occupations in Phase 1 are listed also in Phase 4. The occupations listed across all phases are identical for the administrator, clerical, and technician families. Data from the Hanford 30-year study indicate that managers

Table 1.7. Occupational Family as a Percentage of Total Site Employment Across Activity Phases at the Hanford Site Drawn from the Hanford 30-Year Study

<u>Job Family</u>	<u>Activity Phase</u>	<u>Mean</u>
Administrator	1	0.156
	2	0.152
	3	0.154
	4	0.158
Clerical	1	0.118
	2	0.116
	3	0.114
	4	0.122
Crafts	1	0.142
	2	0.160
	3	0.182
	4	0.178
Engineer	1	0.230
	2	0.226
	3	0.222
	4	0.162
Manager	1	0.120
	2	0.104
	3	0.102
	4	0.102
Operative	1	0.078
	2	0.090
	3	0.080
	4	0.110

Table 1.7. (contd)

<u>Job Family</u>	<u>Activity Phase</u>	<u>Mean</u>
Scientist	1	0.086
	2	0.078
	3	0.068
	4	0.070
Services	1	0.038
	2	0.032
	3	0.032
	4	0.030
Technician	1	0.034
	2	0.036
	3	0.042
	4	0.036

Note: percentages summed by activity
phase may not equal 100% due to
rounding.

Table 1.8. Activity Phases Assumed for the 200 Area Plateau Option for the Hanford 30-Year Study

Phase 1	Evaluation, investigation, characterization and design	0-5th year
Phase 2	Construction and initiation of cleanup	5-15th years
Phase 3	Operations and completion of cleanup	15-30th years
Phase 4	Monitoring, surveillance, and closure	30th year +

Table 1.9. Most Populous Occupations in Each Family Based on Hanford 30-Year Projections

Category	Phase 1	Phase 2	Phase 3	Phase 4
Engineers	Software	Software	Environmental	Chemical
	Chemical	Chemical	Chemical	Software
	Mechanical	Mechanical	Software	Environmental
Scientists	Geoscience	Environmental	Chemist	Chemist
	Health Physics	Chemist	Environmental	Geoscience
	Chemist	Geoscience	Health Physics	Environmental
Administrators	Staff Assistant	Staff Assistant	Staff Assistant	Staff Assistant
	Instructor	Instructor	Instructor	Instructor
	Technical Writer	Technical Writer	Technical Writer	Technical Writer
Crafts	Process Operator	Pipefitter	Process Operator	Process Operator
	Power	Chemical Tech	Chemical Tech	Instrument Tech
	Chemical Tech	Concrete	Instrument Tech	Chemical Tech
Operators	Health Physics Tech	Health Physics Tech	Health Physics Tech	Surveillance
	Drivers	Equipment	Equipment	Health Physics Tech
	Equipment	Drivers	Drivers	Drivers
Clerical	Clerk	Clerk	Clerk	Clerk
	Secretary	Secretary	Secretary	Secretary
	Word Process Clerk	Word Process Clerk	Word Process Clerk	Word Process Clerk
Technicians	Computer	Computer	Computer	Computer
	Environmental	Environmental	Environmental	Environmental
	Quality Assurance	Quality Assurance	Quality Assurance	Quality Assurance

are highly skeptical of their ability to project employment needs over a significantly long period. Providing detailed schedules, cost estimates, and material balance sheets did not give these managers the confidence they needed to project headcounts. They did, however, feel they could assess the need for families of occupations relative to total site employment.

ORAA. The managers who participated found the subset of 27 MNAS occupations to “represent both a relevant and focused list for ERWM projects” (p. 9). The occupations identified by managers in the ORAA study as high needs and potential significant recruiting difficulties matched closely those identified in the MNAS. These are environmental and chemical engineers, project managers, health physicists, hazardous waste management specialists, and hydrogeologists. The authors also predict an increase in the need for engineers as more of the ER/WM budget shifts from site assessment to site cleanup. “Traditional” engineering fields are expected to benefit from this shift; specifically, mechanical, civil, and electrical engineers.

1.2.2 Comparing Projections Across Studies

Growth by Site

Growth projected for each site by the Roadmap, MNAS, and Hanford 30-year study is presented in Table 1.10 for the years FY 1993-FY 1997. Growth tends to be higher (or decreases lower) for the Roadmap data when non-science/engineering/technician occupations are excluded, indicating that, for the short run, the need for scientists, engineers, and technicians will increase relative to other occupations. With the exception of Idaho, projections for the MNAS tend to be higher than Roadmap projections for the same period, particularly for Fernald and Hanford.

Growth by Occupational Family

The growth of the engineering and technician families varies considerably by study (see Table 1.11). The Roadmap study projects a lower rate of growth for engineers and technicians than the MNAS. The Hanford 30-year study reflects the site-wide budget increase projected for accomplishing the scenario chosen as the basis for the Hanford projections.

Differences Among Projections

Several factors can explain the rather large differences among growth projections illustrated in Tables 1.10 and 1.11. These include program funding issues, the time period during which the data were collected, and the varying characteristics of the sites.

Table 1.10. Projected Growth (decline) by Site and Study, FY 1993 - FY 1997

Site	Roadmap (all occupations)	Roadmap (SETs only) ^(a)	MNAS	Hanford 30-Year ^(b)
Fernald	10%	11%	138%	NA
Hanford	29%	37%	45%	56%
Idaho	48%	53%	52%	NA
Rocky Flats	(25%)	(21%)	0%	NA
Savannah River	7%	13%	--	NA

(a) Scientists, engineers, and technicians.

(b) Hanford 30-year projections are based on anticipated budget increases.

Table 1.11. Projected Growth by Occupation Family and Study for Scientists, Engineers, and Technicians, FY 1993 - FY 1997

<u>Job Family</u>	<u>Roadmap</u>	<u>MNAS</u>	<u>Hanford 30-Year^(a)</u>
Scientist	43 %	45 %	56 %
Engineer	24 %	61 %	56 %
Technician	10 %	46 %	56 %

(a) Hanford 30-year projections are based on anticipated budget increases.

Issues Related to Program Funding. Comparing projections across sites is difficult in several cases because of unclear distinctions between site projections and EM projections. At several sites--for instance, Hanford and Fernald--EM is the site landlord. Since EM absorbs the costs of central and infrastructure services at these sites, the number of EM workers nearly equals total site employment. Sites with other landlords, such as DP, will report a much different set of skills if EM program dollars do not carry landlord costs. These "total site" versus "EM program" considerations may have resulted in significant differences in projections among studies, mainly in the Professional, Crafts, and Administrative families.

Rapid shifts in mission and large increases in program funding have undoubtedly increased the EM-funded workforce at several sites. EM-funded employment at Rocky Flats, for instance, increased from approximately 800 in 1991 to 8375 in 1993, and at Savannah River by an even greater amount. An unresolved question is whether this increase represents the addition of "EM-relevant" skills to the workforce or the simple transition of DP (or other program) personnel as a consequence of changes in landlord status. If the latter, further adjustments can be expected as these sites reduce their security perimeters, discontinue production/maintenance activities, and begin Remedial Investigation/Feasibility Study (RI/FS) characterization and preliminary site cleanup efforts. The impact of these changes on overall headcount at sites is unclear. Headcount, however, will clearly be more sensitive to program-related funding, work scope, and scheduling changes than skills mix. As noted in the MNAS, the experience and flexibility of the workforce reduces the likely changes in the occupational skills mix needed to achieve the EM mission. However, marked changes in the skills mix are likely at sites such as Rocky Flats and Savannah River that have fewer technicians, professionals, and scientists and relatively greater skilled production workers whose skill sets may not match EM needs.

Issues Related to Time of Data Collection. Data for the MNAS were collected in July and August 1991 for Fernald and Hanford, and October through December 1991 for most other sites. Roadmap data were collected from all sites a year later, October through December 1992. Although separated by only a year, several major changes occurred which partially account for the sometimes

significant differences in projections. At Fernald the MNAS researchers interviewed project managers shortly after Fernald became an EM site and just as site restoration (and significant hiring) efforts began in earnest. The Fernald Roadmap projection of a 10% increase in FTEs fails to factor in the 1200+ increase in headcount that occurred between July 1991 and October 1992. If this pre-FY 1993 increase is included, the growth of Fernald to present is 110%, which is much closer to the 138% growth predicted by the MNAS. The same is true for Hanford; actual site growth calculated from the time data were collected is much closer to the MNAS-predicted growth.

Fernald and Hanford appear to be unique among the sites examined here in that they hired relatively quickly and began cleanup efforts before the others. Further efforts to examine workforce changes should clearly explain the period of data collection, status of landlord changes, and reconfiguration plans of other programs, such as DP.

Issues Related to Site Characteristics. Sites vary on several factors which affect workforce projections. Site acreage, production/research mission, type and extent of contamination, cleanup schedules and plans, and current skills mix all affect the "need" for employees. Sites have, on many occasions, been asked to project their human resources needs without adequate site characterization and beyond the plans (or planning horizon) that have been adopted. There have been few attempts to classify sites along these dimensions to project workforce needs. As a result, workforce comparisons have been made between sites that may share few technical problems or environmental restoration plans in common.

A gross attempt to avoid comparing "apples and oranges" can be accomplished here by concentrating on a relatively short timeframe (the FY 1993-FY 1997 planning frame) and taking the major sites characterized in this study. Hanford and Idaho are large sites with major production/reactor and research components. Rocky Flats and Savannah River are large sites with primarily production missions. Fernald is a small multi-program site with a (former) production mission. A brief examination of Table 1.4 indicates that whereas all sites project a relatively high concentration of engineers, sites with research missions tend to "need" more scientists, and sites whose primary mission is production tend to "need" more operators, technicians, and craftworkers.

Differences such as these, which have produced apparent contradictions in workforce projections in the past, can be used to categorize sites to yield more accurate estimates. Hanford and Idaho, for instance, may serve as models for Oak Ridge. Experiences at Fernald may provide insights into workforce needs and transitions at the Mound, Paducah, and Piketon plants. Evidence from relatively "clean" sites which have been decontaminated, such as Shippingport, may be used to model activities at Pinellas.

1.3 Discussion of the Studies

The five studies examined here provide data on several different aspects of EM workforce needs. Three examined a relatively consistent set of occupations, and three used similar techniques for gathering data. When differences in site characteristics, data collection periods, and occupation definitions are considered, the studies paint a relatively consistent and coherent picture of future needs. Most studies across sites report a need for a greater number of workers with skills relevant to the EM mission. Although they did not report in depth their reasons for doing so, sites that predict decreases in the workforce in the short run seem to do so for budgetary reasons, not lack of work. Workforce decreases in the longer run, of course, result from decreased work scope as the sites near completion of their environmental restoration mission. Work-based decreases, however, are not projected to occur for a significant period of time. Managers throughout the complex believe that the work to be accomplished in the 30-year goal established by DOE warrants a workforce that will increase over the next 10 to 20 years and decrease thereafter. Total headcount projections, however, are highly sensitive to a complex web of factors, including budgets, work schedules, site landlord status, and the size and site presence of other DOE programs (such as Nuclear Energy and Energy Efficiency). Projections of total employment, therefore, are likely to be volatile over time.

Though unique site characteristics will cause the skill mix to vary from site to site, skills mix changes are likely to be less sensitive to site characteristics than overall headcount. Therefore, despite valid differences among sites, several generalizations regarding the skills mix over time are possible based on the reports examined here. Engineers have traditionally been, and apparently will continue to be, a significant percentage of the workforce. Although some reports listed projections for engineering specialties it seems that greater emphasis should be placed on hiring and retaining an adequate number of engineers in general rather than specific types of engineering specialties. Participants in the MNAS and ORAA told researchers that engineers (and other well-trained technical people) are versatile employees whose experience allows them to apply their technical skills to a variety of problems. The "need" for engineers and other technical skills, then, may be more easily and accurately predicted on the basis of this broader occupational classification than the more specific ones traditionally used.

The need for other types of employees will probably depend on the activities planned for each site. Greater numbers of technicians and professionals will be needed for site characterization and environmental restoration design and scheduling. Craftworkers will be needed in greater numbers when site grading and construction begins and operators will be in demand when waste management processes are undertaken. The use of activity phases, tailored for each site, is a simple method for enforcing some consistency among sites when detailed ER/WM schedules are not available.

The need for scientists is projected to grow. Even so, scientists will average approximately 5% of total employment. Higher concentrations of scientists will continue to be found at sites with research missions as long as research on ER/WM technologies, methods, and processes is warranted.

Methodological similarities among the studies are significant. The EHM Tech, MNAS, ORAA, and Hanford 30-year studies used a combination of surveys and interviews/focus groups to collect data. These are standard, widely accepted methods. Survey data are rapidly collected and analyzed. They provide quantitative information regarding the numbers of workers needed in occupations and the perceptions of employers, managers, students, and others regarding specific issues. Interviews and focus groups, when properly conducted, deliver qualitative data which expand on the survey input. Combining the two methods permits a uniform data collection process which is sufficiently flexible to capture site-specific differences. The three reports that used these techniques included the surveys and interview/focus group guides used in their efforts.

Unfortunately, reports from the Roadmap exercise include minimal descriptions of the methods used by sites to collect data. Two methods seem to have predominated: interviews and surveys involving project managers. But for many studies it is unclear how the surveys were administered, how many managers they were administered to, and whether the managers had the opportunity to provide feedback on their input once collected. The assumptions used as the basis for Roadmap projections have, to date, been published only for the "fast-track" sites (Fernald, Hanford, Idaho, and Rocky Flats). It is thus difficult to estimate the extent to which differences in workforce projections are due to site characteristics, data collection methods, planning assumptions, or the particular individuals contacted. Future workforce studies should provide full descriptions of the methods, tools, and assumptions used to generate projections. As the work of EM progresses, it will be possible to create standard industrial workforce ratios for different types of contaminants, technologies, and schedules. Until then, extrapolations based on survey and interview data will be necessary.

A legitimate question, however, is, who fills out the survey or responds to the interview? The studies presented in this report all relied on the input of contractors or subcontractors to the DOE. Their input, it has been suggested, may be biased toward overstating personnel needs in order to increase job security, promotion potential, or other benefits. At issue is whether current contractors should be party to projecting workforce needs on contracts they manage. It seems, of necessity, that they must. Although current contractors may tend to push employment numbers upward, firms which are potential bidders on contracts might find it to their benefit to understate the numbers of workers needed to fulfill a goal. The fact is that there are no "independent" parties with the technical and site knowledge needed to produce a credible estimate. Whether we must rely on the inflated estimates of current contractors may be answered by examining employment projections from the MNAS based on managers' judgments and budget projections. Recall that managers projected a 45% increase in the workforce, whereas constrained and unconstrained budget figures project 49% and 87% increases in employment, respectively. It appears, at least for the MNAS, that managers did not inflate their workforce needs when compared with anticipated budget increases. This finding, however, warrants replication.

1.4 Chapter Summary

Given current work plans and technologies, contractor and federal managers at DOE sites anticipate that the EM-funded workforce will increase. There will be a need for engineers, technicians, craftworkers, and operators to perform ER/WM activities. Professional and administrative workers will support their efforts. Continued technology development is expected and the need for scientists will rise accordingly.

Managers in the studies examined here expect that the development of technology and progress of technical activities will mirror that of the recent past. As a result, the well-trained, highly versatile operators, engineers, technicians, and scientists who have typically worked in the complex will be able to accommodate the needs of DOE. The feeling among managers is that these individuals have lived through change before and, with sufficient time to plan a coordinated change, will do so again. More problematic will be the "niche" occupations identified in the MNAS, such as hydrogeologist, radiological chemist, and safety engineer. These occupations are, for the DOE complex, homegrown specialties which are anticipated to be in high "demand" as the cleanup progresses.

There continue to be difficulties conveying the assumptions, budgets, timeframes, and planning scenarios to be used when developing workforce projections. Even when a scenario is specified, such as the most likely technical solution, multiple interpretations are possible. The failure to provide a stable planning platform has unnecessarily reduced the utility of the workforce projections completed to date. Future workforce studies should clearly specify the factors used to define the boundaries of the estimates. More thorough analyses are necessary in order to eliminate effects due to differences in assumptions and more accurately highlight site differences based on valid factors. Finally, it appears that site visits afford more control over the data collection process and greater opportunities to collect qualitative data than other alternatives. Capitalizing on the knowledge of workers at the sites should be an integral part of the workforce analysis program.

Despite sometimes significant differences among the five studies examined in this report, a set of general conclusions can be formed. As the EM mission becomes more clearly defined, it will be helpful to use the contacts and forms developed in all these efforts to update future projections and test the accuracy of old ones. In time, EM will be able to develop a historically based set of standard ratios for estimating personnel needs, given a package of work assignments. Until then, reliance on surveys and interviews/focus groups is warranted. These methods should, however, be constructed consistently, analyzed thoroughly, and supplemented with studies regarding the use of personnel within the DOE complex.

2.0 Supply: Occupational Mobility and the Availability of Workers

Often, the term "shortage" has been used without regard for the supply half of the supply/demand equation. Three of the five studies examined in Chapter 1.0 assessed the supply of potential employees; yet only one of those, the MNAS, used macroeconomic data as well as the assessment of project and human resources managers. In general, too little emphasis has been placed on characterizing the availability of workers with skills appropriate for EM needs. Even less emphasis has been placed on examining the mobility potential of employees with technical skills developed in other industries (several of which may currently be downsizing). Finally, the potential role of wage and salary adjustments in alleviating workforce shortages must be recognized in policy discussions. These issues suggest that significant work needs to be accomplished before strong conclusions can be made about potential demand/supply imbalances in the market for EM-relevant skills.

Based on the data presented in Chapter 1.0, the work to be accomplished at EM-funded sites will support a larger workforce that, in percentage terms, looks much like the workforce today. However, these simple percentage comparisons mask the real changes that will take place in the activities scheduled for the workforce. Nuclear scientists and engineers will still be necessary but will concentrate less on the containment of radioactive particles in a production process and more on their migration through soil, water, concrete, and air. Chemical engineers will design and manage processes to separate multiple, possibly unknown, chemicals from a chemical stream rather than one. Many heavy equipment operators who moved earth for capital construction projects will now do so as part of an environmental restoration effort.

There is no "different" science or engineering which will be used to accomplish these ends. The tools, equipment, and instruments used by employees to work on these issues will operate on the same principles in use today. Scientists and engineers will not necessarily abandon their field of study but will apply it to a different set of problems. To do so, they will have to work more closely with science disciplines not traditionally part of the DOE culture. Technicians and craftspersons will not measure different radiation or move different earth. Instead, they will operate their instruments and equipment in different environments, perhaps using different measuring techniques, working within different regulations, or taking different preventive measures.

Recognizing these basic constraints on restructuring the workforce eliminates many bewildering possibilities. However, it still leaves a difficult task. The question remains: how closely do occupational skill sets currently in the DOE complex or industry at large meet the needs of EM?

Managers feel that 1) good basic science and engineering skills are transferable, 2) skill sets will largely remain constant with the onset of the EM mission, and 3) education must be paired with experience to be effective. Therefore, it may be useful to expand consideration of the availability of workers beyond college and graduate school graduation rates and determine how readily skills can be applied to

different jobs. Excellent data already exist on degree enrollments and production. Accordingly, this chapter focuses on the potential for increasing workforce availability via mobility based on occupational and industry characteristics and salary adjustments.

2.1 Changes in the Conduct of R&D

The advances made in basic science and engineering technology in this country have not been translated as successfully into commercial products. As a result, U.S. companies have experienced increased competition and decreased profitability. To combat this trend many companies have increased their investment in R&D; the employment of scientists and engineers (S&Es) has grown faster than the growth of the economy, and has increased even in declining industries, such as manufacturing. Some large companies now boast research facilities better than those of the best universities. Their focus, however, is R&D applied to product development. Business pressures permit few organizations to support the basic research they encouraged in the past. Even Bell Labs, long considered a pre-eminent private basic research lab, has restructured to develop more of its science into marketable products (Fortune 1993).

Tight budgets have also affected the universities. Research grants are now harder to obtain and universities have pursued industrial partners to capitalize on their research experience. Although the university remains the last refuge for those interested purely in basic research, it is increasingly difficult for a researcher to carve out such a niche (The Scientist 1991).

It remains to be seen if industry's investment in scientists and engineers will pay off. The key may be in the selection and development of these professionals. Our level of scientific knowledge resulting from basic research, by many accounts, has increased geometrically. Yet, our application of this knowledge proceeds linearly. It is quite possible that applying scientific knowledge differs markedly from creating it. Different teams of researchers, levels of investment, states of thinking, and experimental approaches are required.

Table 2.1 outlines some of these differences. The scientists and engineers involved in the application of scientific knowledge will have to be willing to work in environments which change rapidly in response to market conditions and technological developments. They will also have to become acclimated to publishing in new journals, reading a new set of literature, and exploring the boundaries of their specialization with professionals in other fields. Innovative ideas will be drawn more from manufacturing, marketing, and design in addition to basic research (Kline and Kash 1992). Project and financial management will assume an even larger percentage of the time of S&Es. The typical degree demanded for employment in research application and technology transfer may change as well. As the need for specialized experts decreases and breadth of knowledge becomes important, the need for large numbers of Ph.D.-trained individuals may decrease. Taking their place will be bachelor's- and master's-level workers with strong basic technical skills and broad experiences (National Academy Press 1985). They will work in relatively short-lived teams on rapidly changing problems. Individuals

Table 2.1. Differences Between Science Knowledge Creation and Application

<u>Science Knowledge Creation</u>	<u>Science Knowledge Application</u>
exponential growth	linear growth
increased specialization of personnel	broad and interdisciplinary personnel
more atomistic	more holistic
small teams of like professionals	large teams of multiple perspectives
small number of large investments ("big science")	large number of small to moderate investments (prototype development)
distant returns on investment (science for science's sake)	quick returns on investment (market driven)

will, in many cases, need not only to work with people from different fields, but will have to learn something about that field and its application to their own. The question then arises, "How readily can these individuals cross occupational boundaries?"

2.2 National Trends in Occupational Mobility

Simply put, occupational mobility is the tendency for individuals in one occupation to switch to another. It has been tracked for the general population by the Bureau of Labor Statistics via its Current Population Survey (CPS) since 1967. Markey and Parks (1989) used the CPS to characterize workers who switched occupations between 1986 and 1987, and report several generalizations:

- occupational mobility is much greater for younger than older workers
- higher levels of education are associated with higher rates of mobility, except for individuals with highly specific professional training (i.e., lawyers, MDs)
- workers with longer occupational tenures switch occupations less than those with shorter tenures.

Although the U.S. has a relatively mobile labor workforce, occupational mobility is mostly confined to younger workers. For example, Mincer and Jovanovic (1979) concluded that 70% of the males with one year of tenure and 10 years of overall experience would make voluntary occupational changes. By contrast, only 6% of the males with 10 years of tenure and 40 years of overall experience would undertake a voluntary occupational change. Parsons (1986, p. 792) estimated that 28% of workers were occupying a job that would last 20 years or more. Finally, Markey and Parks (1989) found relatively little voluntary occupational change in the middle-age segment of the labor force; the

“so-called midlife career changers” (p. 6). They speculate that the wealth of experience and knowledge gained through tenure makes career and occupational changes more risky for older workers. In short, older, more experienced workers with longer tenure are less likely to switch occupations or geographic locations.

2.3 Mobility Patterns in Science and Engineering

Specific data on the employment and occupational mobility of scientists and engineers have been published by the National Science Foundation (NSF) for the past several decades. Several of these reports (NSF 1980, 1982, 1985) indicate that the S&E workforce is more mobile and responsive to changing conditions in the labor market than the general population. “By and large, net transitions have occurred from fields in which employment demand has been weak to fields in which employment demand has been strong” over the past 20 years (NSF, 1985, p. 33). Occupational changes (between fields of study) tend to be more common than might be expected. As of 1982, for instance, most bachelor’s degree-level computer scientists held their degrees in disciplines other than computer science (fully 16% majored in the social sciences).

Occupational changes for science and engineering occupations decrease with increased education, as they do for the general population. However, the rate of decrease is lower for S&Es and it is not uncommon to find field-switchers even at the doctoral level. Twenty percent of individuals who earned non-engineering doctoral degrees in 1973 were working as engineers in 1981 (NSF 1985, Chart 37). A slightly smaller percentage of field-switchers was found for the environmental and physical science fields.

Scientists and engineers appear more mobile than the general population for two reasons. First, the standardized education that scientists and engineers undergo is generally similar across fields and applications. Math, statistics, and computer skills, and knowledge of research methodology and analytical techniques are critical in several fields. Second, scientists and engineers may be more occupationally mobile because of more varied career opportunities than other, similarly degreed professionals. Lawyers and doctors may experience only one or two career tracks, such as partnership in a practice or a position in academia. Scientists and engineers, on the other hand, can progress in their profession; enter academia, consulting, or government; or become administrators at universities or line or project managers in industry. In fact, recent NSF surveys indicate that many scientists and engineers who leave the S&E field do so to take administrative and management positions.

Scientists, engineers, and technicians (SETs) will have to become even more flexible in response to sudden and apparently permanent changes in the funding for research and development. Defense industry engineers are finding that they must show prospective new employers how their skills can be applied to non-defense areas. Several SETs who had successfully made the switch were recently profiled in *IEEE Spectrum* (December 1992). One Ph.D. nuclear engineer became a risk analyst for a health maintenance organization by emphasizing his work in probability projections, reliability and

systems analysis, and statistical quality control. In another case, a Ph.D. physicist began work for a firm specializing in medical applications. These cases illustrate the flexibility of the science and engineering workforce and the need for individuals to emphasize their skills and accumulated experiences rather than their research interests or field of study.

2.4 Occupational Mobility in the DOE Complex

Occupational mobility will play an important role in the DOE weapons complex as its production and research facilities assume new missions or are closed. Personnel at these sites will, like their private industry counterparts, have to emphasize their skills, experience, and background in ways that go beyond their discipline-specific jargon. This presents DOE with a unique opportunity to plan and manage this transition. Its workforce is literate, intelligent, and generally well-grounded in basic sciences and systems operations. DOE complex workers are therefore, in theory, more mobile than workers in most industries.

Scientists and engineers can be expected to adapt to these shifts most easily. Their research, mathematical, statistical, and analytical skills should be useful to employers inside and outside the DOE complex. By all reports S&E personnel can get up to speed on new projects which capitalize on their basic skills with a very short period of on-the-job experience.

Crafts, laborer, and some skilled operator personnel are likely to experience somewhat more difficulty during this transition phase. Craftworkers have, through years of schooling and apprenticeship, developed a high level of skill and tend to prefer remaining in their craft. As a result, they are more likely to follow the work that becomes available within their craft. Their employment opportunities in the DOE complex will depend on the scheduling of capital construction projects and decontamination work and (possibly) their willingness to retrain for jobs outside their craft and pay scale. Laborers vary considerably in education level and can transition to new jobs given the proper training. Operator personnel possess considerable training and site experience. They, too, can transition to new jobs. Production system operators, however, may not possess the background necessary to transfer easily to many EM positions in the operator and technician classes. Workers at the Rocky Flats and Savannah River Plants may be particularly vulnerable (MNAS 1992).

Training is crucial for many occupations in the laborer and operator job families. Whereas scientists and engineers receive a great deal of their discipline-specific training in school before entering the job market, operator and many laborer occupations require extensive knowledge of the operation of specific pieces of equipment, production systems, or site operating procedures. Unlike the general analytical skills which scientists and engineers develop, the equipment- or facility-specific skills of an operator must be developed on the job and largely do not transfer to other equipment or facilities. An operator, for instance, is generally trained and certified to work in a particular building on a

particular instrument panelboard after being hired. Although the operator will understand the principles by which another facility works, he/she will need to become qualified at that facility by completing a different training sequence.

2.5 Conclusions Relevant to Occupational Mobility

Several conclusions relevant to occupational mobility within the DOE complex are warranted based on this brief overview of national and DOE data.

First, switching occupations is relatively frequent among younger workers and more common among the science and engineering occupations than the general public.

Second, career-enhancing mobility for the general population is frequent, and possibly undercounted, by the CPS. Occupational mobility and career enhancing moves are studied in more depth by the NSF for scientists and engineers. Based on these data, S&Es seem to have little difficulty switching occupational specialties as the demand for these specialties changes. Qualitative data from multiple sources within the DOE complex indicate that S&Es change their research areas regularly without changing their occupational specialty.

Third, adjustment requirements for employees within the DOE complex will differ based on the nature of their jobs. SETs seem to require mainly a reorientation to a new application area, on-the-job experience, and training in resume preparation and packaging to help them showcase their skills and capabilities. Crafts, laborer, and operator personnel will require retraining for specific site needs if demand for their particular expertise decreases. They may possibly require additional education to support retraining.

Fourth, R&D work will more likely be accomplished in somewhat larger teams with a broader interdisciplinary focus. The application of technologies may rely more heavily on well-trained bachelor's and master's level S&Es with the assistance of more rigorously trained and experienced technicians.

2.6 Occupational Transition Sequences

Given the constraints and trends outlined above, it is possible to plan general transition sequences for the most critical occupations within the complex. These plans are necessary, but largely absent from the DOE complex. They are necessary because many of these occupations fall into the "niche" occupational categories identified by the MNAS (1992). That is, they require unique skills or training which are customarily not found in the general labor force. DOE and its contractors cannot recruit these people in any large measure; they must be "grown." These plans are generally absent because individuals who fill these occupations do so almost by chance. Organizations opportunistically look for

individuals who can become, say, safety or fire engineers as the need arises. Training in these fields is therefore informal and characterized by mentoring, intermittent external training, and a great deal of on-the-job experience.

Transition sequences can improve the "pipeline" of these workers by specifying career paths and formalizing training and accreditation processes. In this way the "supply" can be increased while the time needed to achieve competence is reduced. Niche positions will be open to a broader set of employees who, because of clearer career paths and training and development opportunities, may be more willing to remain employed in the DOE complex. Table 2.2 illustrates the academic, general, and DOE-specific experience needed as well as the possible candidate occupations, time-to-competence, cost, certification, and career paths of the occupations of most concern to DOE. The table was built from salary surveys, published sources, and job and training descriptions from DOE contractors at the Hanford, Rocky Flats, and Savannah River sites (Foushee 1992; Wm. M. Mercer 1991; Brauer 1992; DOE Order 4700.4; ASCE 1991; Watson 1989). The matrix does not specify exhaustive academic requirements or specific training needs. For instance, the need for engineers to be good writing communicators and managers to be good conductors of meetings is assumed. Not including them in the matrix does not imply that they are unimportant skills. This exclusion simply acknowledges that these are not the distinguishing characteristics of the occupations being considered.

In Table 2.3 is a matrix of training costs and time for a broader set of job families. These costs include formal training costs only (no stipends or salaries) and are derived from contractor training databases, trainer estimates, and published reports (Brouns 1971; Ledbetter 1993; Chapple 1992). They do not include the time-to-competence estimates in Table 2.2. Although a distinction is made among training workers with experience (E) and those without (N), there is no attempt to specify the amount of experience necessary to transition to another occupation or occupational family since this will vary considerably across both sites and jobs.

2.6.1 Specific Training and Experience Requirements

As indicated by the open cells, these data are difficult to collect. Few contractors run their training organizations on a cost center basis and few studies have concentrated on the costs as well as the probability of occupational moves. The data in Tables 2.2 and 2.3 are very preliminary. However, three notable points emerge. First, DOE-specific experience reduces markedly the amount of training needed by job candidates. Although occupations differ in the absolute amount of training needed to achieve competence, individuals with no DOE experience take longer to become competent and exceed the training costs of experienced employees by an average of roughly 300%. Second, the general work experiences desired for most occupations involve the practiced application of academic skills (whether gained in high school, college, or graduate school) in a broad variety of contexts. For instance, many managers do not consider an engineer seasoned until he/she has had five or so years to experience a variety of engineering problems. Most craftworkers learn their trade in classes and on-the-job training over a four-year period. Third, the niche occupations tend to require more DOE-specific experience and time-to-competence than other jobs in the same family. Operators and technicians who work with

Table 2.2. Characteristics of Occupations of Concern to DOE-EM

Occupation	Candidate occupations	Degree	Academic KSAs	Desirable general KSAs/experience
Safety (IH)	-Engineer -Scientist -Industrial Hygienist	-BA/BS* -MA/MS	-calculus -statistics -one year each science w/lab -applied mechanics	-familiarity with manufacturing processes -interface w/finance, engineers, etc. -safety principles and their application in broad contexts
HPT	-Security guard -Crafts -Operator	-AS* -BS	-basic sciences -basic numeracy	-HP principles in application such as experience in commercial nuclear facilities or nuclear Navy -radiation basics -6 mo. basics course
Regulatory Analyst	-Engineer -Scientist -Policy Analy. -Attorney	-BS. E* -J.D.	-chemistry thru organic -law; rulemaking and administrative procedures	-regulatory processes -project management -interface w/ engineers
Engineer (professional)	-Engineer -Computer scientist -Mathematician	-BS.E* -AS -MS	-to calculus III -differential equations -statics -dynamics -one year each science w/lab	-interface with non-engineering specialties -value analysis and engineering economics and finance -project management -applications in area of specialty -interaction with other engineering and science specialties
Engineer (research)	-Engineer -Scientist	-BS.E -MS* -PhD*	-above -advanced computer -advanced math and statistics -research design -content specialty	-research experience -applications in area of specialty -interaction with other engineering and science specialties
Project/Program Manager	-Engineer -Scientist	-BS* -MS* -PhD	-same as for engineer/scientist (professional)	-same as for engineer/scientist (professional) -substantial project and finance management

Table 2.2. (contd)

Occupation	Specific experience	TTC	Cost	Certification	Career paths
Safety	-radiation -fire protection -occupational hygiene -site specific knowledge	-varies, OSHA up to 10 years	- ?	-CIH -CSP	-grade promo. -supervision -training -other mgmt
HPT	-instrument qualification -building qualification -DOE sanctioned course	-3-4 wks (E) -3-9 mos (N)	-\$8K -\$25K	-site qualification	-grade promo. -plant engineer -safety engr. -supervision
Regulatory Analyst	-regulatory specialty (OSHA, NEPA, CERCLA) -regulatory constraints on technology and vice versa	-1 yr (E) -5 yr (N)	- ?	-none	-grade promo -management
Engineer (professional)	-DOE internship/co-op	-1-2 yrs (E) -2-3 yrs (N)	-\$2K -\$6K	-PE -other professional certifications	-grade promo. -management -supervision -professional
Engineer (research)	-DOE internship/co-op	-1-2 yrs (N)	-\$2K	-none	-grade promo. -management -supervision -professional
Project/Program Manager	-DOE internship/co-op -knowledge of DOE finance and mgmt systems	-2 yrs (E) -8-10 yrs (N)	- ?	-none	-promotion in management

Table 2.2. (contd)

Occupation	Candidate occupations	Degree	Academic KSAs	Desirable general KSAs/experience
NMPO	-entry level	-HS -AS	-HS math and sciences -2 yrs vocational training	-line process experience
Envir. Scientist/ Scientist	-Scientist -Engineer	-BS -MS -PhD	-advanced math and statistics -research design -advanced lab sciences -content specialty	-same as for research engineer
Chemical Technologist	-entry level	-HS -AS* -BS	-advanced algebra -lab sciences	-familiarity with lab chemistry equipment
Radiochemist	-Chemist/ Scientist	-MA -PhD	-same as for scientist	-same as scientist/engineer
HM Handler (D&D Tech)	-entry level -craft jobs	-HS -AS	-basic numeracy -HS sciences	-on-site experience
Clerical/ Project Clerk	-secretary	-HS -AA	-basic numeracy -communication skills -bookkeeping	-basic competence with computers and spreadsheet and word processing programs

Table 2.2. (contd)

Occupation	Specific experience	TTC	Cost	Certification	Career paths
NWFO	-facility specific knowledge	- ?	- ?	- ?	-grade promo -supervision
Envir. Sci	-DOE internship/co-op	-1-2 yrs (N)	-\$2K	-none	-grade promo. -management -supervision -professional
Chemical Technologist	-lab specific procedures and instruments	-6 wk course (N)	?	-none	-grade promo. -supervision -training
Radiochemist	-DOE internship/co-op	-? years	?	- ?	-grade promo -management -professional
HM Handler (D&D Tech)	-40 hour hazardous materials course	-2 months	?	-site certification	-few
Clerical/ Project Clerk	-DOE reporting and financial systems -project tracking and management	-varies by contractor to 1 yr.	- ?	-none	-administrative assistant -supervision

Table 2.3. Preliminary Formal Training Costs and Times for Occupational Families

From To	Administrative	Crafts	Engineer	Laborer	Manager	Operator	Professional	Scientist	Technician
Administrative	\$300/ 8 hours (E)	NET*	NET	NET	NET	NET	NET	NET	NET
Crafts		\$3500/ 108 hours (E)	NET		NET		NET	NET	NET
Engineer	NET	NET	\$2000/ 60 hours (E) \$6900 9 weeks (No DOE exper.)	NET				\$2000/ 60 hours (E) \$6900 9 weeks (No DOE exper.)	\$2000/ 60 hours (E)
Laborer	NET		NET	80 hours for no DOE exper.	NET		NET		
Manager	NET	NET	\$1725/ 80 hours (E)	NET		NET			
Operator	NET				NET	\$1935/ 120 hours (E)	NET	NET	
Professional	NET		\$5000/ 136 hours (for Trainer)	NET		\$5,000/ 136 hours for Trainer	\$2000/60 hours (E) \$5000/136 hours (for Trainer occupation)		
Scientist	NET	NET		NET					
Technician (HPT/ Instrument Tech)	NET	\$25,000/ 3 months		\$25,000/ 3 mos. (N)	NET	\$8,000/ 88-120 hrs (E)			\$25,000 3 mos. (N) \$8,000 88-120 hrs (E)

* NET = not an expected transition

radiological elements, for instance, require more extensive training than the 40-hour courses offered to most hazardous material workers. Scientists in niche occupations experience long training times. Niche occupations tend to be more interdisciplinary, more applied, and less closely related to typical academic degree fields. Safety engineers, for instance, require more training and time-to-competence than professional engineers who stay in a specialty (i.e., mechanical or chemical engineering) which capitalizes more directly on academic experiences.

2.6.2 Critical Occupations

The characteristics of occupations of concern to DOE-EM as outlined in Table 2.2 are discussed below.

Safety Professional

Typical titles for this occupation are safety engineer, safety compliance inspector, or industrial hygienist. Industrial hygienists will typically have a bachelor's or master's degree in that specific field, but the largest segment of the safety occupational group consists of engineers and scientists with formal training in another field who transferred into the safety area. Emphasis is placed on broad experiences, such as familiarity with production processes, and the application of safety principles based on in-depth knowledge of site operating practices and procedures. For this reason the time needed to achieve proficiency in the safety field varies with the scope of the position and the complexity of the site. Although an engineer or scientist with several years of experience can transition into a safety role and achieve minimal performance standards with some mentoring, true professional competence takes several years. By one manager's estimate, achieving competence in analyzing, evaluating, and applying complex regulations, such as the Occupational Safety and Health Administration (OSHA), can require up to 10 years experience. A more common estimate, however, is seven years experience with a bachelor's degree.

Safety training curricula are generally patched together from various other training programs. With the exception of industrial hygienists, professional society standards and academic degree curricula have only recently been developed (Brauer 1992). Career paths for safety professionals are generally limited to promotion in grade or positions in training. Greater consideration should be given to positions that safety professionals can aspire to in order to enhance the attractiveness of this occupation.

Health Physics Technician (HPT)

HPT incumbents have typically come from the commercial nuclear industry or the nuclear Navy. Though this is still the preferred candidate path, sites now have the resources to train individuals with no prior radiological experience. Some HPTs have high school diplomas but the preferred individuals have earned AS degrees in a general science field.

Extensive training is required of HPTs regardless of their experience since protective equipment, instruments, and facility characteristics vary by site, and sometimes, by facility within a site. At a large multi-program DOE site, a minimum of three weeks training is required to attain probationary status. One to two years of performance is then required to advance to journeyman technician. The training time for personnel with no experience is three to nine months depending on the individual's grasp of math and science concepts. The HPT occupation has been in such great demand that little thought has been given to career paths which lead to other occupations. The evidence presented in Chapter 1.0 indicates that the HPT occupation will be in demand for some time to come. Nevertheless, mobility options should be outlined in the event that future mission changes affect that prediction.

Regulatory Analyst

Intermittent formal training, a science and engineering background, and extensive on-the-job training and experience characterize the background of a regulatory analyst. Because there is little planned training, individuals often require five years experience to become a competent professional. Even those with extensive experience generally require a year to learn the particular regulatory nuances of a new industry.

Extensive regulatory experience is usually gained in one type of regulation. Managers speak of the need for people with CERCLA experience or their desire to hire a "NEPA person." The cost associated with training to competence in any of these fields is difficult to estimate due to the largely informal nature of the training.

Managers and regulatory analysts interviewed for this report are beginning to see a shift in DOE's approach to regulatory compliance. Technical considerations are now given greater weight in compliance agreement negotiations and, as a result, technical issues are beginning to shape the schedule of cleanup. As a result, these individuals agreed that the critical part of a regulatory analyst's background is technical proficiency. It is scientists and engineers who come to grasp regulations and regulatory processes, through time, who are in demand. The skills in administrative law that attorneys bring are helpful, but not critical to analyzing regulations applicable to DOE.

Professional and Research Scientists and Engineers

The primary distinguishing characteristic of these occupations is academic degree. Professional engineers tend to have a BS, one-year master's degrees, and the PE designation, whereas research engineers typically have research-based master's and doctoral degrees. Scientists are generally more cleanly separated by degree since they often lack discipline-specific certifications. Professional scientists are those with bachelor's degrees, whereas research scientists have advanced degrees (these distinctions are consistent with those used by the NSF in their reports on scientist and engineer employment). As noted by the NSF (1982; 1985), professional engineers and scientists are more mobile than researchers, but as a class, S&Es tend to switch specialties in response to changes in demand.

Despite their education level, S&Es often require several years experience beyond the bachelor's degree to become fully seasoned. This period seems to be shorter for researchers, possibly because they have had more time to learn their profession and possibly because their industry work tends to correspond more closely with their academic and post-doctoral training. Earning a master's degree typically reduces the experience level required of senior-level engineers, scientists, and many other professionals as well, by about two years. Professional engineers tend to gain experience in project management, scheduling, and cost and workforce estimation over time (ASCE 1991, p. 167).

Career options for S&Es are varied. They can rise in grade level and often aspire to positions in project, program, and line management. Since S&E occupations use similar analytical techniques, career growth may involve crossing discipline boundaries. As mentioned above, this is a common option for S&Es.

Project/Program Manager

Project manager, according to data in the MNAS, is the most critical occupation in the EM workforce. Good project managers are difficult to recruit, train, and retain for several reasons. Managers perceive that the pay and authority which go along with the position are not commensurate with the responsibility, especially in light of the financial and legal accountability that managers assume for environmental work. The S&Es who move into program/project management positions typically do so with little training in management techniques and financial control systems. Thus, they are "not sufficiently well-versed in business and management concepts to grasp the scope of the job" (MNAS 1992, p. 3.17).

Managers who participated in the MNAS could not resolve whether individuals with little technical experience but substantial management experience could assume project/program manager positions. DOE, however, has suggested the technical experience necessary for DOE program managers of major system acquisitions and major projects stated in DOE Order 4700.4. These requirements specify a technical background, extensive experience in smaller project management gained over a six- to eight-year period, and the completion of a minimum of 240 hours of management training. Career paths for program/project managers generally lead to upper management positions.

Nuclear Waste Process Operator (NWPO)

Titles for this occupation vary greatly depending on the production processes of each site. NWPOs, however, can be readily classed with chemical operators and process operators. Process operators generally begin their careers with vocational or associate degrees. On-site training provides necessary site-specific knowledge. Operator qualification is generally limited to a particular process line. NWPOs, like reactor operators, are seen as critical to the environmental mission due to their extensive site experience and knowledge of the systems which must be decontaminated. Little consideration is given to the career paths of NWPOs but common options are promotion in grade and promotion to supervision.

Reactor Operator (RO)

Certification training for RO positions continues for two years and includes academic, applied, and facility-specific knowledge and skills. Educational training includes classical and reactor physics, chemistry, materials science, instrument theory, and electrical theory. Applied experience is gained in plant systems via classroom instruction and on-the-job experience.

A significant amount of time is spent in training after certification to review basic knowledge and skills and to learn of design changes and equipment upgrades. Certifications must be renewed every year. As is the case for HPTs, ROs are certified on the design of a given plant and must receive plant-specific training each time they move.

Preferred backgrounds for ROs are the nuclear Navy or a two- to four-year degree. Surprisingly, more than a few ROs have liberal arts college degrees. As long as they have some background in lab science, the intensive training courses offered at the site give liberal arts majors a sufficient background in science and engineering basics to perform the job.

ROs are highly skilled individuals within the industry and have numerous career options. With an additional year of training they can rise in grade to senior ROs and progress to shift manager and plant operations management. Other career paths within the organization are in the training, quality assurance, engineering technician, and plant engineer occupations. These positions capitalize on the well-developed knowledge ROs have obtained in plant operations and radiological control. Management opportunities in these areas are also a possibility.

Given the prospects of government and commercial nuclear plant construction, special consideration should be given to determining how the skills and training of ROs should be applied to the EM mission. ROs currently find themselves in a potentially dying field. A concerted effort to capture their knowledge and skills could benefit sites tremendously.

Chemical Technologist

Alternative titles for this position are lab or analytical technician. Labs in the complex generally do not have a certification process for chemical technologists. They do, however, have programs which normally span six weeks to train new technicians in the use of instruments and technical knowledge. The minimum educational requirement is a high school diploma, but an AS degree in general sciences is preferred. No particular general or specific work experiences could be determined.

Radiochemist

Radiochemistry is a niche occupation sought by the DOE complex and specialized areas of the medical industry. Though academic degree programs in radiochemistry exist, many radiochemists in

the DOE complex enter the field through years of on-the-job experience (MNAS 1992). Radiochemists follow the same career paths as other scientists, although most stay closely allied with the radio-chemistry field.

Hazardous Material Handler

This occupation often has several titles associated with it, including environmental technician, field technician, decontamination and decommissioning (D&D) technician, and environmental hazardous material (EHM) technician. It is generally regarded as a relatively unskilled entry-level position which requires basic math and sciences and a relatively short (40-hour) course in the fundamentals of hazardous material management. In a few industries, however, these jobs are first-year positions for scientists and engineers which are the equivalent of engineer- or scientist-in-training positions and lead to rotational assignments for the subsequent year or two.

2.7 Salary Compensation in EM-Relevant Occupations

In any given labor market there is a supply of workers with given characteristics desiring job positions and a corresponding demand for these individuals to fill job vacancies. In the process, wages and salaries are determined jointly by supply and demand as they adjust in attempts to balance these opposing market forces. The key result of this market-clearing process is the formation of an observable salary structure that, in part, reflects both job characteristics and workforce skills. In this section we describe the median salary levels for selected EM-relevant occupations observed in Foushee's Environmental Health and Safety Compensation Survey (1992).^(a) Based on this survey we then examine more closely various salary differentials which seem to exist across selected industrial employers and geographic regions. Technical aspects of the analysis are left for discussion in the Appendix of this report.

The salary information for the various environmental, health, and safety occupations covers 9,547 employees across 65 different job categories. The industry categories covered by the survey are energy (petroleum and natural gas producers), utilities, research laboratories (including DOE national laboratories), and environmental services organizations (including DOE M&O contractors, engineering consulting firms, and waste management services organizations). Workers in each job category share similar amounts of education, on-the-job training, and work experience. Their salaries do not account for any of the additional incomes they might have earned over the year; for example, bonus pay, profit sharing, or overtime hours. Table 2.4 presents the overall median salary for each of the 65 job categories, as well as the industry- and region-specific salaries in these selected job categories.

(a) The rationale for using the median base in salary is that earnings data tend to be skewed. The median, as opposed to the mean, is less sensitive to such extreme values.

Table 2.4. Median Salaries for Environmental Occupations by Industry and Region

ER Occupation	N	Industry Median Salary					Regional Median Salary						
		Overall Median Salary	Overall Standard Deviation	C.V.	Energy	Utility	Research	Services	West Coast	South Central	North Central	South East	North East
Environmental Sciences, Mgr. **	75	62,280	-	-	72,905	75,800	66,000	58,380	58,560	65,750	64,572	58,710	70,260
Environmental Sciences, Supv. **	41	55,200	-	-	64,688	50,267	68,700	55,900	54,180	64,149	58,134	49,080	49,415
Environmental Scientist, Sr.	261	57,000	9,333.33	6.11	67,406	74,244	57,150	53,040	56,600	57,770	54,350	55,164	60,080
Environmental Scientist III	263	47,892	6,977.78	6.86	51,550	52,732	46,318	44,520	45,864	51,906	46,752	50,400	54,660
Environmental Scientist II	185	39,166	6,222.22	6.29	53,500	46,524	40,236	35,640	38,718	46,300	39,600	39,240	37,752
Environmental Scientist I	131	33,228	4,318.52	7.69	42,280	35,261	34,200	31,350	33,174	40,065	32,520	30,605	34,680
Environmental Technician 3 *	189	32,750	-	-	28,314	35,000	34,100	28,950	29,100	30,001	31,724	29,580	29,378
Environmental Technician 2	130	27,254	5,018.52	5.43	28,236	31,050	31,052	24,000	26,624	31,108	26,952	24,936	23,393
Environmental Technician 1	91	23,700	2,631.11	9.01	24,681	25,093	24,908	22,230	23,600	33,101	23,566	23,580	21,889
Hydrogeology, Mgr. *	59	62,640	-	-	76,980	58,320	72,790	60,120	63,592	62,815	58,320	55,080	63,000
Hydrogeologist, Sr. **	131	54,000	-	-	71,419	45,552	54,200	52,500	56,040	54,240	49,980	53,660	52,850
Hydrogeologist III	137	45,960	5,288.89	8.69	64,370	38,808	52,176	45,000	46,752	47,877	43,967	45,960	44,430
Hydrogeologist II *	128	40,770	-	-	48,268	33,317	42,850	39,750	40,812	45,227	36,000	39,166	39,428
Hydrogeologist I	64	35,570	3,631.11	9.80	37,778	31,597	35,442	34,830	36,000	37,596	32,500	35,009	34,200
Industrial Hygiene, Mgr.	60	64,489	10,790.37	5.98	65,400	66,458	64,923	66,960	66,960	59,550	58,688	67,470	65,000
Industrial Hygiene, Supv. **	22	53,190	-	-	-	60,372	49,488	52,740	55,392	49,488	36,276	47,219	60,327
Industrial Hygienist, Sr. *	143	56,856	-	-	62,400	57,296	56,650	57,060	56,712	56,800	52,015	56,575	58,886
Industrial Hygienist III	169	47,444	7,010.37	6.77	57,800	48,060	52,788	49,080	49,900	46,200	44,226	46,947	47,518
Industrial Hygienist II	169	40,000	4,862.22	8.23	47,605	41,628	41,300	37,780	38,000	42,000	41,028	40,000	43,288
Industrial Hygienist I	99	34,656	4,788.52	7.22	42,079	37,392	35,640	31,200	35,000	37,900	32,325	33,900	37,521
Industrial Hygiene Technician 3	53	35,900	8,860.74	4.05	31,655	-	38,200	43,848	43,849	34,926	33,447	28,584	36,110
Industrial Hygiene Technician 2	52	26,472	2,705.93	9.78	30,811	26,844	-	26,163	28,062	30,150	26,844	25,200	-
Industrial Hygiene Technician 1	48	22,915	2,122.96	10.79	-	39,800	25,532	25,228	20,930	23,662	23,697	23,100	-
Risk Assessment, Mgr. *	23	75,900	-	-	75,250	-	76,797	58,260	71,841	69,261	67,800	73,688	77,253
Senior Risk Analyst/Specialist *	35	70,000	-	-	71,063	-	74,735	63,950	71,418	77,500	71,700	57,180	70,000
Risk Analyst/Specialist III	28	54,576	8,757.04	6.23	43,220	-	46,920	37,620	43,542	57,291	-	39,360	42,997
Risk Analyst/Specialist II *	21	43,500	-	-	43,220	-	46,920	37,620	43,542	57,291	-	39,360	42,997
Risk Analyst/Specialist I **	14	43,620	-	-	31,000	-	50,113	38,640	38,200	52,466	-	-	36,000
Health Physics, Mgr. *	53	67,059	-	-	-	72,300	67,100	63,420	66,396	65,874	64,080	66,234	77,448
Health Physics, Supv. **	215	45,540	-	-	-	54,929	50,000	46,260	46,830	57,612	47,436	44,940	54,929
Health Physics, Sr. *	177	58,659	6,017.04	9.75	-	60,113	60,925	65,300	59,430	57,621	60,072	56,952	59,180
Health Physics III	204	51,131	5,726.67	8.93	-	51,220	51,160	49,659	51,000	53,496	50,922	49,296	51,131
Health Physics II **	136	44,382	-	-	-	51,252	53,600	42,240	44,160	48,372	47,904	40,272	49,272
Health Physics I **	75	37,560	-	-	-	43,826	37,160	33,737	37,560	37,200	39,500	35,970	43,826
Health Physics Technician 3 *	908	38,889	-	-	-	45,874	40,260	38,888	38,888	40,000	35,859	37,336	45,874
Health Physics Technician 2 **	389	31,300	-	-	-	44,004	31,461	33,000	35,000	43,992	29,776	28,056	40,498
Health Physics Technician 1 **	240	24,856	-	-	-	31,512	27,666	28,766	29,016	25,105	22,728	24,024	31,000
Safety, Mgr.	125	63,240	8,894.81	7.11	60,260	63,900	70,128	63,104	64,872	63,200	59,160	63,104	67,400
Safety, Supv. *	107	53,640	-	-	-	45,874	40,260	38,888	38,888	40,000	35,859	37,336	45,874
Safety Engineer/Specialist, Sr.	177	55,078	9,031.11	6.10	63,400	58,230	60,950	50,832	57,232	54,539	53,314	47,815	55,620
Safety Engineer/Specialist III	222	49,710	6,564.44	7.57	56,073	49,740	53,600	50,100	52,824	51,070	46,224	47,458	49,207
Safety Engineer/Specialist II	209	42,432	5,208.89	8.15	48,321	43,560	42,768	38,088	42,550	41,860	41,382	40,740	46,672
Safety Engineer/Specialist I	131	36,842	4,071.85	9.05	39,985	37,140	36,048	31,794	36,764	38,000	36,460	36,296	38,636
Safety Technician 3 *	67	40,497	-	-	39,816	50,388	40,386	29,835	29,646	38,442	41,158	40,167	48,438
Safety Technician 2 **	23	34,386	-	-	27,170	34,140	41,760	-	41,760	35,256	-	33,240	40,632
Safety Technician 1 *	10	26,900	-	-	-	-	24,233	-	30,000	19,092	28,917	26,940	-
Environmental Protection Engrg, Mgr.	58	64,352	8,820.00	7.30	62,996	87,420	71,250	62,256	63,544	62,604	59,494	76,850	68,138
Environmental Protection Engr, Sr. **	137	55,620	-	-	71,810	61,139	51,100	56,120	57,800	52,860	58,044	56,280	60,944
Environmental Protection Engr III	179	49,800	7,622.22	6.53	54,300	50,492	55,000	47,112	49,580	47,340	54,576	48,255	50,550
Environmental Protection Engr II	159	42,924	6,792.59	6.32	50,544	49,257	38,837	38,064	39,408	41,610	49,225	42,800	41,106
Environmental Protection Engr I	105	36,600	4,792.59	7.64	36,745	38,288	34,325	33,920	35,816	37,800	38,760	39,790	33,800
Hazardous Materials Management, Mgr.	38	62,844	11,731.11	5.36	-	54,508	67,392	62,600	63,906	56,236	61,608	62,710	76,880
Hazardous Materials Specialist, Sr. *	116	59,814	-	-	-	53,844	62,896	49,643	61,162	58,500	52,841	56,811	50,440
Hazardous Materials Specialist III	180	48,300	6,381.48	7.57	-	45,960	49,332	41,883	49,260	45,660	40,980	55,140	-
Hazardous Materials Specialist II *	71	41,548	-	-	42,900	41,801	41,951	38,417	40,800	43,080	41,000	32,852	43,000
Hazardous Materials Specialist I **	44	32,625	-	-	-	32,148	35,672	33,516	34,764	32,199	29,200	31,361	38,160
Environmental Laboratory, Mgr	57	71,400	11,335.56	6.30	75,566	72,007	68,550	72,090	63,250	72,352	75,400	80,337	77,272
Environmental Laboratory, Supv. *	64	55,607	-	-	62,000	55,436	51,972	48,158	48,368	56,100	51,012	65,220	62,344
Analytical Chemist, Sr	149	54,696	7,466.67	7.33	52,322	63,526	60,558	51,292	56,800	44,947	57,192	52,638	63,562
Analytical Chemist III	168	46,710	6,120.00	7.63	44,642	51,277	48,632	43,320	45,708	53,136	48,500	45,624	51,277
Analytical Chemist II	182	37,952	4,584.44	8.28	38,588	47,412	42,404	35,400	37,740	36,624	40,900	38,268	32,453
Analytical Chemist I *	172	32,575	4,947.41	6.58	36,213	37,274	33,858	27,810	32,705	28,000	29,861	33,443	27,021
Laboratory Technician 3 *	873	39,468	-	-	50,674	46,082	35,027	39,990	39,990	42,182	35,027	38,428	45,220
Laboratory Technician 2 **	358	27,102	-	-	22,485	40,498	31,860	23,066	38,043	44,772	26,100	25,480	32,143
Laboratory Technician 1	178	24,024	4,082.96	5.88	-	34,908	26,616	27,040	27,924	23,803	26,616	23,100	17,680

* Others

** Log transformation

Median salary levels follow expected patterns. Salaries rise with grade in each occupation and the professional and management occupations, on average, pay more than technician occupations. Consistent with the skew generally found in salary data, standard deviations at lower salaries are lower than those at higher salaries. High coefficients of variation (CVs), however, tend to be associated with lower salaries indicating that, when the level of salary is standardized across occupations, salaries vary more greatly for technician occupations than the others. This finding is consistent with information reported in the MNAS (1992), which notes that local labor markets must be relied upon for technicians (and other non-exempt employees) since moving expenses are not generally reimbursed for these employees. If employees are constrained in their mobility by high moving costs, salaries will tend to vary more across geographical regions since local, not national, labor markets will determine salaries. Higher relative salary differentials, therefore, will be necessary to encourage mobility. Professionals and managers, who can expect to have moving costs reimbursed, should be willing to move for a smaller relative increment in salary than technicians, thus the lower average CV.

Reviewing the last nine columns in Table 2.4 suggests that occupational base salaries may differ significantly across the various industries and regions. If they do, the magnitude of these salary differentials will tend to affect how the market allocates the workforce in the future, both across industry and regions. Given the nation-wide configuration of the DOE complex, further understanding of these salary differentials would seem pertinent to the EM mission. Accordingly this issue is examined below.

2.8 EM Salary Differentials Across Industry and Regions

Salary differentials were examined by applying analysis of variance (ANOVA) methods to first test whether median base salary levels differ across industries and regions. Based on these statistical tests, the existence of significant salary differentials across industries and regions was apparent in many job categories. Accordingly, the statistical method of *pairwise comparison* was used to measure their size. These significant differences in salary across industry and region are reported in Tables 2.5 and 2.6, respectively.

Salary differences by industry indicate that companies in the energy industry tend to pay higher salaries for environmental occupations than utilities, which in turn pay more than the research and service industries. Companies in research (including DOE national laboratories) pay relatively better than the environmental services industry. Thus, the organizations in the government complex of national labs and M&O contractors pay significantly less for environmental talent than their rivals in the energy and utility industries.

Regional salary differences reveal that salaries tend to be greatest in the South Central part of the country followed by the Northeast. Salaries in the West and Southeast are similar and tend to be higher than salaries in the North Central region. Therefore, salaries in regions where DOE facilities and workforces tend to be concentrated (the Southeast and West) tend to be below average.

Table 2.5. Salary Differences Across Industry

ERI Occupation	Median Salary Gaps					
	Research VS Energy	Research VS Utility	Research VS Services	Energy VS Utility	Energy VS Services	Utility VS Services
Environmental Sciences, Mgr. **	-	-	-	-	-	17,420
Environmental Sciences, Supv. **	-	(18,433)	-	-	-	-
Environmental Scientist, Sr.	-10,256	-17,094	4,110	-	14,366	21,204
Environmental Scientist III	-5,232	-8,414	-	-	7,030	8,212
Environmental Scientist II	-13,264	-8,288	4,596	6,976	17,860	10,884
Environmental Scientist I	-8,080	-	2,850	6,998	10,910	-
Environmental Technician 3 *	-	-	5,150	-	-	6,050
Environmental Technician 2	-	-	7,052	-	-	7,050
Environmental Technician 1	-	-	2,678	-	-	2,863
Hydrogeology, Mgr. *	-	-	-	-	-	-
Hydrogeologist, Sr. **	-17,219	-	-	25,867	18,919	-
Hydrogeologist III	-12,194	-	7,176	25,562	19,370	-
Hydrogeologist II *	-	9,533	-	14,951	8,518	-
Hydrogeologist I	-	-	-	-	-	-
Industrial Hygiene, Mgr.	-	-	-	-	-	-
Industrial Hygiene, Supv. **	-	-	-	-	-	-
Industrial Hygienist, Sr. *	-	-	-	-	-	-
Industrial Hygienist III	-	-	-	9,740	8,720	-
Industrial Hygienist II	-6,305	-	3,540	5,977	9,845	-
Industrial Hygienist I	-	-	-	-	10,879	-
Industrial Hygiene Technician 3	-	-	-	-	-	-
Industrial Hygiene Technician 2	-	-	-	3,967	4,648	-
Industrial Hygiene Technician 1	-	-14,268	-	-	-	14,572
Risk Assessment, Mgr. *	-	-	(18,537)	-	-	-
Senior Risk Analyst/Specialist *	-	-	-	-	-	-
Risk Analyst/Specialist III	-	-	-	-	-	-
Risk Analyst/Specialist II *	-	-	(9,300)	-	-	-
Risk Analyst/Specialist I **	-	-	-	-	-	-
Health Physics, Mgr. *	-	-	-	-	-	-
Health Physics, Supv. **	-	-4,929	3,740	-	-	8,669
Health Physics, Sr.	-	-	-4,375	-	-	-5,187
Health Physics III	-	-	-	-	-	-
Health Physics II **	-	-	11,360	-	-	9,012
Health Physics I **	-	-6,666	-	-	-	10,089
Health Physics Technician 3 *	-	-5,614	1,371	-	-	6,985
Health Physics Technician 2 **	-	-12,543	-	-	-	11,004
Health Physics Technician 1 **	-	-	-	-	-	-
Safety, Mgr.	-	-	-	-	-	-
Safety, Supv. *	-	-	-	-	-	-
Safety Engineer/Specialist, Sr.	-	-	10,118	-	12,568	-
Safety Engineer/Specialist III	-	3,860	-	-	-	-
Safety Engineer/Specialist II	-5,553	-	4,680	-	10,233	-
Safety Engineer/Specialist I	-3,937	-	-	-	8,191	5,346
Safety Technician 3 *	-	-	-	-10,572	-	20,553
Safety Technician 2 **	-	-	-	-	-	-
Safety Technician 1 *	-	-	-	-	-	-
Environmental Protection Engrg, Mgr.	-	-	-	-24,424	-	25,164
Environmental Protection Engr, Sr. **	-20,710	-	-	-	15,690	-
Environmental Protection Engr III	-	-	7,888	-	7,188	-
Environmental Protection Engr II	-11,707	-	-	-	12,480	11,193
Environmental Protection Engr I	-	-	-	-	-	-
Hazardous Materials Management, Mgr.	-	-	-	-	-	-
Hazardous Materials Specialist, Sr. *	-	-	13,253	-	-	-
Hazardous Materials Specialist III	-	-	7,448	-	-	-
Hazardous Materials Specialist II *	-	-	5,293	-	-	6,289
Hazardous Materials Specialist I **	-	-	-	-	-	-
Environmental Laboratory, Mgr.	-	-	-	-	-	-
Environmental Laboratory, Supv. *	-	-	-	-	-	-
Analytical Chemist, Sr.	-	-	9,266	-11,204	-	12,234
Analytical Chemist III	-	-	6,312	-	-	7,957
Analytical Chemist II	-	-5,008	7,004	-8,824	-	12,012
Analytical Chemist I *	-	-	6,048	-	8,403	9,464
Laboratory Technician 3 *	-15,647	-11,055	-4,963	-	-	6,092
Laboratory Technician 2 **	-	-	8,794	-	-	17,432
Laboratory Technician 1	-	-	-	-	-	-

* Others

** Log transformation

() 95% confidence interval

Table 2.6. Salary Differences Across Regions

ER Occupation	Median Salary Gaps									
	West Coast	West Coast	West Coast	West Coast	South Ctr	South Ctr	South Ctr	North Ctr	North Ctr	Southeast
	VS South Ctr	VS North Ctr	VS Southeast	VS Northeast	VS North Ctr	VS Southeast	VS Northeast	VS Southeast	VS Northeast	VS Northeast
Environmental Sciences, Mgr. **	.	.	.	.	.	.	.	.	.	.
Environmental Sciences, Supv. **	.	.	.	.	.	.	.	.	.	.
Environmental Scientist, Sr.	.	.	.	.	.	.	.	.	.	.
Environmental Scientist III	-6,042	.	-4,536	-8,796	5,154	.	.	.	-7,908	.
Environmental Scientist II	-7,582	.	.	.	6,700	7,060	8,548	.	.	.
Environmental Scientist I	-6,881	.	.	.	7,545	9,460	.	.	.	.
Environmental Technician 3 *	.	.	.	.	.	4,558	.	.	.	-7,587
Environmental Technician 2	-4,484	.	.	.	4,156	6,172	7,715	.	.	.
Environmental Technician 1	-9,501	.	.	.	9,535	9,521	11,212	.	.	.
Hydrogeology, Mgr. *	.	.	(8,512)	.	.	.	.	.	.	.
Hydrogeologist, Sr. **	.	.	.	.	.	.	.	.	.	.
Hydrogeologist III	.	.	.	.	.	.	.	.	.	.
Hydrogeologist II *	-4,315	4,912	.	.	9,227	.	5,799	.	.	.
Hydrogeologist I	.	.	.	.	(5,096)	.	.	.	.	.
Industrial Hygiene, Mgr.	.	.	.	.	.	.	.	.	.	.
Industrial Hygiene, Supv. **	.	.	.	.	.	.	.	.	.	.
Industrial Hygienist, Sr. *	.	.	.	.	.	.	.	.	(-6,871)	.
Industrial Hygienist III	.	5,674	.	.	.	.	.	.	.	.
Industrial Hygienist II	-3,000	.	.	-4,288	.	.	.	.	.	.
Industrial Hygienist I	.	.	.	.	5,575	4,000	.	.	.	.
Industrial Hygiene Technician 3	.	.	15,265	.	.	.	.	.	.	.
Industrial Hygiene Technician 2	.	.	.	.	.	4,950	.	.	.	.
Industrial Hygiene Technician 1	.	.	.	.	.	.	.	.	.	.
Risk Assessment, Mgr. *	.	.	.	.	.	.	.	.	.	.
Senior Risk Analyst/Specialist *	.	.	.	.	.	20,320	.	.	.	.
Risk Analyst/Specialist III	.	.	.	.	.	.	.	.	.	.
Risk Analyst/Specialist II *	-13,749	.	.	.	.	17,931	14,294	.	.	.
Risk Analyst/Specialist I **	.	.	.	.	.	.	.	.	.	.
Health Physics, Mgr. *	.	.	.	.	.	.	.	.	.	.
Health Physics, Supv. **	-10,782	.	1,880	-8,099	10,176	12,672	.	2,496	-7,483	-9,989
Health Physics, Sr.	.	.	.	.	.	.	.	.	.	.
Health Physics III	.	.	.	.	.	(4,200)	.	.	.	.
Health Physics II **	.	.	.	.	.	8,100	.	7,632	.	.
Health Physics I **	.	.	.	.	.	.	.	.	.	(-7,856)
Health Physics Technician 3 *	.	3,030	1,553	-6,985	4,141	2,664	-5,874	-1,477	-10,015	-8,538
Health Physics Technician 2 **	-8,992	5,224	6,944	.	14,216	15,936	.	.	-10,722	-12,442
Health Physics Technician 1 **	3,911	6,288	4,992	.	.	.	.	.	.	.
Safety, Mgr.	.	.	.	.	.	.	.	.	(-8,240)	.
Safety, Supv. *	.	.	.	.	.	.	.	.	.	.
Safety Engineer/Specialist, Sr.	.	.	9,417	.	.	.	.	.	.	.
Safety Engineer/Specialist III	.	6,800	5,366	.	4,846	.	.	.	.	.
Safety Engineer/Specialist II	.	.	.	.	.	.	.	.	(-5,280)	(-5,932)
Safety Engineer/Specialist I	.	.	.	.	.	.	.	.	.	.
Safety Technician 3 *	.	.	.	-18,792	.	.	-9,996	.	.	.
Safety Technician 2 **	.	.	.	.	.	.	.	.	.	.
Safety Technician 1 *	(10,908)	.	.	.	(-9,825)	(-7,648)	.	.	.	.
Environmental Protection Engrg, Mgr.	.	.	-13,306	.	.	-14,246	.	-17,356	.	.
Environmental Protection Engr, Sr. **	.	.	.	.	.	.	-8,084	.	.	.
Environmental Protection Engr III	.	-4,986	.	.	-7,236	.	.	6,321	.	.
Environmental Protection Engr II	.	-9,817	.	.	-7,615	.	.	6,425	8,119	.
Environmental Protection Engr I	.	.	.	.	.	.	.	.	4,960	5,990
Hazardous Materials Management, Mgr.	.	.	.	.	.	.	.	.	.	.
Hazardous Materials Specialist, Sr. *	.	.	.	.	.	.	.	.	.	.
Hazardous Materials Specialist III	.	8,280	.	.	.	.	.	.	.	.
Hazardous Materials Specialist II *	.	.	.	.	.	10,228	.	.	.	.
Hazardous Materials Specialist I **	.	.	.	.	.	.	.	.	.	.
Environmental Laboratory, Mgr.	.	.	-17,087	.	.	.	.	.	.	.
Environmental Laboratory, Supv. *	.	.	-16,852	.	.	.	.	.	.	.
Analytical Chemist, Sr.	11,853	.	4,162	-8,728	.	.	-18,578	.	.	-10,888
Analytical Chemist III	-7,428	.	.	-5,569	.	7,512	.	.	.	-5,653
Analytical Chemist II	.	.	.	5,287	-4,276	.	.	.	8,447	5,815
Analytical Chemist I *	.	.	.	5,684	.	-5,443	.	-3,582	.	6,422
Laboratory Technician 3 *	-2,192	4,963	1,562	-5,230	7,155	3,754	-3,038	-3,401	-10,193	-6,792
Laboratory Technician 2 **	.	11,943	12,553	.	18,672	19,282	12,629	.	.	-6,853
Laboratory Technician 1	.	.	4,824	10,244	.	.	.	3,516	8,936	5,420

* Others

** Log transformation

() 95% confidence interval

2.9 Lessons Learned

2.9.1 Shortages Come and Shortages Go

The demand for and supply of skilled workers fluctuates to produce "shortages" and "surpluses". It seems safe to say that the only difference between the fluctuations occurring now and those of the past is our ability to measure them somewhat better now. Though business and economic cycles are difficult to endure, the evidence suggests that workers adjust. Craftworkers, for instance, have adjusted to construction booms and busts in the past. Scientists and engineers have adjusted to slack demand by switching areas of research and, not infrequently, occupations. The college science and engineering population seems to pay rather close attention to job opportunities and responds appropriately, albeit with a lag (Finn 1986). For instance, chemical engineering majors declined shortly after the market soured in 1982. Also, the mid-1980s electrical engineering boom has subsided and has been accompanied by a decrease in these majors (Watson 1989). These are not problems in the labor supply to be fixed. Instead, they are relatively well-understood market mechanisms through which career choices and hiring patterns are balanced.

2.9.2 Interdisciplinary Research and Majors Are Rising

The demand for safety professionals has spurred the development of safety undergraduate majors which draw from the sciences, engineering, psychology, and management fields (Brauer 1992). Hybrid majors are being developed in other fields and several established academic majors, such as chemical engineering, have similar interdisciplinary roots. Sub-specialties within established fields tend to blur disciplinary distinctions even further; how does one classify a biomedical engineer who works on electromechanical prosthetic devices? An increasingly small percentage of S&Es and other skilled/technical employees work purely in the area of their degree or narrow technical specialty. Both research and production missions require more interdisciplinary cooperation and knowledge, thereby reducing the need for any given "pure" specialty and increasing the flexibility; hence, a potential "supply" of workers who could fill positions.

2.9.3 Engineers Are Made, Not Graduated

The same is true for scientists, technicians, and many professionals. Academic training provides the tools needed for success but experience teaches how these tools are to be applied to the variety of environments, problems, and issues encountered on the job. Salary surveys and job grade descriptions indicate that professional competence is attained through exposure to and mastery of a broad variety of applied problems, project and financial management techniques, and technical supervision skills. This "experience factor" accounts for the estimated time-to-competence in Table 2.1 and respects the delay between graduation and licensing/certification that many professional societies impose on their members. It also accounts for the confusion that often occurs between managers and workforce planners when they discuss "needs." A manager who expresses a need for an engineer generally means an experienced engineer, not a "green" one who has just graduated. Workforce planners often fail to

recognize this distinction and continue to measure "supply" based on graduation rates from college and trade school programs. The transition into and among engineering specialties by engineers and scientists with several years of experience is more relevant to the "needs" expressed by managers than graduation rates and should be incorporated into policy decisions.

2.9.4 The DOE Has Options, But Must Act

Current salary differentials are not a promising tool for attracting workers from other areas of the country or from other industries since salaries in the DOE complex tend to be lower. For this reason, increasing the supply of engineers and scientists (and other professions) through internship and scholarship programs is not likely to meet EM's needs. As noted in the MNAS (1992), the DOE complex may find that its share of the S&E market decreases as the size of the market increases if it continues to offer poorer pay and working conditions than its competitors in other industries and regions. Economic and marketing strategies must be undertaken. In this way the DOE complex can become the employer of choice in national as well as local labor markets. Developing clear career ladders, gaining a reputation as a place to obtain strong mentoring, and defining DOE skills needs with greater precision will increase the stature of the DOE complex in the market for recruits and improve retention.

2.10 Chapter Summary

There are probably few individuals outside the DOE complex who could quickly assume an EM position and perform to satisfaction. Some period of formal training and on-the-job experience with DOE procedures and operating systems would be necessary. This period, and the cost associated with it, are estimated to be three times that for retraining experienced workers on the basis of the data currently available. Workers employed within other DOE programs, therefore, are likely to transition to EM relatively quickly as long as their previous positions entailed some technical skill. There are likely to be fewer openings and higher transition costs for skilled machine production workers. They, therefore, are not as likely to form a DOE "supply pool" for EM needs. Since managers predict a roughly consistent need for craftworkers and the demand for these occupations cycles with the economy, there is likely to be an adequate supply. Additionally, despite EM's marked growth over the past few years, total DP-funded employment is slightly greater than that of EM. DOE-DP programs that are closing will then provide an additional pool of workers for EM.

In summary, there are ample workers with the requisite education in industries outside the DOE complex. These workers, however, probably lack the DOE and site-specific training needed to have a large and immediate impact on the mission. Workers within other DOE programs, notably DP, largely provide a pool of talent which can be tapped and may, for most occupations, completely satisfy EM's needs. But many other questions remain, such as: when will these workers become available to EM, and how likely are they to accept another position in the DOE complex? These are not questions of supply per se, but of the interaction among demand, supply, production schedules, and organizational/institutional characteristics that will be examined in the next chapter.

3.0 A Framework for Assessing Workforce Transitions

Comparing workforce demand and supply data is not a straightforward process. Yet, workforce needs and the labor supply to meet them have routinely been evaluated by comparing industry and government needs with high school and college graduation rates, as illustrated in Figure 3.1. But the “need” for workers in a given occupation cannot simply be matched with available candidates without considering, at the same time, such factors as the organizational aspects of transferring workers, institutional barriers such as headcount restrictions, the change implications of a new mission, and the need for new technologies. A framework for evaluating workforce changes, therefore, must include more than a simple comparison of supply and demand; it must take a systems-oriented approach to the needs of the organization and the climate it faces.

Such a framework was developed to integrate the data and DOE needs presented earlier for the purpose of evaluating workforce availability and workforce planning policies. The framework is not intended to be a fully specified econometric model which details the interactions among the full set of

Figure 3.1. A Typical Workforce Needs and Availability Comparison

variables that determine the workforce. Instead, it serves as a useful tool for structuring a set of questions to yield data which can be used to achieve a workforce with a desired set of skills. The framework, in other words, does not help determine what theoretically can happen, but what feasibly can be done. Economists would recognize, for instance, that the supply of workers in a given occupation is determined by a complex set of factors beyond internships, scholarships, and salary policies. But since few government agencies have the resources to influence these other factors, the government must react to, rather than influence, them. Accordingly, they are not emphasized in the framework.

The model is comprised of several components: the mission of the organization; the budget associated with the mission; technologies or products which the organization will use/produce to achieve the mission; the skills the organization needs; organizational and institutional characteristics; the workforce needed (the organization's "demand" for labor); the labor market supply; and, finally, the actual workforce (headcount). These components are defined below. "Ideal" interactions among the components are described that show how the workforce is determined in a best-case scenario. Several other scenarios are then examined, including new missions and technology- and budget-driven workforce changes. Policy options are then examined.

3.1 Components of the Framework

3.1.1 Mission

Mission determines the long-term direction of the site, program, or organization, and includes plans such as the level of effort that will be applied over time, the goals to be attained, and the need for research versus production. The development of a mission requires that bottom-up (detailed activity) plans be integrated with the direction issued from top management. Long-term missions for the complex are established at the HQ level. Sites then plan their own long-term mission and craft a shorter-term (generally five-year) plan as well as annual operating plans. Sites, therefore, work within the boundaries established by HQ. At a specific organization, responsibility for developing a mission usually resides with major organizational levels in line or program management such as general manager, program director, manager of strategic planning, etc. Work plans that meet the mission are built at successively lower levels of the organization.

3.1.2 Technology/Products

These refer to the specific manufacturing, technical, engineering, or other materials, machines, and processes used to achieve the mission. These may exist or require development, and technology development may have known or unknown needs. That is, choice among competing technologies may introduce significant trade-off possibilities within the system. Technology decisions are made locally, typically for a moderate to long-term period (five to fifteen years). But for practical purposes they are reviewed on an ongoing basis.

3.1.3 Budget

Budget limits are established initially by HQ. Although line items in the budget detail how much money is to be spent on certain projects, sites have some flexibility to decide how the money for those projects will be spent. In addition, they have substantial latitude over discretionary budgets. Budgets are determined on a one- to two-year cycle.

3.1.4 Skills

Skills refers to the "capability" characteristics of the workforce and are defined in job descriptions; knowledge, skills, and ability (KSA) lists; job analyses; or occupational databases. They are determined at the site level as a direct consequence of the technologies chosen for development/implementation. Like those technologies, skills should be evaluated continuously.

3.1.5 Workforce

Workforce refers to the organizational headcount. Individuals in the workforce have attributes associated with them, included among them are skills. Determinants of the workforce other than the skills needed include the technologies chosen, organizational and institutional characteristics, and of course, the labor market supply. Various combinations of headcount can yield the skill sets demanded by the organization. Planning, selection, and retention strategies controlled at the organization (site) level, therefore, are critical to workforce management.

3.1.6 Organizational and Institutional Characteristics

Organizational characteristics are the policies, practices, and structures adopted by the organization to facilitate business management. Institutional characteristics include regulations and restrictions imposed on the organization by external authorities or precedent. Thus, some characteristics are within the control of the site while others are determined by HQ or others. Organizational and institutional factors typically govern hiring practices, work safety rules, project management, organizational communication, security restrictions, and similar organizational functions.

3.1.7 Labor Market Supply

This is the pool of individuals who could potentially fill the positions in demand. These individuals have education, training, and/or experience which qualifies them for the positions, though all may not be equally qualified. The supply consists of individuals internal to the complex (those in other DOE programs) as well as those in external organizations.

3.2 The “Ideal” Scenario

In the “ideal” scenario the workforce size and skills are determined directly by the scope of the technologies to be developed/employed and the characteristics of the organization. These, in turn, are determined by the trade-offs made among scope, mission, budget constraints, and choice of technologies. For instance, if insufficient financial resources are available, cheaper technologies may be chosen or the mission may be changed. The lack of technologies, on the other hand, may cause the mission or budget to expand. Although missions and budgets will be revised yearly and technologies can fail or emerge at any time, these factors are, over the long term, relatively consistent in the “ideal” scenario. That is, mission, budget, and technologies are planned in advance and scheduled to provide a stable platform for scheduling operational activities.

The skills needed in the workforce are determined by the technologies/products as well as organizational characteristics. The technology/products factor directly affects the workforce by placing constraints on the number of workers needed. For instance, the development of two technologies may require chemistry, biology, and technical writing skills. However, one may require three chemists and one biologist whereas the other requires one chemist and two biologists. Organizational/institutional characteristics also affect the relationship between skills and the workforce. For instance, union rules or safety regulations may determine crew size or shift changes for certain organizations. An organization’s culture affects the workforce as well. An organization which encourages multi-disciplinary teams and productivity improvement may find that its cross-trained workers are more flexible and that it consequently needs fewer workers to achieve a given amount of work. Thus, technologies/products, organizational and institutional characteristics, and skills needed constitute the “demand” for employees.

The “ideal” scenario, as shown in Figure 3.2, illustrates a requirements-based planning approach to workforce management. The workforce is not determined by the budget or past production activities. Instead, workforce changes are planned on the basis of the work to be accomplished. Although mission and technologies in the “ideal” scenario are reconciled with budget, the budget does not directly drive the number and type of individuals who will comprise the workforce. Several workforce planning guidelines result from the ideal scenario.

Figure 3.2. The "Ideal" Scenario

1. A stable planning platform is necessary for the productive and efficient use of human resources. Coordinating mission, budget, and technology choices across multiple levels (HQ, site, organization) provides that platform.
2. Skill specifications should be drawn directly from the planned use or development of technologies.
3. Under a requirements-based planning system, skill needs, organizational characteristics, and technologies have the most direct effect on the size of the workforce. The budget has an important, but indirect, effect.
4. Organizational and institutional constraints must be identified and managed to maximize workforce flexibility.

One method of posing the questions management must answer in the ideal scenario is depicted in Figure 3.3. These questions may be rearranged and still conform to the interactions outlined in the "ideal" scenario. However, in no case will the budget directly determine the workforce.

Figure 3.3. Structuring Questions for an “Ideal” Scenario Workforce Change

3.3 “Non-ideal” Scenarios

3.3.1 An Exogenous Shock to the Organization Mission

A mission change may occur due to factors external to the framework. DOE’s new mission in environmental restoration is an example of a radical change in mission prompted by developments outside the factors in the framework. A change in mission, illustrated in Figure 3.4, produces the same budget and technology/product trade-offs encountered in the “ideal” scenario. New technologies/products and organizational/institutional characteristics determine the skills and workforce size as before. The new relationships are those of old organizational/institutional characteristics to new and old workforce to new. Since the new mission may require skills different than those used previously the organization and workforce for the new mission may differ (represented in the framework by the dotted line relationship). Guidelines derived from workforce planning based on a change in mission include:

1. As with the “ideal” scenario, planning the new mission and coordinating the technology and budgetary implications should occur before any implementation which affects the workforce.
2. The workforce, as before, is determined mainly by the technologies, skills needed, and organizational characteristics. Budget still has an indirect effect.

Figure 3.4. Mission Change Scenario

3. The old to new workforce transition should occur over a time period sufficient to allow retraining. The length of this period (and amount of retraining required) will depend on how different the new technologies are from the old, the extent to which the line organization is cross-trained, and the extent to which facility- or job-specific knowledge is critical to the new mission.

3.3.2 An Exogenous Shock to the Budget

The “ideal” and mission change scenarios illustrate workforce changes rooted in requirements-based planning. Budget changes can also be accommodated within a requirements-based planning framework. Financial constraints, if planned properly, would simply cause adjustments to the mission and choice of technologies. Skill needs and workforce levels would be determined as before.

Budget changes, however, are not always planned. Since budget changes (especially cuts) typically allow little time for planning, the budget tends to drive workforce levels directly (see Figure 3.5). Thus, budget-based planning with rapid implementation reverses the workforce planning process outlined in the “ideal” and mission-change scenarios. In this scenario, workforce adjustments are made in the short term and are reconciled over a longer period of time with the skills needs that result from adjustments to the mission and technologies/products. The rapid adjustments to the workforce which are characteristic of budget changes drive changes in organizational characteristics (via the changes in division of work responsibilities and changes in the size of organizational units) and the personnel planning cycle (due to the need for new succession plans, training requirements, and attrition rates). The questions which may be asked in response to a budget change are illustrated in Figure 3.6.

Figure 3.5. Scenario Depicting an Exogenous Shock to the Budget

Figure 3.6. Structuring Questions for a Budget Shock Scenario

The number of workers who can be employed now drives adjustments in technology and mission. A new equilibrium must now be established within the constraints of the budget. Under the DP production mission these adjustments could be handled readily. In fact, budget-based planning was a fast and effective method of workforce (and work activity) planning since production methods changed infrequently, productivity ratios were historically valid, and product mix requirements well-known.

The environmental restoration and management mission, however, is marked by none of these characteristics. Technologies are unproven in many cases, large projects are still in progress and few in number, and completed projects do not necessarily provide the data needed to complete future projects. In short, the EM program must build the data necessary to implement a budget-based system. Under these circumstances, projects which are initiated early in the mission evolve to incorporate lessons learned and productivity improvements. Until these experiences are codified and demonstrated reliable, the addition of budget-driven changes compounds the changes that otherwise naturally occur and make it difficult to attribute workforce allocations clearly to budget changes or evolution. Thus, efforts to baseline project cost, efficiency, material, and labor hour parameters for future projects must start anew after a rapidly implemented budget change. Several workforce management guidelines can be drawn from the budget-change scenario:

1. Rapidly implemented budget changes can be accommodated by missions with historically valid productivity ratios, a stable product line, and known product mix proportions. In fact, since the skills, headcount, and production proportions for these projects are well known, budget-based planning is probably the simplest and preferred option.

2. Projects (or missions) without known production/skill/headcount parameters must develop then via experience. Until these parameters evolve and are shown reliable, budget-driven planning with rapid implementation will complicate workforce management and frustrate efforts to document workforce characteristics.
3. Budget-driven changes can be accommodated within the "ideal" and mission change scenarios as long as those changes are reconciled with mission and technologies/products first.

3.4 Time Constraints on Scenario Changes

Each factor in the framework has a time frame associated with it which specifies the planning horizon for the factor (such as a five-year mission plan or two-year budget cycle) or the time necessary to produce a result (the four years it generally takes to graduate a bachelor's level engineer). Time frames differ greatly, and it is the difficulty linking them which largely accounts for the severe problems encountered when planning the size and composition of the workforce.

A simple overall timeframe is depicted in Figure 3.7. In it, site mission planning is conducted on a five-year basis and updated annually. The time frame associated with technologies/products will differ greatly depending on the complexity and novelty of the technologies involved. In this example, technology development is implemented immediately, updated on an ongoing basis, and continues for the entire five-year time cycle. Budgets are generally planned on an annual or biannual basis depending on whether the funding is discretionary or line item (biannual budgets are assumed in the example). Internships and scholarships operate on a two- to six-year period and are assumed here to produce workers in two years. That is, most students enter the scholarship/fellowship program with two years of education remaining.

Mission, budget, and technologies are established prior to the start of the timeline and are implemented at time zero. It requires one quarter to hire new workers who then need an average of one year before they are competent on the job. By this time the mission (site goals) have been updated and the workforce shifts accordingly. In year 2 the mission is revised again and a new budget is approved, and the scholarship/fellowship recipients enter the workforce. The cycle established during the first two years is repeated for the remainder of the five-year period illustrated.

Even this simple example, which depicts only mission, budget, technology, and scholarship/fellowship programs, demonstrates the time and coordination needed to manage the workforce. Several of the time spans assumed in the example are aggressive; one quarter is needed to hire an individual and the workforce is assumed to be competent after one year on the average. However, the time needed to bring on a new hire is often greater than three months and, as noted in Table 2.2, for several critical occupations the time-to-competence is much greater than one year. Thus, at a minimum, the workforce for a new mission will not be fully capable for 5 quarters after initiation. If budget and mission undergo only minor changes at the specified intervals the workforce is likely to

Figure 3.7. An Example Time Scenario

adjust appropriately. But scholarship recipients will enter the "supply pipeline" two mission revisions and one budget cycle after beginning their program. Changes in mission requirements and budget constraints, as well as developments in the general economy, may create an excess supply of the graduating recipients, as happened to chemical engineers in the two-year period, 1981-1983. Although the education programs may refocus in response to these changes, two years will elapse before these "new" workers enter the labor pool.

Expanding the number of factors in the time frame would complicate it considerably. There are dozens of organizational and institutional constraints which influence the workforce and multiple technologies being implemented at any given time. Technology will also fail/emerge and budgets can undergo rapid changes. However, several useful points can be drawn from the example without complicating it so.

1. There will be a period of transition after the implementation of a new mission, even one that is planned thoroughly. For a workforce composed largely of experienced S&Es working in a dynamic regulatory environment, that time is at least one, and up to two, years. Adding the time needed to change organizational structures, implement regulatory requirements, and respond to budget changes and labor market conditions can lengthen the transition period considerably.
2. Training interventions will, on average, result in a qualified workforce more quickly than education interventions. Education interventions, therefore, should be planned on a long-term basis to result in a more flexible, general, and basic set of skills than training. Training should be the primary tool by which the workforce is transitioned and should be guided by site-specific needs and short cycle times.
3. Experience markedly reduces training time and time-to-competence. Cross training and other employee development programs which emphasize flexibility permit more rapid cycles in mission, budgets, and technology changes.
4. Coordinating time frames reduces operational problems. Moving more items to line budget status (hence longer funding cycles) would reduce the inconsistencies associated with budgetary changes. Strengthening the tie between schedules, technologies/products, internships, and other factors will reduce the likelihood that "demand" will change more quickly than supply.

3.5 Applying the Framework to DOE

Thus far the model has been described under the assumption that mission or organization changes are being planned and that relatively few resource constraints exist. Rarely is this the case. Managers assume responsibility for existing programs and organizational goals and resources often change with

little advance notice. The framework, then, will generally be applied to an existing organization and may be used as a guide to the issues that should be considered or investigated when planning workforce changes and evaluating workforce planning options at DOE.

The framework may be most usefully thought of as a structured method of posing questions that pertain to the workforce. For example, since a mission is necessary to guide the activities of workers it is sensible to ask if the mission is clear, if the goals established to meet the mission conflict, and if there are multiple stakeholders or authorities who decide whether goals are met. Similarly, it makes sense to investigate the institutional and organizational practices and barriers which shape the organization's need for and ability to recruit a workforce. These questions, and their relationship to the factors in the framework, are presented in Figure 3.8 and detailed below. Evidence from studies which examine workforce-related issues at DOE and federal agencies with similar environmental missions is fit into the framework and used to examine possible interventions.

3.5.1 Mission

According to most sources, the long-term mission of DOE-HQ and the sites is clear. There are, however, perceptions of conflicting and unclear goals, multiple authorities and reporting relationships, and lack of coordination between short-term and long-term goals (MNAS 1992; Weiss et al. 1993). These discrepancies exist within and between the sites and HQ and are illustrated in the 1992 DOE report, Schedule Optimization Study (SOS), Hanford RI/FS Program: "While EM leadership has made it clear that the primary mission of the site is cleanup, this message is understood differently by the different parties at the site and regulatory agencies having oversight responsibility for Hanford...The site does not lack strategic plans, five-year plans, and mission statements. While all these documents address in some manner the way in which ER goals will be achieved, none provide [sic] a clear vision for Hanford in the future, and, taken as a whole, they are not being implemented" (DOE 1992, p. 2.8). Evidence from other studies (MNAS 1992; Weiss et al. 1993) indicate that these experiences are common across the complex. Because of unclear implementation instructions, the activity plans at the lowest levels in the organizations do not roll up to goals which meet the overall mission.

Conflicting goals and unclear implementation plans cause organizations to retain policies, practices, and organizational structures that could otherwise be discarded. For instance, the complex continues to rely on the use of DOE Orders despite their widely perceived inappropriateness for EM activities (Weiss et al. 1993). The use of Orders to issue blanket instructions for action are seen as a major deterrent to the effective use of personnel. Reports cite the "tremendous proliferation of DOE Orders and directives" (Weiss et al. 1993, p. 3-24) and the belief that Orders originate in multiple groups who do not consult each other and that "[c]urrent DOE Orders do not adequately recognize the significant differences between production and ER activities" (DOE 1992, p. 2.5). Thus, an administrative control mechanism held over from a different program and production environment is causing duplication and misallocation of effort and personnel in EM.

Figure 3.8. Applying the Framework by Structuring Workforce-Related Questions

Multiple and conflicting goals at HQ and the sites have led to the development of multiple technologies or to no development where technologies are needed in the field. Poor strategic planning has, in at least one instance, ensured that a major program received no products within a deliverable time-frame (DOE 1992, p. 2.26). Shifting goals also produce fluctuations in funding which interrupt technology development, hamper the continuity of projects, and demoralize staff (MNAS 1992, p. x).

3.5.2 Budget

As noted above, some budget fluctuations are due to changing goals. Others are due to downturns in the economy, DOE's continuing mission transition, and the redistribution of resources within the agency. The actual budget increases/decreases which accompanied these changes have been more extreme than anticipated. In the short run, as depicted in Figure 3.3, these budget swings have directly affected the workforce. Some DP-funded plants have been forced to lay off workers due to sudden budget cuts and are now in the process of rescoping their workload and scheduling new production runs at the same time their EM-related work is being planned. The rapid rise in the EM budget, on the other hand, drove scheduling, work scope, and hiring decisions that were not well coordinated (DOE 1992). Budget changes were not coordinated across programs either; EM hiring peaked shortly before DP budget cutbacks began. Relatively few of the currently employed DP workers are now likely to find employment within EM unless EM's budget continues its rapid rise.

Restrictions on the manner in which budgets are allocated or scheduled can affect the workforce. Scholarship and internship programs, for example, are funded from discretionary budget funds. Managers reported that funding these programs as line items in the budget would provide more consistent planning and useful programs (MNAS 1992). Funding levels developed for long-term research programs absorb money from user-driven short-term program which would meet immediate needs (DOE 1992).

3.5.3 Technology/Products

Technology development is subject to the sudden breakthroughs and delays characteristic of any R&D effort. DOE's technology problems are compounded by incomplete characterization and specification of waste sites. Projected decontamination and decommissioning costs for DOE's uranium enrichment plants could increase as much as 50% or decrease by 30% due to limited site characterization and uncertain technology choices (GAO 1991b). Similar problems are faced by the Defense Department; the estimate for the restoration and remediation of DoD sites is estimated to vary from \$4.2 billion to \$42.2 billion "depending on the years of operation and maintenance funding covered and the extent and type of cleanup involved" (GAO 1991a, p. 4).

The "type of cleanup involved" is a crucial issue for workforce planning purposes and shadows the "how clean is clean?" question central to land-use planning. High-tech cleanups of highly contaminated sites will require extensive technology development and application. Employees will, therefore, be highly skilled, presumably well-paid, and (probably) many in number. Low-tech solutions may be

appropriate for sites with single constituent or relatively light contamination. A low-technology solution for a lightly contaminated site was employed at DOE's Shippingport Station Decontamination and Decommissioning Project. Shippingport had been an experimental pressurized water reactor which had undergone several refit and decontamination projects. At final decommissioning, soil and structures at the site were removed to three feet below grade and buried at the Hanford Site. Spent fuel was sent to the Idaho National Engineering Laboratory (INEL). Although low-tech, the approach taken to decontaminate Shippingport was labor-intensive. Labor accounted for nearly \$37 million of the project cost (40.5% of the total cost of \$91.3 million). Murphie (1991) notes, "The labor-intensive nature of decommissioning creates conditions that make final costs highly sensitive to changes in labor rates or work procedures. However, the basic work is nonskilled in nature and a labor force can be qualified and trained quickly" (p.130).

The ability to characterize a site has a marked effect on the technologies to be applied. Poor trench and burial pit marking and incomplete or missing records of the materials buried requires that onsite workers be qualified on and outfitted with extensive personal protection systems and use higher-technology devices, such as remote manipulators and extensive vapor and radiological monitoring devices (Lesperance et al. 1992). Although many sites can be adequately characterized, many cannot, and the number of these sites will increase the need for more highly skilled and qualified workforce.

Delays in scheduling and characterization can also complicate technology choices. In addition, they may, in some instances, preclude the use of a developed technology. Waste migration or reaction may render previously useful technologies obsolete. (The opposite is also true, chemical reactions in waste may make a previously obsolete technology very useful.) It is critical to ensure that the development of technologies, processing/production facilities, and products be coordinated. For instance, are waste processing plants planned that are of sufficient size to handle the type and volume of wastes to be generated? Can technologies be chosen which capitalize on skills already in the workforce? To the extent that technologies demand different skills or are produced on uncoordinated schedules, workforce and skill variety needs will be large.

3.5.4 Schedules

Environmental restoration and management work for sizable projects is characterized by long planning schedules regardless of the type or extent of contamination. The engineering plan for the Shippingport project for instance, took more than three years (Murphie 1991). A more complete schedule outlined by Schreiber (1989, Table 2) is contained in Table 3.1 below. Despite three-plus years of planning, physical decommissioning of Shippingport did not commence until six years after the beginning of Phase 1. The cost for the planning effort totaled slightly more than \$6 million (Schreiber 1989, Table 3). The figures are very similar to data presented by Elliott (1992), who examined the status of 1,222 Superfund site actions. He notes, "it takes seven years and at least \$4 million in transaction costs at each site to conduct necessary studies and design remedies before the final cleanup can begin" (p. 13). "This is 70% of the total time spent and a substantial, although lesser, share of the cost" (Elliott 1992, p. 12). Thus, Shippingport has many features in common with

Table 3.1. Shippingport Station Decommissioning Project Schedule

Phase 1	Engineering and planning	1979-1983
Phase 2	Decommissioning	1983-1989
	Award contract for decommissioning	Mar 84
	HQ approval to start	June 84
	Site turnover	Sep 84
	Start decommissioning operations	Jan 85
	Initiate physical decommissioning	Sep 85
	Complete physical decommissioning	Jul 89
	Stop decommissioning operations	Sep 89
	HQ approval to release site	Nov 89

Source: Schreiber (1989).

the typical Superfund site. These may differ substantially from the typical DOE site (which Shippingport, apparently, is not [GAO 1990]), but nonetheless provide an initial guide for anticipating schedules.

Constraints on the time workers can spend in restoration activities can be obtained from case studies of DOE-expedited removal actions. Limited evidence indicates that field sites which require workers to have Level B protection (supplied air, heavy gloves, and full-body coveralls) gain, at most, four hours of productive labor per an eight-hour workday (Lesperance et al. 1992). Summertime temperatures at several sites can limit that time to two hours and Level A protection (fully encapsulated suits) yields similarly low productivity.

3.5.5 Organizational and Institutional Characteristics

“Organizational and institutional barriers are the most significant obstacles to manpower planning, recruiting, and retention” (MNAS 1992, p. x). Institutional barriers such as regulations increase work-force needs by specifying crew sizes, preparation requirements, and work procedures. In several instances, DOE has compounded regulatory difficulties by specifying more stringent adherence to regulations than is required by other federal agencies. The Departments of Justice and Navy and the EPA, for example, assert that National Environmental Policy Act (NEPA) procedures are not applicable to Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) actions since the two, although not identical, are functionally equivalent. DOE, however, requires that NEPA procedures be applied to CERCLA actions. Thus, the same basic data must be presented in two entirely different ways to serve the requirements of two functionally similar statutes. Redundancies also occur

among OSHA guidelines and DOE-required safety analysis reports. These reports, which are required for nuclear sites, are often required for contamination sites as well. They are time consuming and expensive ("several months... and...\$70,000" in one instance) and provide "little value-added" (Lesperance et al. 1992, p. 496). The implementation of such duplicative procedures "may cause substantial schedule delays" (DOE, 1992, p. 2.37) and was a frequent complaint of program and project managers across the complex (MNAS 1992).

As bad as the extra workload caused by duplicate regulations is, the confusion which results from overlapping and contradictory procedures is worse. "The potential for overlapping application of state law, Resource, Conservation and Recovery Act (RCRA), and CERCLA is an issue common to all federal facilities, and is further complicated by the potential for confusing and overlapping state/federal jurisdictional and regulatory authorities" (DOE 1992, p. 2.43). Regulations which assign personal responsibility for environmental projects to program managers as well as the large dollar value placed on life in risk analyses and legal judgments (\$1 million to \$8.5 million) complicate matters further (MNAS 1992; Miller 1990, Viscusi 1990; Weiss et al. 1993). Managers react to this confusion cautiously; they overimplement, overinterpret, and avoid exercising discretion (Weiss et al. 1993). Consequently, productivity decreases even as workforce demands increase.

Labor laws have a substantial effect on the skills which can be employed in particular positions. The federal Office of Personnel Management determines the qualification standards for federal positions; safety and health regulations determine staffing requirements as well as personnel usage. DOE has also experienced occupational definition problems resulting from the application of wage labor laws. For instance, at the Shippingport Station Decommissioning and Decontamination Project, DOE had determined that the decontamination and decommissioning (D&D) work to be done was not construction labor. It accordingly specified in requests for proposals that rates be paid appropriate for unskilled workers. Labor unions challenged and the Labor Department determined "that the applicable labor rates should accord with those paid for skilled construction work" (Murphie 1991, p. 124). Although DOE appealed and prevailed, wages were nevertheless paid at skilled worker levels due to subcontracts which already had been signed and scheduling pressures. Site managers will need to act with all due caution regarding the application of Davis-Bacon and Service Contract Act provisions. This will increase workforce needs at the planning stage, if not the D&D stage as well.

Organizational roles, responsibilities, and reporting relationships form a complex web of requirements, communication channels, and work demands which inflate workforce demands and cause resources to be deployed inefficiently. Externally imposed restrictions on headcount, compensation policies, and security practices also increase skill demands and limit the potential "pipeline" of workers by reducing the flexibility of organizations in the complex to respond to local needs and discouraging potential employees from working for DOE (MNAS 1992).

One organizational intervention implemented at several sites which has decreased workforce demands and clarified responsibilities and authorities is the creation of Facility Representative positions. These DOE positions place one individual in the field in charge of a facility, auditing, or

functional unit. "The program attracts employees who want hands-on, highly demanding, and responsible positions" and "reduces manpower demands by capitalizing on the capabilities of current employees, reducing lines of authority, and concentrating responsibilities" (MNAS 1992, p. 3.23). The development of similarly innovative programs would reduce workforce demands even further.

3.5.6 Skills and Workforce Needs

The ability of an organization to adjust its staffing profile quickly depends on well-developed human resources databases, staffing/succession plans, career paths, and production/productivity indices. In many organizations these are lacking. As a result, workforce planning at the skills and employee levels become labor-intensive exercises that must be repeated *in toto* for each subsequent analysis. With no consistent database of the distribution of skills in the workforce or productivity rates for work elements, the organization is not able to plan for the jobs at hand. The GAO, for instance, has found EPA needed such planning tools "to better support its Superfund staffing requirements and skill mixes...to carry out planned activities" (GAO 1987, p. 35). The lack of these tools led to understaffing, poor recruitment of critical skills, and schedule delays.

In Chapter 1.0 it was demonstrated the managers in the DOE believe that the skills needs of the complex will not change markedly as a consequence of the change in mission. Most also believe that the requirements of the mission requires that the number of workers in the complex be increased considerably. These projections can be validated only with the development of productivity indices based on technology, contaminant, and headcount data.

3.5.7 Labor Supply

"[L]ong-term projections of supply and demand for scientists and engineers in the economy as a whole are inherently unstable" (OTA 1985, p. 24). NASA, for instance, wildly overpredicted the number of scientists and engineers it would need to achieve the Apollo mission (Levine 1987). Some recent NSF studies on the need for S&Es have been shown to be unduly optimistic. Although some effort to predict long-term needs is necessary to guide educational programs, especially those that the DOE recruits heavily from, the DOE is not likely to reliably predict labor supply in the long run. Much more effort, then, should be placed on developing workforce scenarios and contingencies over shorter (three- to seven-year) planning horizons. Over this time frame, workers will switch occupations in response to changing market conditions (NSF 1980, 1982, 1985) and students, over time, adjust their choice of majors based on what happens in the labor market (Finn 1986). Within such a time frame the DOE can influence proactively the tendency for individuals and students to intern, gain experience with, and subsequently join the DOE complex workforce via its education and training programs.

Overall, the widely predicted shortage of technical personnel has not materialized. Highly talented chemical engineers are facing a tough job market presently (Brennan et al. 1992), and employment figures for other engineering professions are similarly flat. Science occupations are being hit by decreases

in grant monies and public funding for universities (The Scientist 1991). Recruiting difficulties occur mainly for those occupations characterized by a small labor market segment and skills and training unique to the research and development and production activities of DOE.

3.6 Chapter Summary

A framework relating the mission, budget, technologies, skills, workforce, and labor supply was developed as a management tool which can be used to 1) guide the questions managers may ask regarding the workforce and 2) structure the responses/data that result from the questions. At this point in the EM mission, it is much easier to design the questions than respond with answers or data. Despite the fact that relatively few studies have addressed the workforce, organization, and management issues relevant to EM's activities, several clear findings emerge when the data from these studies, as well as those from other federal agencies, are evaluated within the framework.

The labor market supply is typically one of the first variables addressed when issues of workforce planning are considered. Government agencies have few tools which can be used to intervene in the market; they mainly consist of education and training programs. Since labor projections are unstable, DOE must base its policies on the timeframes associated with its interventions. Education (long time frame) is a necessary, but not sufficient part of the development of a qualified workforce. Training (short time frame) for nearly all occupations is also necessary due to the unique nature of the DOE complex. While relatively few workers outside the DOE complex may have the necessary training to work in the EM organization, there is, for most occupations, no current shortage of individuals with the necessary education. In fact, labor market opportunities are currently quite favorable to employers, and are especially so to EM as DP funding decreases. The most feasible solution is to educate for the long run without regard for labor projections (since basic science and technical skills can be applied broadly and there is undisputed value to having a well-educated workforce), and train for skills or positions unique to DOE needs in the short-run (via internships, mentoring assignments, and structured work experiences as well as classes). Over the long run, training should increase the flexibility of the workforce by means of such programs as cross training, rotational assignments, and mentoring.

Unclear missions and goals, fluctuating budgets, uncoordinated technology development or use, and outmoded or inappropriate organizational characteristics account for a far greater percentage of workforce planning and management difficulties than macroeconomic factors. They all, directly or indirectly, affect the workforce that DOE and its contractors need and, ultimately, will obtain. The framework presented here suggests that focusing efforts on resolving these issues, not projecting the labor supply or demand, is the first step to securing a stable and skilled workforce.

4.0 Notes

1. *Roadmap Human Resource Projections*. Presentation to Leo P. Duffy, Assistant Secretary, DOE Office of Environmental Restoration and Waste Management, January, 1993.
2. *Fast Track Site Human Resource Projections Development: Meeting Minutes*. Collection of Roadmap meeting minutes, October, 29, 1992.
3. *Long Term Workforce Projections at the Hanford Site*. Letter report prepared by C. W. Holmes and R. E. Lewis, Pacific Northwest Laboratory, for DOE-EM-52, 1992.
4. *Environmental Restoration and Waste Management: An Occupational Assessment for the Oak Ridge Area (ORAA)*. Draft report produced by H. W. Herzog and A. M. Schlottmann, the Department of Economics, University of Tennessee.

5.0 References

DOE Order 4700.4, "Project Management Certification." (See DOE 1993.)

American Society of Chemical Engineers (ASCE). 1991. "Salary Survey: Summary of Findings." *Journal of Professional Issues in Engineering Education and Practice* 118(2):167-189.

Brauer, R. L. September 1992. "Educational Standards for Safety Professionals. *Professional Safety*, pp. 16-21.

Brennan, M. B., R. L. Rawls, and P. S. Zurer. October 1992. "1993 Employment Outlook." *Chemical and Engineering News*, pp. 24-35.

Brouns, R. J. 1971. *An Experimental Re-employment Program for Determining Significant Factors in Career Transfer among Unemployed Engineers and Scientists in King County, Washington*. NTIS Report, PB 217 006, National Technical Information Service, Springfield, Virginia.

Chapple, A. 1992. "L. A. Plants Engineer Retraining Seed." *Engineering Times* 14 (11):1, 13.

Elliott, E. D. 1992. "Superfund: EPA Success, National Debacle?" *Natural Resources and Environment* 6(3):11-50.

Finn, M. G. 1986. *Factors Affecting the Demand for Natural Scientists and Engineers in the United States, 1985-2010: A Review of Existing Knowledge*. Presented at the Workshop on the Prospective and Expected Economic Effects of the Changing Age Structure of the U.S. Population. NTIS Report, CONF-860781--1, National Technical Information Services, Springfield, Virginia.

Fortune. May 17, 1993. "Bell Labs: Products Before Prizes," p. 63.

Foushee Group, Inc. 1992. *Environmental Health and Safety Compensation Survey*. Foushee Group, Inc., Burlingame, California.

General Accounting Office (GAO). 1987. *Superfund: Improvements Needed in Work Force Management*. GAO/RCED-88-1, General Accounting Office, Washington, D.C.

General Accounting Office (GAO). 1990. *Usefulness of Information from Shippingport Decommissioning for Rancho Seco*. GAO/RCED-90-171, General Accounting Office, Washington, D.C.

General Accounting Office (GAO). 1991a. *Hazardous Waste: DoD Estimates for Cleaning up Contaminated Sites Improved but Still Constrained*. GAO/NSIAD-92-37, General Accounting Office, Washington, D.C.

General Accounting Office (GAO). 1991b. *Uranium Enrichment: Analysis of Decontamination and Decommissioning Scenarios*. GAO/RCED-92-77BR, General Accounting Office, Washington, D.C.

Holmes, C. W., R. E. Lewis, S. T. Hunt, and M. G. Finn. 1992. *Environmental Restoration and Waste Management Manpower Needs Assessment (MNAS): U.S. Department of Energy Complex*. PNL-8171, Pacific Northwest Laboratory, Richland, Washington.

Holmes, C. W., R. E. Lewis, S. T. Hunt, and M. G. Finn. 1993. *Environmental Restoration and Waste Management Manpower Needs Assessment (MNAS): U.S. Department of Energy Complex*. PNL-8171 Addendum, Pacific Northwest Laboratory, Richland, Washington.

Hudis, P. M., S. L. Garland, J. R. Matlof, and K. L. Vork. 1992. *Educational Needs and Employment Trends of Environmental Hazardous Materials Technicians and Related Workers*. MDS-249, National Center for Research in Vocational Education, Berkeley, California.

IEEE Spectrum. December 1992. "Engineers in Profile," pp. 29-36.

Kline, S. J. and D. E. Kash. Summer 1992. "Do We Need a Technology Policy?" *IEEE Technology and Society Magazine*, pp. 18-31.

Ledbetter, D. L. March/April 1993. Status of Skills Conversion and PEI Programs. *California Professional Engineer*, p. 7.

Lesperance, A. M., M. R. Siegel, and M. D. McKinney. Winter 1992-93. "Occupational Safety and Health Issues Relevant to DOE's Environmental Restoration Program." *Federal Facilities Environmental Journal*, pp. 483-497.

Levine, A. S. 1987. The Apollo Program: Science/Engineering Personnel Demand Created by a Federal Research Mission. NTIS Report Y.3T22/2:2 Ed 8/2/pt.4/apollo, National Technical Information Service, Springfield, Virginia.

MNAS. (See Holmes et al. 1992.)

MNAS Addendum 1. (See Holmes et al. 1993.)

Markey, J. P., and W. P. Parks. September 1989. "Occupational Change: Pursuing a Different Kind of Work." *Monthly Labor Review*, pp. 3-12.

Wm. M. Mercer, Inc. 1991. *Environmental and Waste Industry Compensation Survey*. Wm. M. Mercer, Inc., Denver, Colorado.

Miller, T. R. 1990. "The Plausible Range for the Value of Life - Red Herrings Among the Mackerel." *Journal of Forensic Economics* 3(3):17-39.

Mincer, J., and B. Jovanovic. 1979. "Labor Mobility and Wages." *Studies in Labor Markets*, ed. S. Rosen, pp. 21-64. University of Chicago Press, Chicago.

Murphie, W. 1991. "Greenfield Decommissioning at Shippingport: Cost Management and Experience." *Energy Journal* 12:119-132.

National Academy Press. 1985. *Engineering Education and Practice in the United States: Foundations of Our Techno-Economic Future*. National Academy Press, Washington, D.C.

National Science Foundation (NSF). 1980. *Occupational Mobility of Scientists and Engineers*. NSF 80-317, National Science Foundation, Washington, D.C.

National Science Foundation (NSF). 1982. *Changing Employment Patterns of Scientists, Engineers, and Technicians in Manufacturing Industries: 1977-1980*. NSF 82-331, National Science Foundation, Washington, D.C.

National Science Foundation (NSF). 1985. *Science and Engineering Personnel: A National Overview*. NSF 85-302, National Science Foundation, Washington D.C.

Office of Technology Assessment (OTA). 1985. *Demographic Trends and the Scientific and Engineering Work Force - A Technical Memorandum*. OTA-TM-SET-35, U.S. Government Printing Office, Washington D.C.

Parsons, D. O. 1986. "The Employment Relationship: Job Attachment, Work Effort, and the Nature of Contracts." *The Handbook of Labor Economics, Volume II*, eds. O. Ashenfelter and R. Layard, Chapter 14, pp. 789-848. Elsevier Science Publishers BV, New York.

Schreiber, J. J. 1989. Completion of the Shippingport Reactor Decommissioning. DOE/SSDP--0082, U.S. Department of Energy, Washington D.C.

The Scientist. January 7, 1991. "Despite Scientist Shortage, Future Ph.D.s Fear Joblessness," pp. 24-32.

U.S. Department of Energy (DOE). 1991. *Environmental Restoration and Waste Management: Five Year Plan 1993-1997*. U.S. Department of Energy, Washington, D.C.

U.S. Department of Energy (DOE). 1992. *Schedule Optimization Study Hanford RI/FS Program Volume 2: Final Report*. EMO 1080 Vol.2, U.S. Department of Energy, Washington D.C.

U.S. Department of Energy (DOE). 1993. "Project Manager Certification," DOE Order 4700.4.

Vesilind, P. A. 1991. "What Should We Teach Civil Engineering Students?" *Journal of Professional Issues in Engineering Education and Practice* 117(3):287-294.

Viscusi, W. K. 1990. "The Econometric Basis for Estimates of the Value of Life." *Journal of Forensic Economics* 3(3):61-70.

Watson, J. S. 1989. *Adaptability in Chemical Engineering*. Presented at the Workshop on National Priorities and Technological Change: Fostering Flexibility in the Engineering Work Force. NTIS Report, CONF-8909200--1, National Technical Information Service, Springfield, Virginia.

Weiss, M. A., J. S. Carroll, K. F. Hansen, C. Perin, H. A. Hahn, and J. A. Morzinski. 1993. *Making Progress in Cleaning Up DOE's Weapons Complex: Issues of Organization and Management*. MIT Energy Laboratory Report, MIT-EL 93-001, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Appendix A

ANOVA Methodology

Appendix A

ANOVA Methodology

Single-factor ANOVA models offer a versatile method of studying relations between median salary levels (the dependent variable), and the industry or region employing Environmental Restoration (ER) manpower (the independent qualitative variables). The industry ANOVA covers four employers of ER manpower: research laboratories, ER services, energy, and utilities. The regional ANOVA covers five locations: West Coast, South Central, North Central, Southeast, and Northeast. Both models decompose the variability in ER salaries into two components: the error sum of squares (SSE) and the treatment sum of squares (SSTR). The SSE measures random variations in the base salary around the median salary in each industry or region, while the treatment sum of squares (SSTR) measures variations in the median salaries of the industries or regions based on their deviations around the combined median salary of the industries or regions.

These two types of variability in base salary have been calculated for the various ER occupations based on the computational formulas displayed in the following ANOVA table.

ANOVA Table for Single-Factor Studies			
Source of Variation	SS	df	MS
Between treatments	$SSTR = \sum n_j (\bar{Y}_j - \bar{Y})^2$	$r-1$	$MSTR = \frac{SSTR}{r-1}$
Error (within treatments)	$SSE = \sum \sum (Y_{ij} - \bar{Y}_j)^2$	$n_T - r$	$MSE = \frac{SSE}{n_T - r}$
Total	$SSTO = \sum \sum (Y_{ij} - \bar{Y})^2$	$n_T - 1$	

The symbolic notation used in expressing these formulas is standard. Y_{ij} represents the salary of the i th ER employee in the j th industry or region. Thus, in the industry ANOVA, Y_{11} denotes the salary of worker one in industry one. Similarly, in the regional ANOVA, Y_{11} denotes the salary of worker one in region one. Therefore, the mean salary in the j th industry or region is represented by

$$\bar{Y}_j = \frac{\sum_i Y_{ij}}{n_j} = \frac{Y_{.j}}{n_j}$$

where the dot in the subscript indicates that the averaging was done over i workers. The total of all observations in the study is represented by

$$Y_{..} = \sum_j \sum_i Y_{ij}$$

where the two dots indicate summation over i workers and j industries or regions. Accordingly, the mean for all observations is denoted by

$$\bar{Y}_{..} = \frac{\sum_i \sum_j Y_{ij}}{n_T} = \frac{Y_{..}}{n_T}$$

Based on this symbolic notation, the treatment sum of square and error sum of squares are expressed by

$$SSTR = \sum_j n_j (\bar{Y}_j - \bar{Y}_{..})^2$$

and

$$SSE = \sum_j \sum_i (Y_{ij} - \bar{Y}_j)^2$$

These formulas have a straightforward interpretation. The larger the median salary differentials across industries or regions, the larger $SSTR$ becomes. Thus, if the median salary in all industries or regions are the same, $SSTR=0$. On the other hand, the more the salary levels in a given industry or region differ, the larger SSE becomes. Accordingly, if $SSE=0$, all ER workers in a given industry or region earn the same base salary. Finally, the means of the $SSTR$ and SSE are obtained by dividing each sum of squares by its associated degrees of freedom. These are represented by $r-1$ and n_T-r for $SSTR$ and SSE (respectively), where r denotes the total number of industries or regions.

Based on the ANOVA formulas described above, we first analyzed whether the median salary levels are statistically different across industry or regions. For both cases, the alternative conclusions are represented by:

$$\text{Industry: } H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4$$

$$H_1: \text{ not all } \mu \text{ are equal}$$

$$\text{Region: } H_0: \mu_1 = \mu_2 = \mu_3 = \mu_4 = \mu_5$$

$$H_1: \text{ not all } \mu \text{ are equal}$$

The relevant test statistic for choosing between these alternatives is defined by

$$F = \frac{MSTR}{MSE}$$

Large values of the test statistic support H_1 , since MSTR will tend to exceed MSE when H_1 holds. On the other hand, values of F near 1 support H_0 since both MSTR and MSE have the same expected values when H_0 holds. Accordingly, the relevant test is an upper-tail one. The results of these F -tests are reported in the table.

Referring to this table the median salary levels in the majority of ER occupations appear to differ across both industries and regions as implied by the alternative hypothesis H_1 . The significant F values are denoted by F^* . For these cases, the next step in the ANOVA is to compare the various industry or regional salary differentials using Bonferroni's method of multiple comparisons. This method is particularly useful for making pairwise comparisons when the factor level sample sizes are not equal.

Because four industries are under consideration, up to six industry pairwise comparisons are possible.^(a) Out of these six, however, the most relevant to DOE/ER's manpower assessment are the possible gaps in salaries between research laboratories and the other industries. Thus we limit the investigation to no more than four pairwise comparisons of industry salary levels in each of the targeted occupations where significant F values have been identified. Meanwhile, as many as ten pairwise comparisons of regional salary levels are undertaken given the five regional locations under consideration.

In applying Bonferroni's multiple comparison methodology to the industry and regional ANOVA models considered above, confidence intervals are obtained for the specific salary gaps under study. Using general notation these salary gaps are denoted by $L_{i,j}$ and measure the difference between the median salary in the i th and j th industry or region. The confidence intervals associated with each of these gaps are defined by

$$L_{i,j} - S(L_{i,j})B \leq L_{i,j} \leq L_{i,j} + S(L_{i,j})B$$

where $S(L_{i,j})$ denotes the standard deviation of the salary gap between the i th and j th industry or region, and B denotes the Bonferroni confidence coefficient associated with each occupational class. These Bonferroni confidence coefficients are calculated using the t distribution after modifying the level of significance to reflect the number of pairwise comparisons and adjusting for $n-r$ degrees of freedom. The following formula is used in calculating the various Bonferroni confidence coefficients.

(a) The number of pairwise comparisons associated with n groups is defined by the following formula:

$$\binom{n}{2} = \frac{n!}{2!(n-2)!}$$

$$B=t(1-\frac{\alpha}{2m};n_r-r)$$

For example, given four industry salary levels ($r=4$) involving six comparisons ($m=6$) over 219 observations ($n=219$), a two-sided test at the 95% level of significance ($\alpha=.05$) implies a Bonferroni confidence coefficient value of $B=2.66$. Depending on these B-values then, the decision rule for determining the statistical significance of any salary comparison is:

if $|L_{i,j}| > B$ S($L_{i,j}$) then significant, otherwise not.

The results of these multiple salary comparisons are reported in tables (2.D) and (2.E) at both the 95% and 99% confidence levels.

Distribution

No. of
Copies

No. of
Copies

OFFSITE

12 DOE/Office of Scientific and
Technical Information

1 A. Behr
DOE PR-15 FORSTL
1000 Independence Ave., S.W.
Washington, DC 20585

T. C. Chee
U.S. Department of Energy
EM-50, GTN
19901 Germantown Road
Germantown, MD 20874

C. Dobbins
Basic Technologies International
4641 Montgomery Avenue, Suite 300
Bethesda, MD 20814

M. G. Finn
Oak Ridge Associated Universities
230 Warehouse Road
P.O. Box 117
Oak Ridge, TN 37830-0117

Susan Prestwich
U.S. Department of Energy
EM-50, GTN
19901 Germantown Road
Germantown, MD 20874

I. Sewell
U.S. Department of Energy
EM-50, GTN
19901 Germantown Road
Germantown, MD 20874

ONSITE

2 U.S. Department of Energy

J. E. Ollero
D. J. Sansotta

Westinghouse Hanford Company

L. P. Bundy

16 Pacific Northwest Laboratory

J. F. Keller
R. E. Lewis (8)
C. A. Ulibarri
Publishing Coordination
Technical Report Files (5)

**DATE
FILMED**

1 / 12 / 94

END