STATE OF ARIZONA
OFFICE OF THE
AUDITOR GENERAL

A PERFORMANCE AUDIT
OF THE

ARIZONA DEPARTMENT OF TRANSPORTATION MATERIALS TESTING FUNCTION

NOVEMBER 1982

A REPORT TO THE
ARIZONA STATE LEGISLATURE

REPORT 82-6

DOUGLAS R. NORTON, CPA
AUDITOR GENERAL

STATE OF ARIZONA
OFFICE OF THE
AUDITOR GENERAL

November 10, 1982

Members of the Arizona Legislature
The Honorable Bruce Babbitt, Governor
Mr. William A. Ordway, Director
Arizona Department of Transportation

Transmitted herewith is a report of the Auditor General, A Performance Audit of the Arizona Department of Transportation - Materials Testing Function. This report is the third of a series of reports to be issued on the Arizona Department of Transportation and is in response to Senate Bill 1001 enacted by the Thirty-fifth Legislature, Second Special Session in 1981.

The blue pages present a summary of the report; a response from the Arizona Department of Transportation is found on the yellow pages preceding the appendices.

My staff and I will be pleased to discuss or clarify items in the report.

Respectfully submitted,

Douglas R. Norton

Douglas R. Norton
Auditor General

Staff: William Thomson
Peter N. Francis
Steve H. Thacker
Arthur E. Heikkila
Richard Stephenson

Enclosure

111 WEST MONROE • SUITE 600 • PHOENIX, ARIZONA 85003 • (602) 255-4385

OFFICE OF THE AUDITOR GENERAL

A PERFORMANCE AUDIT OF THE ARIZONA DEPARTMENT OF TRANSPORTATION MATERIALS TESTING FUNCTION

A REPORT TO THE

ARIZONA STATE LEGISLATURE

REPORT 82-6

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

The Office of the Auditor General has completed a performance audit of the Arizona Department of Transportation (ADOT) - materials testing function. This audit was conducted in response to Senate Bill 1001, enacted by the Thirty-fifth Legislature, Second Special Session requiring a performance audit of the Arizona Department of Transportation and is one of a series of audits to be completed on the Department.

ADOT conducts inspection and testing activities during highway construction to control the quality of roads built under its supervision. ADOT project engineers are responsible to see that the materials and workmanship incorporated in their projects meet standards. To carry out this charge, each project engineer is assisted on the construction site by a staff of inspectors. Samples of construction materials are sent to ADOT laboratories for testing. ADOT has a three-level organization for materials testing, consisting of project or area labs, district labs and a central lab. In addition to testing materials during construction, ADOT has several crews which perform materials investigation and testing activities prior to construction in order to obtain data useful in the design of the highway. These latter crews are located in the Materials Section - Highways Division.

Our preliminary review included project inspection activities as well as the materials testing function. However, early in our audit ADOT contracted with two consulting firms to address the major problem areas we had identified regarding project inspection activities. Therefore, our detailed audit work was limited to the materials testing function.

We found that the materials testing function is overstaffed because ADOT has failed to reduce staffing levels to match declining work loads. Overstaffing occurs in several district labs, the District 1 Area Lab and in several units of the Materials Section - Highways Division. In total, we identified 33 positions which could be eliminated for an annual savings of $825,000. We also found that materials testing costs could be reduced by controlling oversampling. Each of these problem areas is summarized below.

District labs were overstaffed by a total of 10 positions in fiscal year 1981-82. Unless adjustments are made, this overstaffing will increase. According to our analysis of future work loads, ADOT can reduce district lab staffing by 19 positions by July 1, 1983, saving $475,000 annually. These reductions are supported by ADOT's plans for district reorganization--developed during the course of our audit--which now call for a reduction of 16 lab positions (see page 9).

The ADOT District 1 Area Lab is also overstaffed by a total of seven positions. During the first half of 1982, productivity declined 47 percent due to this overstaffing. Future work loads are not expected to increase; therefore, seven positions should be eliminated--an annual savings of $175,000 (see page 19).

ADOT could save at least $125,000 annually by performing the materials investigation function more efficiently. ADOT could eliminate three positions and reduce travel-related costs by transferring core sampling activities from the Materials Section - Highways Division to the district labs. Another two positions could be eliminated by reducing the size of the pit investigation crews in the Materials Section (see page 25).

ADOT could reduce personnel and equipment costs by combining drill crews of the Structures and Materials Sections (Highways Division) into a single unit. Current work load does not justify both crews. A consolidation would enable ADOT to avoid the replacement of some expensive drilling equipment--a savings of $150,000. In addition, two positions could be eliminated, saving another $50,000 annually (see page 35).

ADOT could further reduce materials testing costs by controlling oversampling. In some instances, project personnel have not fully implemented new sampling guidelines and do not adequately control oversampling. In addition, ADOT should consider eliminating some concrete cylinder tests as another way to reduce lab work loads (see page 43).

We identified potential areas for further audit work that we could not pursue due to time constraints. For a list of these areas, see page 49.

INTRODUCTION AND BACKGROUND

The Office of the Auditor General has conducted a performance audit of the Arizona Department of Transportation (ADOT), materials testing and inspection functions, in response to Senate Bill 1001 enacted by the Thirty-fifth Legislature, Second Special Session in 1981. This report is one of a series to be completed on the Department of Transportation.

Since its creation as the Highway Department in 1927, ADOT has conducted inspection and testing activities during construction to control the quality of roads built under its supervision. This system of inspection and testing, however, became more sophisticated and complex after the Federal Government authorized the Interstate System in 1956 and began funding a large portion of the highway construction in Arizona. Current Federal Highway Administration (FHWA) regulations state:

> "Sampling, testing, and inspection procedures should provide adequate assurance that the materials and work incorporated in each Federal-aid highway construction project are in conformity with the requirements of the approved plans and specifications, including approved changes."

ADOT project engineers have the responsibility to see that the materials and workmanship incorporated in their projects meet standards. To carry out this charge each project engineer is assisted by a staff of inspectors and testers. The inspectors are constantly at the construction site, checking the contractor's work and taking samples of materials. These samples are sent to the laboratory for testing.

FHWA requires ADOT to perform two types of testing during construction:

> "a. Acceptance Samples and Tests - all of the samples and tests used for determining the quality and acceptability of the materials and workmanship which have been or are being incorporated in the project.

"b. <u>Independent Assurance Samples and Tests</u> - independent samples and tests or other procedures performed by State personnel who do not normally have direct responsibility for . . . acceptance sampling and testing. They are used for the purpose of making independent checks on the reliability of the results obtained in acceptance sampling and testing."

ADOT has a three-level organization for materials testing, consisting of project labs, district labs and a central lab.

Project labs are quality acceptance labs--the quality control labs of the highway construction industry. The testers work for the project engineers. Their test results are used by the project engineer to stop a project if necessary or to reduce payments if materials fail to meet specifications. Project labs operate out of trailers or other temporary facilities at the job sites; in general, they have no large or expensive test equipment as compared with the central and district labs. Sometimes several projects in the same area are supported by a single lab; in these cases the lab is known as an area lab.

Each ADOT district* also has a lab with the following duties:

1. Perform independent assurance sampling and testing;

2. Perform the construction acceptance tests that project lab testers are not equipped or trained to perform;

3. Design and test materials used by maintenance crews;

4. Review project-level sampling and testing procedures and documentation;

5. Check and calibrate testing equipment in project labs;

---

* Each project engineer is under the jurisdiction of a district engineer. During fiscal year 1982-83, ADOT is reducing the number of districts from seven to four. Figures 1 and 2 show the alignments of these districts.

FIGURE 1

ADOT Engineering Districts
Prior to July 1, 1982

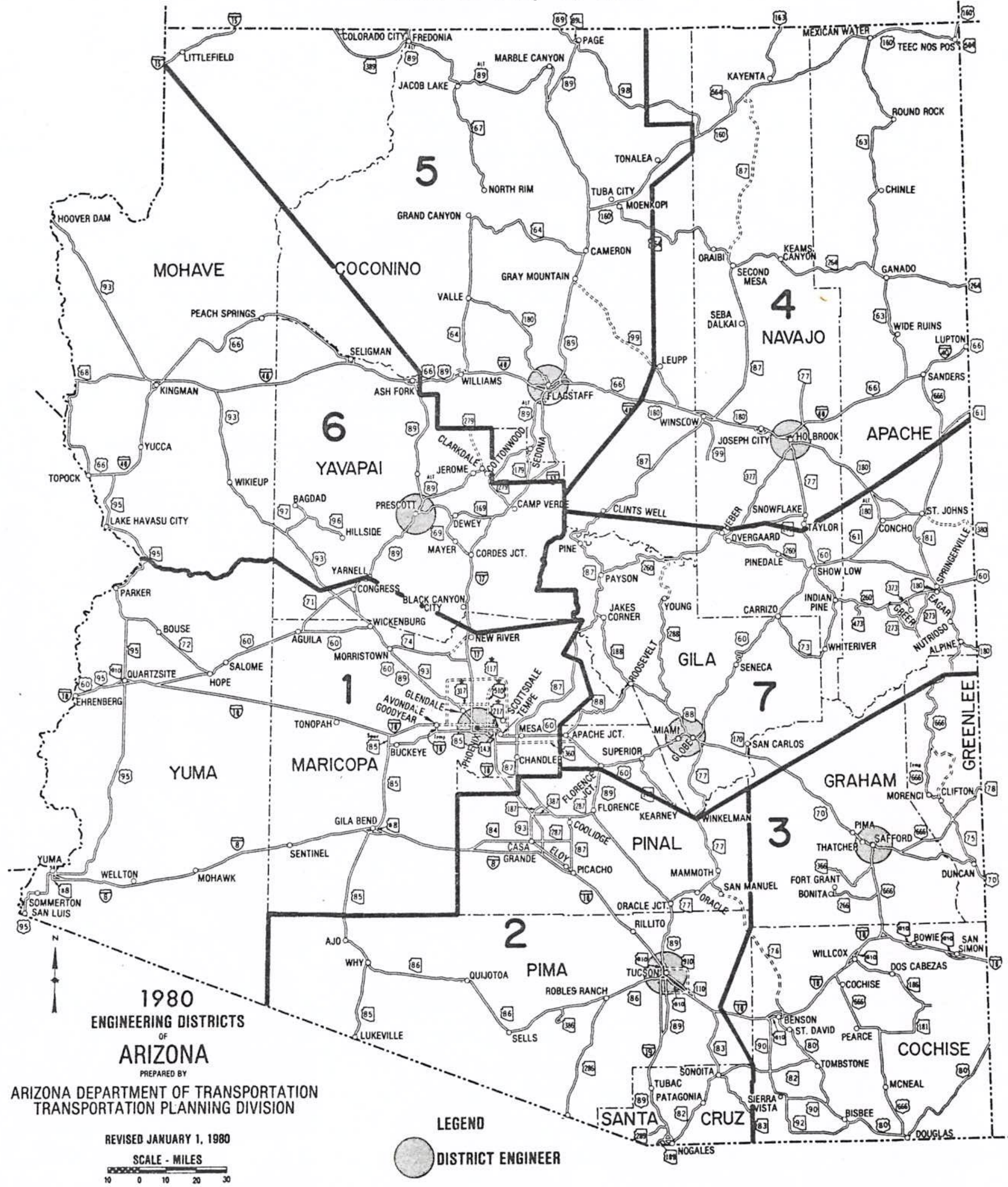
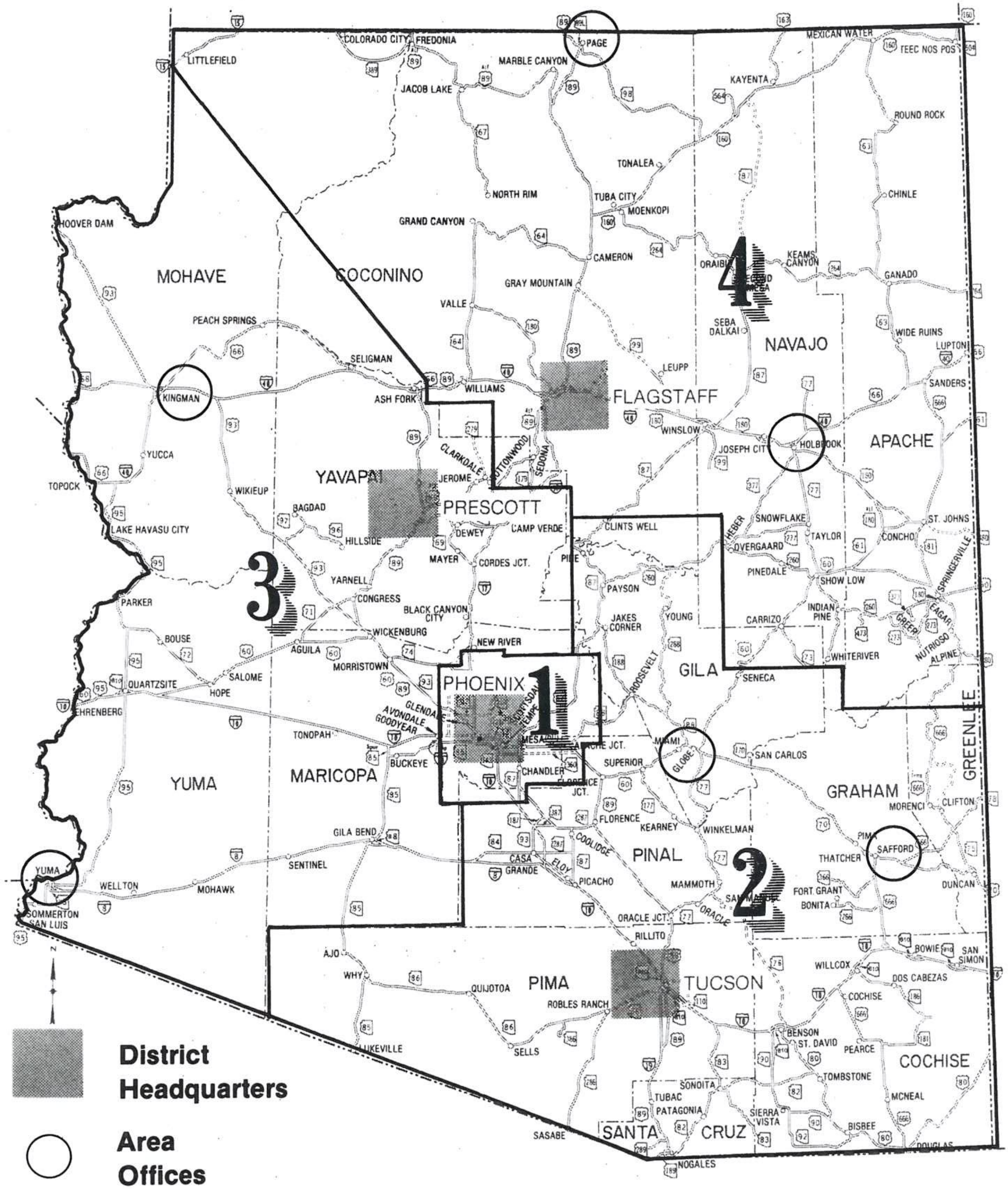


FIGURE 2

New Engineering Districts

Arizona Department of Transportation



6. Train district and project personnel in testing methods, procedures, equipment, etc;

7. Assist in materials research activities; and

8. Act as materials consultant to the District Engineer, project staffs and maintenance personnel.

The central lab is part of the Materials Section, Highways Division. The major duties of the central lab are:

1. Perform tests on construction materials which cannot be tested by project or district labs (These tests require specialized equipment and skills.);

2. Design or approve mixes of materials to be used as road surfaces;

3. Review testing procedures, equipment, etc. used in the district labs;

4. Develop and provide training in materials-related areas;

5. Develop and improve ADOT specifications regarding road-building materials; and

6. Perform preconstruction tests.

Preconstruction tests are performed on geological samples obtained by various field crews in the Materials Section. These geological investigations are critical to the design of the roadway and the location of road-building materials.

Table 1 shows the number of staff (FTEs) budgeted for the district labs and the Materials Section for fiscal years 1980-81 through 1982-83.

TABLE 1

BUDGETED FTEs FOR DISTRICT LABS AND
MATERIALS SECTION, FISCAL YEARS 1980-81 THROUGH 1982-83

Unit	Budgeted FTEs 1980-81	1981-82	1982-83
District Labs	49	46	46
Materials Section			
Administration	*	*	7
Geotechnical Services	*	*	26
Pavement Services	*	*	20
Materials Testing Services (central lab)	*	*	34
TOTAL - Materials Section	91	85	87

* The Materials Section was not organized in this manner during 1980-81 and 1981-82.

As of July 1982, project engineers supervised an approximate total of 550 ADOT personnel on construction projects throughout the State. A number of these employees are directly involved in materials sampling and testing.

Audit Scope and Purpose

The purpose of our audit work was to

1. Review the division of responsibilities among the district labs and the Materials Section, Highways Division.

2. Evaluate the productivity of the Central Lab and district labs, and project future work loads and staffing requirements for these labs.

3. Evaluate the efficiency of various activities within the Materials Section, Highways Division.

4. Review the need for two separate drilling crews within the Highways Division.

5. Determine if the frequency of materials sampling and testing could be reduced.

6. Evaluate the integrity of the construction inspection and testing system.

Because of time constraints, we were unable to address several issues of concern. For a list of potential future audit issues, see page 49.

Several other issues were of interest early in the audit but are being addressed by other entities. One of these issues was the management of project-level personnel. During our audit, ADOT contracted with Roy Jorgensen Associates to develop a Construction Engineering Manpower Management System which would allow ADOT to staff construction projects more efficiently. Early in the audit we also considered the feasibility of requiring contractors to perform more surveying and staking during construction. This issue, however, is being addressed by another ADOT consultant.

The Auditor General and staff express appreciation to ADOT's inspection and testing staff for their cooperation and assistance during the course of our audit.

5. <u>The extent to which the Agency has encouraged input from the public before promulgating its rules and regulations and the extent to which it has informed the public as to its actions and their expected impact on the public</u>

The Board has encouraged public participation in the development of its rules and has complied with the open meeting law. The public and funeral industry were given opportunity for extensive input when the Board revised its regulations in 1981. The Board has also provided the public with adequate notice and minutes of meetings as required by the Open Meeting Law.

The 1981 revision of Board regulations provided opportunity for public and funeral industry participation. The Board complied with all requirements of the Administrative Procedures Act in promulgating the regulations. The Board notified 150 industry members and concerned citizens, received 44 comments, conducted 2 public hearings and obtained input from an advisory committee composed of public and industry representatives before promulgating final regulations.

The Board appears to have complied with the requirements of the Open Meeting Law. For all regular meetings, telephone conferences and subcommittee meetings from January 1982 through March 1983, the Board provided adequate notice and maintained adequate minutes of the proceedings.

6. <u>The extent to which the Agency has been able to investigate and resolve complaints within its jurisdiction</u>

The Board investigates and resolves most complaints in a timely manner. All but 11 of the 99 complaints filed between January 1980 and December 1982 have been closed. The average time required to handle these complaints was approximately three months. Most of the unresolved cases were filed during 1982 and are still under investigation by the Board. The Board closed most of the complaints (74 percent) it received since 1980 without taking action. These

FINDING I

REDUCING OVERSTAFFING IN THE DISTRICT LABS WILL SAVE UP TO $475,000 ANNUALLY.

ADOT district materials labs are overstaffed because ADOT has failed to adjust staffing levels to match changes in work load. The amount of highway construction fluctuated dramatically in most districts in recent years, and district lab work load varied accordingly. However, lab staffing levels remained fairly constant. As a result, lab productivity varied tremendously and district labs on the whole were overstaffed by 10 positions in fiscal year 1981-82. In addition, unless adjustments are made this overstaffing will increase. Analyzing future work loads we found ADOT can reduce district lab staffing by 19 positions by July 1, 1983, producing $475,000 in annual savings. These reductions are supported by ADOT's plans for district reorganization--developed during the course of our audit--which now call for a reduction of 16 positions.

Highway Construction Fluctuated, but Staffing Remained Constant

ADOT has not adjusted district lab staffing levels to match changes in work load. As the amount of highway construction fluctuated from year to year, district lab work load also varied.* However, lab staffing levels remained fairly constant.

District lab work load is largely a function of highway construction. The lab's primary role is to provide testing services during project construction.** Thus, when construction declines in a district, work load for the district lab also declines.

---

* Highway construction, as used in this report, includes preservation projects as well as new construction and reconstruction.

** Preconstruction testing activities are performed largely by the ADOT central lab.

TABLE 2

A COMPARISON OF ADOT PAYMENTS TO CONTRACTORS (IN MILLION $)
VERSUS BUDGETED FTEs PER DISTRICT LAB FOR
FISCAL YEARS 1975-76 THROUGH 1980-81
(CONVERTED TO 1982 $)

	1975-76	1976-77	1977-78	1978-79	1979-80	1980-81
District 1:						
Contractor Payments	$46.4	$53.4	$72.7	$44.2	$57.8	$68.5
Budgeted FTE	10	11	11	11	11	11
District 2:						
Contractor Payments	$31.1	$35.3	$29.9	$39.2	$22.4	$15.9
Budgeted FTE	7	7	6	6	6	6
District 3:						
Contractor Payments	$19.2	$4.9	$6.8	$8.2	$10.5	$17.7
Budgeted FTE	6	6	6	5	5	5
District 4:						
Contractor Payments	$8.9	$11.1	$19.3	$26.6	$41.6	$20.0
Budgeted FTE	9	8	8	8	8	8
District 5:						
Contractor Payments	$22.7	$16.9	$23.7	$14.4	$20.7	$26.5
Budgeted FTE	9	9	8	7	7	7
District 6:						
Contractor Payments	$56.2	$57.6	$56.3	$41.6	$35.5	$20.9
Budgeted FTE	7	7	8	8	7	6
District 7:						
Contractor Payments	$30.2	$17.5	$13.4	$13.0	$15.2	$12.0
Budgeted FTE	7	7	7	7	6	6

In recent years the amount of highway contruction in most districts has varied, but district staffing levels have remained fairly constant. Table 2 compares the amount of construction in each district as measured by payments to contractors (converted to 1982 $) versus the budgeted FTEs for each district lab for fiscal years 1975-76 through 1980-81.

As shown in Table 2, between 1976-77 and 1980-81 annual construction in District 6 declined from $58 million to $21 million, but the number of budgeted FTEs for the District lab descreased only by one. District 4 lab had eight budgeted FTEs in both 1979-80 and 1980-81, although the amount of construction fell from $42 million to $20 million.

Wide Disparities in Lab Productivity

Failure to match staffing levels with work load caused wide disparities in the productivity of district labs. Some labs performed as little as one-fourth the amount of testing per employee as other labs; in addition, most district labs experienced wide fluctuations in their own productivity from year to year.

Method for Measuring Productivity - We used annual testing hours per employee as an indicator of lab productivity.* We first determined the types and number of samples processed annually by each lab. Next, each type of sample was assigned a standard testing time--that is, an estimate of how much time was required to perform all necessary tests on that sample.** This information allowed us to calculate each lab's annual testing work load expressed as total standard testing hours (STH). Finally, we converted each lab's annual work load (STH) to standard testing hours per employee.***

---

* Although materials testing is not a district lab's only duty, it is the primary activity and most other activities relate to the testing function. Other activities include lab administrative duties, quality control of project-level testing, obtaining materials samples, training and informal materials research.

** Standard testing times per sample were developed in consultation with ADOT materials personnel.

*** Appendix I explains in more detail how we measured past productivity of the district labs.

Results of Analysis - Analysis of the standard testing hour data showed annual productivity varied as much as 400 percent between district labs and as much as 200 percent within labs over a six-year period. Table 3 shows the annual productivity of each lab where data was available for the period 1975-76 through 1980-81.

TABLE 3

PRODUCTIVITY OF DISTRICT LABS,
FISCAL YEARS 1975-76 THROUGH 1980-81
(STANDARD TESTING HOURS PER EMPLOYEE)

	1975-76 STH/FTE	1976-77 STH/FTE	1977-78 STH/FTE	1978-79 STH/FTE	1979-80 STH/FTE	1980-81 STH/FTE
District 1 (Phoenix)			1,149	950	1,186	1,168
District 2 (Tucson)		751	975	1,332	760	640
District 3 (Safford)			466			975
District 4 (Holbrook)					734	679
District 5 (Flagstaff)			754	527	798	576
District 6 (Prescott)					688	545
District 7 (Globe)	576	352	479	635	669	614

The disparities among districts are best illustrated by Districts 2 and 7. District 2's productivity of 1,332 STH/FTE in 1978-79 was nearly 400 percent higher than District 7's productivity of 352 STH/FTE in 1976-77. Districts 2 and 3 illustrate the fluctuations that occurred within labs from year to year. Annual productivity in District 2 ranged from 640 to 1,332 STH/FTE, and District 3 had a low of 466 and a high of 975 STH/FTE for the two years data was available--more than 200 percent variation in both districts.

District Labs Are Overstaffed

District labs are substantially overstaffed, according to our analysis of lab work load and productivity. Our analysis revealed that district labs on the whole were overstaffed by 10 positions in fiscal year 1981-82 and that 19 positions should be cut by fiscal year 1983-84. This problem of overstaffing was previously addressed in a 1978 ADOT internal study; however, staffing levels remained largely unchanged until fiscal year 1982-83.

Method For Projecting Staffing Requirements - We developed a model for determining lab staffing requirements based on work load projections. This model consists of the following elements:

1. Productivity standards, expressed as total number of testing hours per employee per year.
2. A statistical formula for projecting total lab testing hours or work load on the basis of the estimated highway construction program for each district.
3. Conversion of projected lab work load (a product of element 2) into FTE requirements by applying the productivity standards in element 1.

The model should enable ADOT to make reasonable lab staffing projections more than one year in advance.* For a detailed discussion of the model, see Appendix I.

---

* The Executive Budget Office and Joint Legislative Budget Committee analysts may also be interested in this model for budgeting purposes.

Labs Overstaffed by 10 Positions in Fiscal Year 1981-82 - According to our analysis, ADOT overstaffed district labs by 10 positions in fiscal year 1981-82. Table 4 compares budgeted FTEs, actual FTEs and FTEs required for fiscal year 1981-82. The table reveals that overstaffing occurred in all district labs except District 2.

TABLE 4

COMPARISON OF BUDGETED, ACTUAL AND MODEL-GENERATED FTEs FOR DISTRICT LABS: FISCAL YEAR 1981-82

	Budgeted FTEs 1981-82	Actual FTEs 1981-82*	FTEs Required by Model 1981-82	Overstaffing 1981-82
District 1	11	10	9	1
District 2	5	4	4	0
District 3	4	4	3	1
District 4	8	4**	3	1
District 5	7	7	4	3
District 6	6	6	4	2
District 7	5	5	3	2
Totals	46	40	30	10

* Actual FTEs do not include secretarial positions.

** District 4 lab reduced actual FTEs from seven to four during the last half of fiscal year 1981-82.

Staff Should Be Reduced Nearly 50 Percent by July 1983 - Our analysis indicates that ADOT should reduce district lab staff nearly 50 percent by July 1, 1983. This reduction of 19 FTEs would save nearly one-half million dollars annually. Table 5 shows the FTE requirements for district labs in fiscal years 1982-83 through 1984-85 as projected by the model.

TABLE 5

FTE PROJECTIONS FOR DISTRICT LABS:
FISCAL YEARS 1982-83 THROUGH 1984-85

District	Actual FTEs 1981-82	FTEs Required by Model 1982-83	FTEs Required by Model 1983-84	FTEs Required by Model 1984-85
1	10	10	8	8
2	4	4	5	7
3	4	3	Eliminated under four-district plan	
4	4	2	Eliminated under four-district plan	
5	7	3	(New District 4) 4*	4*
6	6	4	(New District 3) 4*	4*
7	5	4	Eliminated under four-district plan	
Totals	40	30	21	23

* According to the model, Districts 3 and 4 each need only three FTEs in fiscal year 1983-84 and 1984-85. However, the model-generated FTEs in these cases have been adjusted upward for three reasons: to 1) offset the additional travel time which will be required under the four-district plan; 2) provide adequate staffing in times of sickness or vacation; and 3) offset the increased work load if core sampling duties are transferred to the district labs (see Finding III).

Table 5 shows that the 1981-82 staffing level (40 FTEs) should be reduced by 19 positions in order to reach the justifiable level of 21 FTEs in fiscal year 1983-84. Assuming that salary and employee-related expenses average $25,000 per year for each FTE, a reduction of 19 FTEs represents an annual savings of $475,000.

The model's 1983-84 and 1984-85 FTE projections for District 1, as well as the 1984-85 projection for District 2, may be inflated. These projections are based on official highway construction estimates which include unusually large sums for purchasing right-of-way. Right-of-way acquisition does not generate work load for the district lab; therefore, the model's estimate of work load is probably overstated. The District 1 lab, for example, may be able to support actual construction in 1983-84 with fewer than eight FTEs.

1978 Study Revealed Overstaffing - Overstaffing in the district labs has been previously addressed. A 1978 ADOT internal study concluded that some district labs were overstaffed and recommended that future staffing levels be based on projections of lab work load. However, staffing levels remained largely unchanged through fiscal year 1981-82 (See Tables 2 and 4).

ADOT District Reorganization - During the course of our audit, ADOT developed plans to reorganize the districts and reduce the number of district personnel. An internal committee recommended that the number of districts be reduced from seven to four. The transition to four districts will occur during fiscal year 1982-83 and will eliminate some district lab FTEs. In August 1982 ADOT officially adopted a plan to reduce the number of district lab personnel to 24 by July 1983. As shown in Table 5, our analysis--which was completed prior to ADOT's--indicates that total staff in the district labs should be only 21 FTEs at that time.

Changes in Record Keeping Are Needed - Accuracy of FTE projections could be improved in the future if district labs made changes in the way they record work load data. As explained in Appendix I, lab personnel presently log the types of samples received each day but not the kinds of tests performed on each sample. Therefore, we had to estimate past work load (testing hours) using the number of samples. If lab personnel began recording the types of tests performed and summarized this data periodically, then standard testing hours per lab could be calculated more precisely, eventually improving the model in two ways:

1. The selection of productivity standards (STH/FTE) would be based on more exact historical measures of productivity and
2. The relationship between contractor payments and standard testing hours needed to support that construction could be established more precisely. (See Appendix I for explanation of the relationship between contractor payments and standard testing hours.)

---

* A significant change in sampling frequency would affect the relationship between contractor payments and standard testing hours and thus would alter the model's projection formula. See Appendix I.

The model may also need to be adjusted in the future to reflect changes in the frequency of sampling and testing during construction (see Finding V). If ADOT reduces sampling frequency significantly, then the model overstates the number of FTEs needed to support future estimated construction.*

CONCLUSION

ADOT has failed to adjust district lab staffing levels to match changes in work load. As a result, district labs are substantially overstaffed. Reducing overstaffing will save up to $475,000 annually.

RECOMMENDATIONS

1. ADOT immediately begin reducing district lab FTEs, working toward a total staff of 21 FTEs (or fewer) by July 1, 1983.

2. ADOT require district lab personnel to begin logging the number and types of tests performed each day and summarizing this data periodically in order to improve the projection model developed by audit staff.

3. ADOT use the projection model as the basis for budgeting FTEs for district labs.

4. ADOT periodically review the productivity of each district lab, comparing actual productivity against the standard.

FINDING II

ADOT COULD SAVE $175,000 ANNUALLY BY REDUCING STAFF IN THE DISTRICT 1 AREA LAB.

The ADOT Division 1 Area Lab was overstaffed by seven positions during the first half of 1982. This overstaffing represents an annual cost of $175,000. Because a decline in work load in 1982 was not matched by a reduction in staff size, productivity dropped 47 percent from the 1981 level. This decline in work load is not expected to change in the near future. In addition to eliminating positions in the Area Lab, ADOT may also be able to reduce testing costs in District 1 by expanding the Area Lab's jurisdiction to include all construction within the district.

Background

The District 1 Area Lab functions as a project-level lab for all ADOT projects in the Phoenix area except the I-10 projects, which are supported by a separate lab. Materials samples from the construction site are taken and transported to the Area Lab by project personnel, whereas samples from commercial plants (concrete and asphalt plants) are obtained by Area Lab personnel. The Area Lab reports the results of all tests to the respective project engineers.

Work Load and Productivity Declined

ADOT has not adjusted the Area Lab staffing level to match the decline in work load. Work load--as measured by standard testing hours--during the first half of 1982 was 54 percent less than the work load for the same period in 1981. Table 6 compares work load and staffing levels for the same six-month periods in 1981 and 1982. As shown, monthly work load declined from 904 to 418 standard testing hours; however, lab staff was reduced by only one position (from 19 to 18 FTEs).

TABLE 6

DISTRICT 1 AREA LAB
WORK LOAD AND STAFFING LEVELS FOR THE
FIRST SIX MONTHS OF 1981 AND 1982

Year		Jan.	Feb.	Mar.	Apr.	May	June	Monthly Average
1981	STH*:	697	1,046	1,198	1,074	844	564	904
	FTEs:	(19)	(19)	(19)	(19)	(19)	(19)	(19)
1982	STH*:	561	278	399	532	332	404	418
	FTEs:	(18)	(18)	(18)	(18)	(18)	(18)	(18)

* Standard testing hours

Overstaffing caused productivity to fall almost one-half (47 percent) in 1982. We determined lab productivity by dividing the testing work load (STH) by the number of employees actually performing tests.** As shown in Table 7, average monthly productivity for comparable periods in 1981 and 1982 fell from 113 to 60 standard testing hours per testing employee.

** 7 of the current 18 personnel perform tests. The other 11 perform field or administrative functions.

TABLE 7

AREA LAB PRODUCTIVITY
FOR THE FIRST SIX MONTHS OF 1981 AND 1982

Year		Jan.	Feb.	Mar.	Apr.	May	June	Monthly Average
1981	Standard testing hours:	697	1,046	1,198	1,074	844	564	904
	Number of testing personnel:	(8)	(8)	(8)	(8)	(8)	(8)	(8)
	Productivity (STH/FTE):	87	131	150	134	106	71	113
1982	Standard testing hours:	561	278	399	532	332	404	418
	Number of testing personnel:	(7)	(7)	(7)	(7)	(7)	(7)	(7)
	Productivity (STH/FTE):	80	40	57	76	47	58	60

ADOT should reduce the Area Lab staff by a total of seven positions to regain the 1981 productivity level. Testing personnel should be reduced from seven to four, which was determined by dividing the 1982 average monthly work load by the 1981 average monthly productivity rate. Corresponding reductions should also be made among the nontesting personnel because their activities are roughly proportional to the amount of testing performed. Table 8 compares the actual number of lab personnel in 1982 with positions required to accomplish the work (based on 1981 productivity rates).

TABLE 8

ACTUAL AND JUSTIFIED STAFFING LEVELS FOR THE AREA LAB - JANUARY THROUGH JUNE 1982

Function	Actual Personnel (January-June) 1982	Number of Personnel to Maintain 1981 Productivity Rate
Testing Personnel	7	4
Nontesting Personnel:		
Sampler	1	1
Plant inspectors	5	3
Lab manager	1	1
Lab supervisor	1	*
Secretary	1	1
Computation of test results	1	1
Receiving and logging samples	1	**
TOTALS	18	11

* Lab manager and supervisor positions can be combined due to the fewer number of personnel to supervise.

** Because of the 54 percent decline in work load, one employee can compute test results as well as receive and log samples.

As shown, the area lab could have processed the work load in 1982 with seven fewer employees. These seven positions represent an annual salary cost of $175,000.

Future Area Lab Staffing Requirements

The anticipated future work load for the Area Lab does not justify a staffing level of 18 FTEs. Area Lab work load should not increase in the near future, according to a District 1 official and our review of the estimated construction program for District 1. Although the I-10 and Papago Freeway projects will bring an increased amount of construction to District 1, these projects will continue to be supported by a project lab rather than the Area Lab. Therefore, the Area Lab could service future work load with 11 or fewer employees, assuming its jurisdiction remains unchanged.

Eliminate Project Lab in District 1

ADOT may be able to further reduce project-level testing costs in District 1 by expanding the Area Lab's jurisdiction to include all construction in District 1. Under the new four-district plan, District 1 will be geographically smaller and will essentially include the Phoenix metropolitan area. Four labs are presently in the Phoenix area: 1) ADOT Central Lab; 2) District 1 lab; 3) the Area Lab; and 4) a project lab supporting I-10 construction west of Phoenix. In our opinion, separate project labs in addition to the Area Lab are unnecessary in the new, smaller District 1. Under the present arrangement, Area Lab and project lab personnel are servicing overlapping geographical areas. For example, in 1982 Area Lab personnel often traveled to concrete plants within two miles of another plant which was supplying concrete to the I-10 project. We believe equipment and personnel savings may be possible if the Area Lab supported all construction in the Phoenix area, including the I-10 projects. The feasibility of using the Area Lab to support I-10 construction will become even more apparent as the freeway progresses eastward into Phoenix.

CONCLUSION

The ADOT District 1 Area Lab was overstaffed by seven positions during the first half of 1982 because staff size was not adjusted to match a declining work load. The work load for the Area Lab is not expected to increase in the future. These seven positions represent an annual salary cost of $175,000.

RECOMMENDATIONS

1. ADOT eliminate seven positions in the District 1 Area Lab.

2. ADOT consider expanding the Area Lab's jurisdiction to include all construction in District 1 and thereby eliminate the need for a separate project lab.

FINDING III

ADOT COULD PERFORM THE MATERIALS INVESTIGATION FUNCTION MORE EFFICIENTLY.

ADOT could save $125,000 annually by performing the materials investigation function more efficiently. ADOT could eliminate five positions and reduce travel-related costs by 1) transferring core sampling activities to the district level and 2) reducing the size of the materials pit investigation crews. In addition, during the course of our audit ADOT corrected another inefficient practice--that of allowing members of central crews to live in widely scattered areas of the State and then commute to work sites on State time and in State vehicles.

Duties of Materials Field Crews

The Geotechnical Services Unit, Materials Section consists of five field crews and an office support staff. Table 9 shows the number of personnel in each field crew.

TABLE 9

NUMBER OF PERSONNEL IN FIELD CREWS,
GEOTECHNICAL SERVICES, MATERIALS SECTION

Crew	Number of Crews	Staff per Crew
Pit location crew	1	2
Pit investigation crew	2	4
Drill crew	1*	5
Core crew	1	3

* This crew sometimes divides into two crews and includes an engineering geologist.

The pit location crew travels throughout the State locating potential sources for road-building materials. The two pit investigation crews explore the sites identified by the first crew. Using backhoe equipment, these two crews dig pits, sample the various soil layers and transport the samples to the ADOT central laboratory for analysis. The drill crew investigates rock quarries (for road-building materials) and the materials below proposed roadways. This crew also removes hazardous materials from slopes above existing roadways.* The core crew travels throughout the State obtaining three types of pavement core samples: 1) "final record" cores of newly completed roadways to verify that specifications have been met, 2) cores of existing roadways to provide data for pavement rehabilitation, and 3) cores of existing pavements as part of ADOT's research activities. All cores are transported to the central lab for analysis. An office support staff provides supervision, work scheduling and other services for the field crews.

Transfer of Core Sampling to Districts

ADOT could eliminate three positions and reduce travel-related costs by transferring core sampling duties to the districts.

High Travel-Related Costs of Core Crew - The three-man core crew travels extensively throughout the State, incurring high travel-related costs--including employee travel time, vehicle usage and per diem expenses. We analyzed the crew's travel schedule for the period January 1, 1981, through March 31, 1982. Table 10 shows the crew's movement for selected weeks during that period when travel appeared unusually high.

---

* This drill crew is the subject of Finding IV.

TABLE 10

MOVEMENT OF ADOT CORE CREW FOR SELECTED WEEKS
DURING THE PERIOD JANUARY 1, 1981, THROUGH MARCH 31, 1982

Week*	Approximate Location	Type of Activity
March 9-12, 1981	Phoenix	Depart for first work site
	Prescott	Preliminary engineering cores (PE)
	Ash Fork	Final record cores (FR)
	Taylor	FR
	Safford	FR
	Benson	FR
	Phoenix	Return home
	Approximate total mileage:	740
July 13-16, 1981	Phoenix	Depart for first work site
	Kingman	FR
	Tucson	FR
	Nogales	PE
	Sasabe	PE
	Phoenix	Return home
	Approximate total mileage:	790
August 10-13, 1981	Phoenix	Depart for first work site
	Tucson	FR
	Flagstaff	PE
	Taylor	FR
	Ash Fork	FR
	Phoenix	Return home
	Approximate total mileage:	810
October 26-29, 1981	Phoenix	Depart for first work site
	Robles Jct.** (near Tucson)	Research cores
	Phoenix	FR
	Joseph City	FR
	Phoenix	Return home
	Approximate total mileage:	680

* A work week consists of four 10-hour days.
** The previous week the crew was also in Robles Jct. to obtain research cores.

TABLE 10 (Concl'd)

MOVEMENT OF ADOT CORE CREW FOR SELECTED WEEKS
DURING THE PERIOD JANUARY 1, 1981, THROUGH MARCH 31, 1982

Week	Approximate Location	Type of Activity
January 4-7, 1982	Phoenix	Depart for first work site
	Sells	PE
	Chino Valley	Research
	Bullhead City	Research
	Kingman	PE
	Phoenix	Return home
	Approximate total mileage:	860
January 25-28, 1982	Phoenix	Depart for first work site
	Yuma	PE
	Santa Maria Maintenance Yard (Near Bagdad)	Miscellaneous
	Show Low	Research
	Phoenix	Return home
	Approximate total mileage:	820

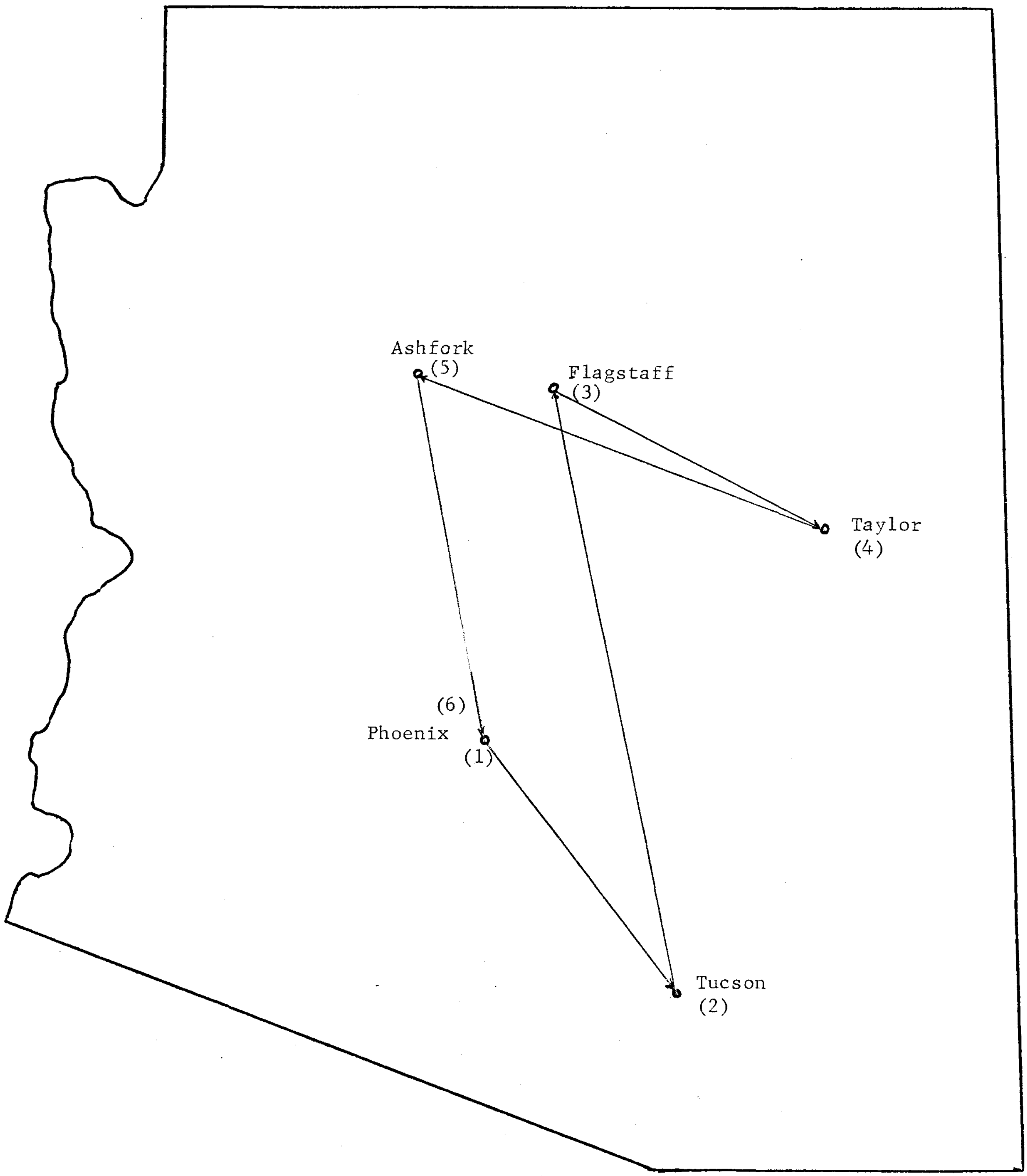
Within a four-day period, the crew may crisscross the State several times. For example, Figure 3 shows graphically the crew's movement for the period August 10-13, 1981. The crew traveled from Phoenix to Tucson, Flagstaff, Taylor and Ashfork before returning to Phoenix, logging a total of 810 miles of travel. Assuming the crew traveled at 45 miles per hour,* almost 18 hours (or 45 percent of the work week) was spent traveling.

According to the crew's scheduling officer, assignments for the crew are grouped geographically as much as feasible to minimize travel. However, the desire to keep the crew busy for the entire work week (rather than sitting idle at the Phoenix office) may explain why the crew is sometimes sent to widely dispersed parts of the State.

* Average speed of the core drill rig on the highway is 45 miles per hour.

FIGURE 3

Travel Schedule for Core Crew
August 10-13, 1981*



---

* Refer to Table 10 for description of crew activities during this period.

The core crew incurs high costs related to its statewide travel. Much of the crew's potential work time is consumed traveling. High mileage also means high vehicle usage costs. In addition, crew members must be paid for food and lodging expenses while on the road--a total of $17,500 in fiscal year 1980-81.

Costs Could Be Reduced - ADOT could reduce personnel and travel-related costs if core samples were obtained by district materials personnel. Districts already have the equipment and available manpower to assume these duties. This transfer of duties would enable ADOT to eliminate three positions and would reduce employee travel time, vehicle mileage and per diem expenses.

ADOT presently has enough trailer-mounted core drills (similar to equipment used by the central crew) to equip each of the four districts for core sampling. In fact, each district is already obtaining core samples of construction work in progress.

District labs could assume all core sampling without increasing their staffs above the levels recommended in Finding I. As documented in Finding I, district labs in general have been overstaffed in recent years. Finding I proposes a method for matching future lab staffing levels with expected work loads. However, even if such adjustments are made, district labs will still experience seasonal fluctuations in work load as well as week-to-week and day-to-day fluctuations. District lab technicians could easily be trained to assume all core sampling within the district. With sufficient advance notice from the Materials Section, many core sampling requests could be reserved for the slow days and periods. One-day excursions to obtain core samples could be inserted on days when lab testing is minimal (which frequently occurs even during the peak construction season).* One way of accommodating priority requests for core samples and still maintain a necessary complement of lab personnel might be to use district maintenance personnel as nontechnical members of the core crew (as flagmen, for example) as needed.

---

* Travel could be minimized by assigning the closest lab to obtain the samples, regardless of district boundaries.

Transferring coring duties to the districts would save ADOT at least $75,000 annually. Three positions in the Materials Section could be eliminated (the central core crew). Shorter distances to work sites would mean more employee time for actual work and less vehicle mileage. Per diem costs would be reduced because one-day excursions--without overnight expenses--would be feasible more often.

Pit Investigation Crews Overstaffed

ADOT could eliminate two more positions by reducing the materials pit investigation crews to three-man crews. The crews were recently increased to four-man crews allegedly for safety reasons. These safety concerns, however, can be satisfied with three-man crews.

ADOT's pit investigation crews operated with three members each for many years prior to March 1982. In March one of the three crews was eliminated due to decreased work loads, but the remaining two crews were expanded to four-man crews. According to the State Materials Engineer, crew size was increased for safety reasons; that is, three employees should be on the job when the backhoe equipment is used. Thus, a four-man crew, including two equipment operators, enables three employees to be on the job even when one crew member is absent for illness or other reasons.

These safety concerns can be satisfied, however, with three-man crews. For those times when a regular crew member is absent, the district in which the crew is working could provide the third crew member. This employee could come from the district materials, maintenance or construction units. This source of manpower is already being used by the central core crew when it needs an extra person for traffic control. Another potential source for temporary help is the Central Lab, which might be able to loan an employee to the crew.

By reducing the pit investigation crews to three members each, ADOT would eliminate two positions, saving $50,000 annually. In addition, the crews could operate with two less vehicles.

Commuting Policy Changed

During the course of our audit, ADOT corrected an inefficient practice which existed for several years--allowing members of central crews to live in widely scattered areas of the State and then commute to work sites on State time and in State vehicles. However, additional action is needed to eliminate vehicles which are no longer needed under this new policy.

Allowing crew members to live in widely scattered areas of the State was a holdover from earlier years when pit investigation crews were geographically decentralized. During the peak of interstate highway construction ADOT had seven pit investigation crews, each assigned to a particular area of the State. For efficiency reasons, crew members lived in the area in which they worked. As the amount of new construction declined, ADOT eventually reduced the number of pit investigation crews to two. Members of abolished crews were transferred to other Materials Section crews as vacancies occurred and began working outside the areas in which they lived. As of May 1982, members of the various crews lived in the following locations:

Core crew	-- Tonto Basin, Phoenix, Phoenix
Pit location crew	-- Show Low, Phoenix
Pit investigation crew	-- Ash fork, Indian Wells (near Holbrook), Sanders, Phoenix
Pit investigation crew	-- Gilbert, Gilbert, Pima, Pima (near Safford)
Drill crew	-- Pima, Tucson, Tucson, Phoenix

To accomodate this arrangement, ADOT allowed crew members to drive between home and their posts of duty or work sites in ADOT vehicles and on ADOT time. This accommodation required more vehicles and employee travel time than should have been necessary to perform the work.

As of July 1, 1982, ADOT began enforcing a new policy addressing this condition. ADOT now requires that crew members travel between home and duty posts in their own vehicles and on their own time. Phoenix is the duty post for all materials crews with the exception of one pit investigation crew which is now stationed in Flagstaff. ADOT has offered crew members a moving allowance so they may locate closer to their duty posts.

We concur with this recent policy change. This change will reduce travel time and vehicle usage and should enable the Materials Section to eliminate three vehicles from its fleet. (This reduction is in addition to the two vehicles mentioned earlier on page 33.) As of June 1982, the Section had plans to eliminate only two of these unnecessary vehicles.

CONCLUSION

ADOT could perform the materials investigation function more efficiently by transferring core sampling activities to the district level and by reducing the size of the materials pit investigation crews.

RECOMMENDATIONS

1. ADOT transfer core sampling activities to the district level and eliminate the three core crew positions in the Materials Section.

2. ADOT reduce the size of pit investigation crews to three members each, thereby eliminating two positions and use district or Central Lab personnel as needed to fill in for absent crew members.

3. The Materials Section reduce its fleet size by five vehicles in conjunction with recommendation 2 and the new policy affecting travel between home and duty post.

FINDING IV

ADOT COULD REDUCE COSTS BY COMBINING DRILL CREWS INTO ONE UNIT.

ADOT could reduce personnel and equipment costs by combining drill crews of the Structures and Materials Sections into a single unit. The two crews perform similar functions using similar equipment and personnel. Both crews may have been needed during the height of interstate highways construction; however, the decline in new construction has altered the crews' work loads and activities, making a consolidation more desirable. ADOT could manage equipment more efficiently and eliminate two positions by combining the two crews into one unit.

Organization and Function of Crews

Two different sections of the ADOT Highways Division have drill crews which perform similar functions using similar equipment and personnel. One crew is located in the Foundation Engineering Branch of the Structures Section; the other one is in the Geologic Investigation Branch of the Materials Section.

The Structures Section drill crew investigates the subsoil of proposed bridge sites, provides soil samples for laboratory tests and gathers other geological information relative to bridge sites. This information is used in the design phase of a construction project. The crew's main equipment is a large truck-mounted drill.

The Materials Section drill crew is also involved in subsoil investigation. Using drilling equipment very similar to that used by the Structures crew, the Materials crew investigates potential material pits (quarries) and the soil below proposed roadways. This information is also used in the design process.

The two crews are composed of personnel with similar training and qualifications. Table 11 shows the classification of positions associated with each crew.

TABLE 11

CLASSIFICATION OF POSITIONS
ASSOCIATED WITH EACH DRILL CREW

Materials Section, Geologic Investigation Branch	Structures Section, Foundation Engineering Branch
Civil Engineer II	Civil Engineer II
Field Crew*:	Field Crew:
Engineering Geologist	Engineering Geologist
Equipment Operator III	Equipment Operator III
Equipment Operator III	Equipment Operator II
Highway Maintenance Worker III	
Equipment Operator I	

* The five-member field crew is sometimes divided into two crews.

Personnel have transferred between the two crews, further indicating the similarities between the crews, and one crew has even performed work for the other crew on occasion.

Decline in New Construction Has Altered Crew Activities

A shift in emphasis in the highway construction program has altered the work load and activities of the two drill crews. The amount of new highway construction has declined in recent years as the interstate system neared completion.* A larger percent of available highway funds is now being used to maintain or rehabilitate the existing roadways.

* The interstate highway system in Arizona is 98 percent complete, as measured in lane miles completed.

The decline in interstate construction has decreased the traditional work load of the Structures Section drill crew. The number of bridge sites investigated annually by this crew has declined in recent years. Table 12 shows the number of "projects" investigated by the crew and the resulting number of borings for the period 1974-1981. This data comes from quarterly reports of the Foundation Engineering Branch, Structures Section.

TABLE 12

STRUCTURES SECTION DRILL CREW WORK LOAD
CALENDAR YEARS 1974-1981

Year	Number of Projects	Number of Borings
1974	23	194
1975	35	228
1976	29	186
1977	23*	170*
1978	-- (data unavailable)	--
1979	21	140
1980	14	73
1981	9	102

* Estimate: One quarterly report unavailable for 1977; estimate based on extrapolation of three available quarters.

Table 12 shows that the crew's work load in 1980 and 1981 was only about half the annual work load in earlier years--as measured by numbers of "projects" and borings.

The decline in new highway construction has also affected the activities of the Materials Section drill crew. In the past, the main activity of this crew was to investigate potential material sources and the subsoil along the routes of proposed roadways. This activity required regular use of the crew's drilling equipment. As new construction declined, the crew began performing more activities related to the maintenance of existing roadways--such as removing hazardous rocks on slopes and stabilizing potential slide areas. Approximately 50 percent of the crew's work load in 1981 could be categorized as "nontraditional." Some of these activities were traditionally performed by contractors.

Combining Crews Would Reduce Costs

ADOT could realize several benefits by combining the two drill crews into a single unit. First, ADOT could avoid the replacement of some expensive drilling equipment which is not being fully utilized under the present arrangement. Second, personnel could be utilized more efficiently, allowing for a reduction of two positions. Third, ADOT may realize other nontangible benefits relating to professional competence and career development opportunities.

Equipment Savings - By combining the two crews, ADOT could avoid replacement of some expensive drilling equipment which currently is not being fully utilized. As mentioned elsewhere, the crews have similar drilling equipment. Each crew has a large truck-mounted drill. In addition, the Materials Section crew has a smaller drill rig. Usage of these drills in recent years does not justify continued replacement of all three rigs. Table 13 shows the usage of this equipment during 1980 and 1981.

TABLE 13

DRILLING EQUIPMENT USAGE
AS SHOWN BY PERCENTAGE OF DAYS IN USE -
1980-1981

	1980			1981		
	Number of Workdays*	Number of Days Drill Was Operated	Percent Usage	Number of Workdays*	Number of Days Drill Was Operated	Percent Usage
Structures Section -						
Large drill	200	119	60%	200	124	62%
Materials Section -						
Large drill	200	59	30	200	0 **	0
Small drill	200	48	24	200	85	43
Combined Utilization	600	226	38%	600	209	35%

* Based on 10-hour workdays, 4 days per week; holidays not included
** Drill was inoperable; eventually replaced in 1982.

As shown in Table 13, combined utilization of the drilling equipment, which averaged less than 40 percent in 1980 and 1981, does not justify the continued replacement of all three rigs. However, in July 1981 ADOT awarded a bid for $150,000 to replace the large drill in the Materials Section.* The Structures Section drill rig will be due for replacement in four or five years, according to an ADOT estimate. This replacement can be avoided if the two crews are combined into one unit--a savings of at least $150,000.

Personnel Savings - Staffing could be reduced and personnel could be utilized more efficiently if the two crews were combined into a single unit.

We estimate that two positions could be eliminated if the crews were combined. Combining crews would still allow the Materials Section - Geologic Investigation Branch to staff two drilling rigs (3 members each) and meet all the drilling work load. As shown previously in Table 16, the combined utilization of all drilling equipment has recently been from 35 to 38 percent. This work load could be performed by a combined crew using two drilling rigs. Further, a combined crew would still have as much as 40 percent of its time available for nondrilling activities.

Combining drilling crews and staffing two drilling rigs with three crew members each would allow for a reduction of two positions at a savings of $40,000 to $50,000 per year.**

Combining functions would also provide for more efficient use of personnel. Bad weather, equipment downtime, sick leave and vacations would have less impact on productivity if the crews were combined. Presently, members of the Structures Section drill crew are largely limited to one type of activity--investigation of foundations of existing or proposed structures. Therefore bad weather, equipment downtime, sick

---

* Equipment was delivered to ADOT in August 1982.

** Amount of savings depends on which positions ADOT eliminates.

leave or vacations halt the crew's activity. Equipment downtime alone caused 45 crew-days of lost work in 1980 and 1981 for the Structures Section drill crew; sick leave caused an additional 20 crew-days of lost work during the same period. Loss of productivity due to these reasons would be much less under a combined unit because personnel could be shifted among crews or to other assignments as needed.

Nontangible Benefits - The Federal Highway Administration (FHWA) believes ADOT would realize some additional nontangible benefits by combining the crews into one unit. In 1974 FHWA reviewed the soils-related functions within ADOT; the report contains this statement:

> "The majority of States have found it beneficial to combine the soil engineering functions into one unit. These benefits are the unified control of personnel and equipment that are involved with the same basic problems--soils and geology, the ability to maintain a higher general level of soil engineering expertise due to the concentration of experience within the single section, the opportunity for engineers and geologists to more rapidly develop broad experience in highway soils engineering, and the means of providing a career program in the soils and geology area, which is most necessary and attractive in retaining professional personnel. It is felt that the Arizona Department of Transportation could benefit by a consolidation of this effort."

In a follow-up review in 1975, FHWA again recommended combining the crews into one unit.

ADOT Response to Proposal - Our proposal to combine the drill crews into a single unit received mixed response from ADOT managers associated with these functions. Supervisory personnel in the Geologic Investigation Branch, Materials Section, supported the idea of a combined unit. In fact, during the course of our audit, they submitted this suggestion to an ADOT group seeking cost-cutting ideas. They made the same recommendation to upper management within the Highways Division in June 1981. In both cases they estimated that two positions could be eliminated if the crews were merged into a single unit. When we reviewed our proposal with Structures Section officials, however, they expressed two reservations about a consolidation, particularly if the unit was located within the Materials Section. First, they feared a loss of quality in the foundation data used in the design of structures.* Secondly, they feared the timeliness of foundation investigations would suffer, thereby affecting design activities.

According to the Structures Section manager, the first reservation would be mitigated if the Civil Engineer II position, which is a foundations engineer, was retained in the Structures Section. This engineer interprets the soils data and works with the bridge designers on a daily basis. Our recommendation for staff reduction leaves this position in the Structures Section. We believe the second potential problem could be avoided by advance scheduling and by administrative mechanisms which would clearly establish crew priorities when conflicts arose.

CONCLUSION

The combining of drilling crews into a single unit would enable ADOT to reduce equipment and personnel costs. The replacement of some expensive drilling equipment could be avoided--a savings of at least $150,000. In addition, two positions could be eliminated at a savings of $40,000 to $50,000 per year.

RECOMMENDATIONS

1. ADOT combine the Foundation Engineering Branch of the Structures Section and the Geologic Investigation Branch of the Materials Section into a single organizational unit located within the Materials Section.

---

* A 1974 FHWA report, cited earlier, seems to dispute this claim. The report notes that other states with combined units have achieved "...a higher general level of soil engineering expertise due to the concentration of experience within the single section...."

RECOMMENDATIONS (Concl'd)

2. ADOT eliminate two positions as this merger occurs.

3. ADOT adopt policies and administrative mechanisms which will enable the timely transmission of requests and foundation data between the Structures Section and the combined investigative unit.

4. ADOT not replace the Structures Section drill rig but use it as a backup rig for the combined drill crew until its useful life is expended.

FINDING V

ADOT COULD REDUCE THE FREQUENCY OF MATERIALS SAMPLING AND TESTING.

ADOT could reduce staffing requirements and project engineering costs by controlling materials oversampling. Although the Department has issued guidelines aimed at reducing the frequency of materials sampling, in some instances project personnel have not fully implemented the guidelines and do not adequately control oversampling. In addition, ADOT should consider eliminating some concrete cylinder tests as another way to reduce lab work loads.

Efforts to Reduce Materials Testing Costs

In recent years governmental agencies involved in road building have experimented with ways to reduce materials testing costs without jeopardizing the quality of roads built. ADOT has taken several steps in this direction.

The Blatnik Investigation in 1962-63* initiated a period in which state governments established comprehensive, costly systems of control over road-building activities, including an extensive system for sampling and testing construction materials. More recently, however, the cost-benefit of some testing has been seriously questioned by governmental officials, leading to experimentation in the materials testing area.

---

* The Blatnik Investigation was a congressional investigation into construction practices in federal-aid highway projects throughout the nation. The investigation revealed that state supervision and control over these projects was generally inadequate.

For example, some states have adopted "end-product" type specifications which reduce the overall amount of materials testing. End-product specifications require that the product of construction be tested rather than the individual materials which make up that product. In addition, FHWA guidelines concerning federal-aid highway projects have been revised to allow small quantities of materials to be accepted on the basis of visual inspection or manufacturer's certification.

ADOT has taken several notable steps toward reducing materials testing costs. For example, in 1978 ADOT adopted an end-product type specification for concrete* which reduces the amount of testing and inspection required before the concrete can be used in the project. Further, in September 1981 ADOT discontinued a three-level correlation testing program, concluding it added an unnecessary and ineffective layer of control to the testing system. Finally in February 1982, ADOT issued a new Sampling Guide which established lower sampling frequencies for many types of materials.** This was in response to a series of FHWA audits citing ADOT for oversampling certain types of materials.

New Sampling Guide Is Not Fully Implemented

Although ADOT has issued guidelines establishing reduced sampling frequencies, in some instances project personnel have not fully implemented the new sampling guidelines and philosophy. More particularly, some project personnel 1) are not knowledgeable of the new sampling frequencies, 2) lack methods for actively monitoring and controlling oversampling, or 3) have not adopted a flexible approach to establishing actual sampling frequencies.

Some project personnel responsible for materials quality are not well informed regarding the new guidelines. In June and July 1982 we visited six ADOT project offices to discuss the new Sampling Guide and review materials testing records. At one project office we learned that the office had received the new guidelines; however, concrete test cylinders

* §503 - Structural concrete (class S), ADOT Supplemental Specifications (August 1978)

** The changes in sampling frequency were officially adopted in November 1981.

were still being made according to the frequency established in the old guidelines--one set per 25 cubic yards. The office labman was not aware that the new recommended frequency was one set per 50 cubic yards. At a second project office we learned that the office labman was not aware of the new sampling frequency for concrete aggregates, even though the revised guidelines had been received several months earlier. At a third project office we learned that the materials personnel did not receive the new Sampling Guide until three months after the official issuance of the document by the Central Lab.

In addition, some project offices are not actively monitoring the frequency of materials sampling. In 1981, FHWA conducted "inspections-in-depth" of 13 highway projects in Arizona. These inspections included a detailed review of the materials testing records. According to FHWA officials involved in those inspections, they noticed a conscious effort to control oversampling in only three of the 13 project offices. In its summary report issued in January 1982, FHWA recommended a monitoring method that it had seen used in a few project offices.

> "...(A) active monitoring of frequencies by the project quality control supervisor or resident engineer as the project progresses would aid in detecting materials that are undergoing excessive testing or insufficient testing. The Materials Services Division's "Sample Checklist" could be used in establishing the basic number of samples needed to meet the Sampling Guide recommendation prior to the start of the project. This could be used as a guide as the project progresses and modified when conditions change. In addition a running total of material quantities used could be maintained in the materials logs to monitor the sampling and testing activity."

During our visits to project offices, we noted that several offices used this method. However, other offices had no apparent method to actively monitor sampling frequency.

Sampling frequency could be further reduced if all project materials personnnel used a flexible, judgmental approach to establishing actual sampling frequency. FHWA has encouraged ADOT to base sampling frequency somewhat on prior test results for materials from the same source. In its January 1982 report, FHWA recommended:

> "...the development of the philosophy among supervisory personnel that sound judgement can be used with the Sampling Guide to establish actual sampling frequencies. When there are doubts or problems with the quality of a material, the frequency may be increased. When there is sufficient data, plant history and/or project test results, which would support a high degree of confidence in the quality of materials, the frequency may be decreased which would allow personnel to be used for other duties."

A related recommendation in the same report reminded ADOT that they could accept small quantities of materials on the basis of visual inspection or manufacturer's certification. FHWA officials, in a later interview with Auditor General staff, reaffirmed their opinion that ADOT could better allocate project personnel if sampling was based partly on past test results, particularly when small quantities are involved and the high quality of past materials from the same source is well documented.

As a result of our visits to project offices and construction sites, we do not believe that this flexibilty has been adopted by all ADOT field personnel involved with materials sampling. This new philosophy differs from past practices and the adjustment is apparently occurring slowly.

An example of how this flexibility can be further implemented involves the sampling of aggregates at commercial concrete plants. The ADOT Sampling Guide recommends that aggregates from a plant be sampled every other day during the period the plant is supplying concrete to ADOT projects. The District 1 Area Lab has this responsibility for most of the plants in the Phoenix area. According to Area Lab personnel, many of these plants use aggregates which are consistently within specifications over long periods of time. In cases like this, when sufficient data exists to establish the plant's history, we believe it would be consistent with the FHWA recommendation cited earlier to reduce the actual sampling frequency to perhaps once a week on a random basis.

Reduce Number of
Concrete Cylinder Tests

In addition to controlling materials oversampling, ADOT could reduce its laboratory testing work load by eliminating some concrete cylinder tests. By making appropriate changes in specifications and lab procedures, a number of 28-day concrete cylinder tests could be avoided.

Concrete cylinder tests are an important part of project quality control. Concrete used in highway projects must have a compressive strength equal to or exceeding the strength required in the specifications 28 days after it is poured. During a pour, ADOT personnel fabricate several sets of concrete cylinders which are to be tested for strength later. Seven days after the pour, one set of cylinders is broken by laboratory equipment. This 7-day test serves as an early indicator of what concrete strength is expected to be at 28 days.* Sometimes cylinders are also broken at other intervals - five days, ten days, etc. - for other purposes.** In all cases, a set of cylinders is broken at 28 days to serve as the official determination that specification compressive strength was achieved.

Most concrete used on ADOT projects equals or exceeds 28-day requirements within the first week after being poured. For 10 projects completed during 1981, we determined that 66 percent of all 7-day cylinder tests exceeded the 28-day strength requirements.***

---

* Concrete continually becomes stronger as time passes. The industry has developed tables which allow 28-day strength to be predicted on the basis of its strength at 7 days.

** For example, cylinders are often broken to determine if concrete is of sufficient strength to allow forms to be removed.

*** We analyzed test results for Class S concrete only. According to ADOT officials, most concrete now used in highway projects is Class S.

Current ADOT specifications require that a 28-day test be performed in all cases. If ADOT revises its specifications to take into account the results of the 7-day test, a number of the 16,000 concrete cylinder tests performed annually could potentially be eliminated.

CONCLUSION

Some ADOT project personnel have not fully implemented the new sampling guidelines or do not use adequate methods to control oversampling. In addition, the overall laboratory testing work load could be reduced by revising specifications to take into account the results of the 7-day concrete cylinder tests.

RECOMMENDATIONS

1. The ADOT Materials Section and district materials engineers
   a. Immediately determine if all materials personnel at the project level are knowledgeable of the recent changes in recommended sampling frequencies and provide instruction as needed;
   b. Encourage all project materials supervisors to establish methods to actively monitor and control actual sampling frequency (such as that recommended by FHWA - see page 45); and
   c. Continually promote the attitude of flexibility regarding sampling frequencies and encourage reductions where past test results indicate a consistently high quality of materials.

2. ADOT consider revising standard specifications and lab procedures to allow 7-day concrete cylinder tests to satisfy strength requirements where appropriate.

AREAS FOR FURTHER AUDIT WORK

During the course of the audit, we identified several potential areas for further audit work. These areas, which were outside the scope of our audit (see page 6), include as follows:

- Whether more preliminary engineering (preconstruction) activities should be transferred from the Materials Section to the districts, including
  - pit location and investigation and
  - pavement design.

- Causes of project engineering cost overruns on minor construction projects.

- Potential unnecessary duplication between research activities of the Materials Section and the Research Section, Highways Division.

- Adoption of more end-product type specifications which will reduce project sampling and testing costs.

ARIZONA DEPARTMENT OF TRANSPORTATION

206 South Seventeenth Avenue Phoenix, Arizona 85007

BRUCE BABBITT
Governor

WILLIAM A. ORDWAY
Director

November 9, 1982

AUDITOR GENERAL

Mr. Douglas Norton
Auditor General
Auditor General's Office
111 W. Monroe, Suite 600
Phoenix, AZ 85003

Dear Doug:

Thank you for the opportunity to review the revised preliminary report draft of the performance audit of the Arizona Department of Transportation - Materials Testing Function.

Since high-quality materials testing is essential to the proper design, construction, and maintenance of our roadways, we are quite naturally very interested in the audit report and have, within the time limits, carefully reviewed it. Our attached comments include one overall comment and comments on each specific finding, as well as an appendix which analyzes the mathematical model utilized in Finding 1 of the report. We understand that these comments will be included in the text of the published report.

Again, thanks for this opportunity to comment and for the cooperation extended by the Audit staff.

Sincerely yours,

Bill Ordway

WILLIAM A. ORDWAY
Director

WAO/EFS/aa
Attachment

ADOT'S COMMENTS ON AUDITOR GENERAL'S PERFORMANCE AUDIT OF THE ARIZONA DEPARTMENT OF TRANSPORTATION'S MATERIALS TESTING FUNCTION

The Arizona Department of Transportation believes the report prepared by the Auditor General's staff on the materials testing function contains some points with which we certainly agree and others which warrant further study. Adoption of certain of the recommendations could reduce effectiveness in designing, constructing and maintaining our state highway system. Our concern over the possible adverse effects might be better explained by a very brief description of ADOT's Materials Engineering practice.

Since state roadways are constructed of many different materials, the practice of highway materials engineering is very important. ADOT engineers have developed a system for designing and obtaining materials for roadways to give the required performance at least possible cost. This system consists of gathering all the necessary materials information, utilizing this data and the latest "state of the art" technology to design and specify the materials, and finally, controlling the materials received. Each of these tasks is of extreme importance in the economics and performance of Arizona's roadways. Insufficient or inaccurate materials information may result in overdesign that wastes construction funds or underdesign, resulting in early failure and high maintenance costs.

Comments on specific findings follow:

FINDING I - REDUCING OVERSTAFFING IN THE DISTRICT LABS WILL SAVE UP TO $475,000 ANNUALLY.

ADOT POSITION: PARTIALLY CONCUR

While we do not agree that the mathematical model presented in the report realistically predicts our District Materials staffing requirements, we were aware that the anticipated completion of the interstate system and the present economic conditions demand austerity in our operations. Accordingly, early in 1981 we decided to reduce the number of engineering Districts. After considerable analysis, a decision was made to reduce the number of Districts from seven to four. Our present budget reflects that decision which will save over one million dollars per year. Included are reductions in District Materials personnel which lower the number of these personnel to 24 by January 1, 1983. This is six less than that recommended in Table 5 of the audit report.

As previously mentioned, we do not fully agree with the model (see our comments in the appendix). In actuality, we predict considerable understaffing during peak workload periods which we hope to alleviate with temporary measures. We plan to closely monitor this situation and if additional full-time assistance is necessary, we will arrange for such.

The real solution, we feel, is to accept those recommendations on page 16 of the report wherein changes in record keeping are suggested. We are committed to do just that. We will begin keeping account of the time necessary to accomplish every function of the District Materials units, and plan shortly to be able to predict those needs.

FINDING II - ADOT COULD SAVE $175,000 ANNUALLY BY REDUCING STAFF IN THE DISTRICT I AREA LAB.

ADOT POSITION: PARTIALLY CONCUR

The conclusions are based on a productivity study comparing the first six months of 1981 with the same period in 1982, recommending reductions based on the comparisons. Such comparisons are not totally accurate as they omit consideration of overtime which was considerably higher in 1981 than in 1982, thereby narrowing the productivity differences. Regardless, the variation in testing-hour requirements in this lab points out a problem with which we are currently dealing, that being the significant fluctuation in workload over periods of time. Such a problem affects not only laboratory work, but other construction engineering work areas as well. Recognizing this, in the fall of 1981, ADOT began the development of a Construction Engineering Manpower Management System (CEMMS). This system is designed to accurately predict project manpower requirements including lab personnel. When personnel are found to be unnecessary in any assignment, they will be transferred to other productive work assignments.

AUDITOR GENERAL COMMENT: ADOT's statement above regarding overtime is not correct. Audit staff documented overtime for both 1981 and 1982 and included this in the productivity analysis.

The area lab is, in effect, a consolidation of several project labs for the sake of efficiency. Accordingly, manpower for the area lab will be controlled by the new system (CEMMS) which will be in effect by January 1, 1983. We have every confidence that this system will assure the efficiency of the area lab.

FINDING III - ADOT COULD PERFORM THE MATERIALS INVESTIGATION FUNCTION MORE EFFICIENTLY.

ADOT POSTION: PARTIALLY CONCUR

We agree that scheduling of the core crew's travel can be improved; however, we disagree that the core sampling crew duties can be transferred to the Districts and that the Pit Investigation crews should be reduced from four to three men each.

As outlined in our response to Finding I and Appendix, District Materials units will be in no position to handle this additional task. With a staff of four technicians (as in new Districts 3 and 4), they will possibly be understaffed to fulfill their regular duties. It is therefore not likely that they could assume the duties of continually marshalling three personnel to meet the demands for core samples. Nearly 80% of the core crew's work lies in obtaining samples for utilization by our designers in pavement preservation, rehabilitation, and recycling designs. These designers have a demanding schedule and having such a crew at their disposal in the Materials Section assures the provision of the necessary information on a timely basis which provides a proper flow of budgeted projects on schedule.

We believe the selected examples are not typical of our crew's travel practice. We recognize the need to better schedule such activities in order to reduce travel time, per diem and equipment costs.

The second recommendation deals with the observation that Pit Investigation Crews are overstaffed. This observation is based on the fact that we recently changed from three 3-man crews to two 4-man crews. It is stated in the report that we increased the crew size solely for safety reasons and reduced the number of crews due to declining workload. Safety is definitely a concern in crew size determination; however, the reason for this change was efficiency. Also, with the new emphasis on pavement preservation projects requiring numerous materials pits, our workload is very high and has not decreased.

The report does not analyze the efficiency of a 4-man crew vs. 3-man crew. During the recent reorganization of the Materials Section, this area was investigated by our State Materials Engineer. That investigation indicated that 4-man crews offered sufficient additional efficiency that one of the crews could be eliminated, and was the basis for the change, although increased safety was certainly an added asset. A recent analysis confirmed this earlier indication; however, this operation is being studied in detail by our Productivity Resource Management Study. Should this study reveal that 3-man crews can perform the operation more efficiently, without sacrificing safety, we will return to three 3-man crews.

FINDING IV - ARIZONA DEPARTMENT OF TRANSPORTATION COULD REDUCE COSTS BY COMBINING DRILL CREWS INTO ONE UNIT.

ADOT POSITION: CONCUR

This suggestion has been under consideration for some time. As the audit report points out, the nearing completion of the interstate system now makes implementation of the suggestion possible. We will begin immediately to analyze our projected workload to determine the best method for accomplishing this consolidation.

FINDING V - ADOT COULD REDUCE THE FREQUENCY OF MATERIALS SAMPLING AND TESTING.

ADOT POSITION: PARTIALLY CONCUR

We do agree that occasionally there are instances of oversampling, and as was noted in the report, we have taken several steps to reduce materials testing. One of these steps was the issuance of a new Sampling Guide Schedule. The report points out that this new guide has not been fully implemented by project personnel. One of the reasons why it has not been fully implemented, is that the new Sampling Guide Schedule can only be used on contracts advertised for bid after the effective date of the new Sampling Guide Schedule. On contracts advertised prior to this date, the old Sampling Guide Schedule would have to be used. Our Quality Control Services personnel have been checking ongoing construction projects to make sure that, where appropriate, the new Sampling Guide Schedule is being used. Another reason is that the Sampling Guide Schedule is intended to be used as a guide only and establishes certain minimum sampling frequencies. Our Resident and Project Engineers are charged with assuring that materials incorporated into the work meet all the applicable specifications. There will be many occasions when they feel it is necessary to take more samples than dictated by the guide. For example, when a certain material is barely meeting specifications, many samples are taken to determine whether the material is acceptable or unacceptable.

Our present specifications require that concrete cylinders are broken at 28 days. In fact, these cylinders are the acceptance point for all of our Class "S" concrete. The 28-day concrete cylinders are a nationally-accepted standard, and are specified in the manuals of the American Concrete Institute. At the present time, we have no plans to revise our specifications to allow any cylinders, other than the 28-day concrete cylinders, to be our acceptance point for concrete.

APPENDIX TO ADOT COMMENTS ON AUDITOR GENERAL'S PERFORMANCE AUDIT OF THE ARIZONA DEPARTMENT OF TRANSPORTATION MATERIALS TESTING FUNCTION

ANALYSIS OF STAFFING PROJECTION MODEL FOR DISTRICT LABS.

The mathematical model developed by the audit is a very ambitious endeavor for an understandable purpose, which is to determine a method to predict the staffing needs of District materials units. Such a procedure is of value and assistance in functions where variables are controlled, such as in factories. In this particular case, however, there are variables and outside factors which were either not addressed or not fully considered in developing the model, thereby weakening the model's applicability and accuracy. The following is our analysis of the two major weaknesses of the model:

Weakness 1. The model does not fully address the other duties of a District materials unit. The model utilizes testing hours as its measure of personnel requirements, assuming all other duties are proportional to the testing performed. Productivity rates are thus defined as the average amount of testing time per employee and acceptable rates are selected based on past demonstrated ability to meet these rates. This has two major shortcomings: First, far from being just a testing unit, these units have a vast number of other duties necessary to each District's proper functioning. The duties of these units are fully described in the attachment to this appendix. While some of these duties are dependent on construction, many are not. With the new vastly larger Districts, the personnel assigned will assume an even more important role. Our experienced materials engineers estimate the following requirements for each District for non-testing personnel.

(1) A District Materials Engineer. Consultant to the District staff and overall director of District materials functions.

(2) An experienced lab supervisor to oversee the day-to-day materials testing functions.

(3) An experienced technician to perform the District quality assurance program; visiting projects, checking lab logs, equipment, etc.

Another major shortcoming in this same area is that past productivity rates did not consider that these units were often understaffed and had to utilize considerable overtime and/or additional assistance in order to perform their duties; thus the model's decision as to acceptable productivity is based on insufficient information. This effect is better seen when examined in the light of Weakness 2, below.

Weakness 2. The model does not consider the effects on testing requirements of different types of construction projects. Large projects, which have little, if any, surfacing work ("grade and drain" projects) do not require a large amount of testing, while smaller surfacing projects are highly materials intensive and require a great amount of testing. Also, small urban projects require an inordinate amount of testing. Surfacing (pavement preservation) projects are often prevalent in the rural Districts, especially during times of low construction budgets, while small urban projects are common in District 1. To examine this effect, we combined the information from Tables 2 and 3 of the report to obtain the relationship of materials testing intensity (STH/$ million contractor payments) to construction volume ($ million contractor payments). The result is shown on the attached graph 1. This graph shows that as construction volume increases, the testing intensity decreases. As suspected, the rural Districts ordinarily experience high construction volume only when given a few large "grade and drain" type projects, while District 1, with its prevalent urban work, has a much higher base, but experiences the same effect. While correlation is poor and a definite representation is not possible, graph 2 represents a "reasonable" consolidation of the points on graph 1. To properly assess future staffing requirements for any District for any fiscal year, we would have to analyze the number and types of construction projects scheduled for that year; however, lacking that information, graph 2 allows for a "reasonable" estimate. Assuming the formula for construction volume (contractor payments) is correct, we need only to find the intensity (STH/contractor payments) from graph 2 and multiply it by the contractor payment figure to obtain an estimate of the number of testing hours required for that fiscal year. Dividing this by the average yearly testing hours available for each testing employee gives the resultant estimate of number of testing employees required. Adding non-testing employees gives estimated total staffing requirements.

A method to demonstrate the effect of this consideration is to recompute the example given on the last page of the audit report (I-5); however, before doing so, the average yearly testing hours available for each employee must be determined:

Total hours, excluding holidays	2000
Illness, vacations (average)	-224
Subtotal	1776
Training, break time (6.25%), administration, lab cleanup, etc. = 25%. .25x1776 =	-444
Net testing hours available	1332

Recomputation of example:

Contractor Payments = $5,190,888 + .514 x ($22,943,200)
= $5,190,888 + $11,792,804
= $16,983,693

Using graph 2, testing intensity = 270 STH/$ Million
270 x 16.98 = 4585 STH
4585 ÷ 1332 = 3.44 or 4 employees just for testing.
Adding the 3 non-testing employees, a total staff of 7 is indicated.

Another good example would be District 1's 1980-81 figure, which showed a high "productivity" (see tables 2 and 3 of the audit report).

Using graph 2 for the $68.5 million in contractor payments, testing intensity = 170 STH/$ Million. 68.5 x 170 = 11,645 STH for FY 80-81. 11,645 ÷ 1332 = 8.74 or 9 employees for testing. Adding the 3 non-testing employees gives a total of 12. In effect, then, District 1 was understaffed by one employee. This helps us to understand why overtime and additional assistance was necessary in that District lab during that period.

We do not feel that such models are appropriate. If, as suggested in the report, record keeping practices are improved, we will obtain information that will allow us to accurately estimate future requirements. We plan to do so.

<u>AUDITOR GENERAL COMMENTS</u>: The models projections do include administrative and other nontesting duties. For example, the model's productivity standard of 800 STH/FTE (expressed as an <u>average</u> for all lab employees) for districts II, III and IV allows nearly 1000 hours per FTE for the performance of nontesting activities - even after allowing for holidays, illness and vacations. The need for three non-testing employees <u>in addition</u> to the model's projections is not supported by the workload data.

ADOT's "testing intensity" curve in Graph 2 is <u>not</u> a reasonable representation of how testing intensity fluctuates with construction volume because:

1) ADOT used budgeted rather than actual FTEs in deriving the points plotted in Graph 1. This artificially shifted the points upward beyond our data which used actual figures.

2) ADOT's curve for districts 2-7 on Graph 2 was drawn free-hand on the basis of visual judgment of the points in Graph 1. No statistical method was used to validate the appropriateness of their curve.

Finally, ADOT's own representation of our model does in fact account for testing intensity as shown by the downward slope of the model's curve in Graph 2.

ATTACHMENT TO APPENDIX
DISTRICT MATERIALS UNIT RESPONSIBILITIES

QUALITY CONTROL ON CONSTRUCTION PROJECTS

1. Obtain independent assurance (progress record) samples.

2. Witness and perform testing for direct checks on the project testing procedures.

3. Check construction materials logs and materials certifications.

4. Assist construction project personnel with materials quality control problems, especially in asphaltic concrete operations.

5. Repair and calibrate project lab equipment.

6. Perform liaison work between project, district and central lab on special tests and assist in clarification of specifications and test procedures.

7. Witness and assist project labs in hot plant and concrete batch plant calibration and scale tolerance checking.

8. Review computer forms, computer printouts and maintain accurate computer application work on all materials test results.

9. Perform core drilling and testing on projects to correlate and set up nuclear density testing of asphaltic concrete.

TESTING

1. Perform correlation testing and test independent assurance samples.

2. Perform testing for which project laboratories are not equipped.

3. Test maintenance materials and materials used in permit work.

DESIGN

1. Perform mix design checks for asphaltic concrete and portland cement concrete for construction projects and then continually check mix design as asphaltic concrete is produced.

2. Perform soil cement, cement treated base and lime stabilization designs for construction projects.

3. Perform asphaltic concrete or portland cement concrete mix designs for maintenance or permit work.

4. Make recommendations for materials design on proposed construction projects. Review and comment on Materials Design Memos, communicating with the Materials Section.

TRAINING

1. Conduct lab training courses for construction and maintenance personnel.

2. Conduct nuclear density training course with emphasis on radiological safety.

3. Conduct special seminars as the need arises.

OTHER

1. Assist district and projects in preparing and coordinating materials related changes.

2. Assist in or perform research and prepare reports.

3. Act as materials consultant to District Engineer, his staff and field maintenance.

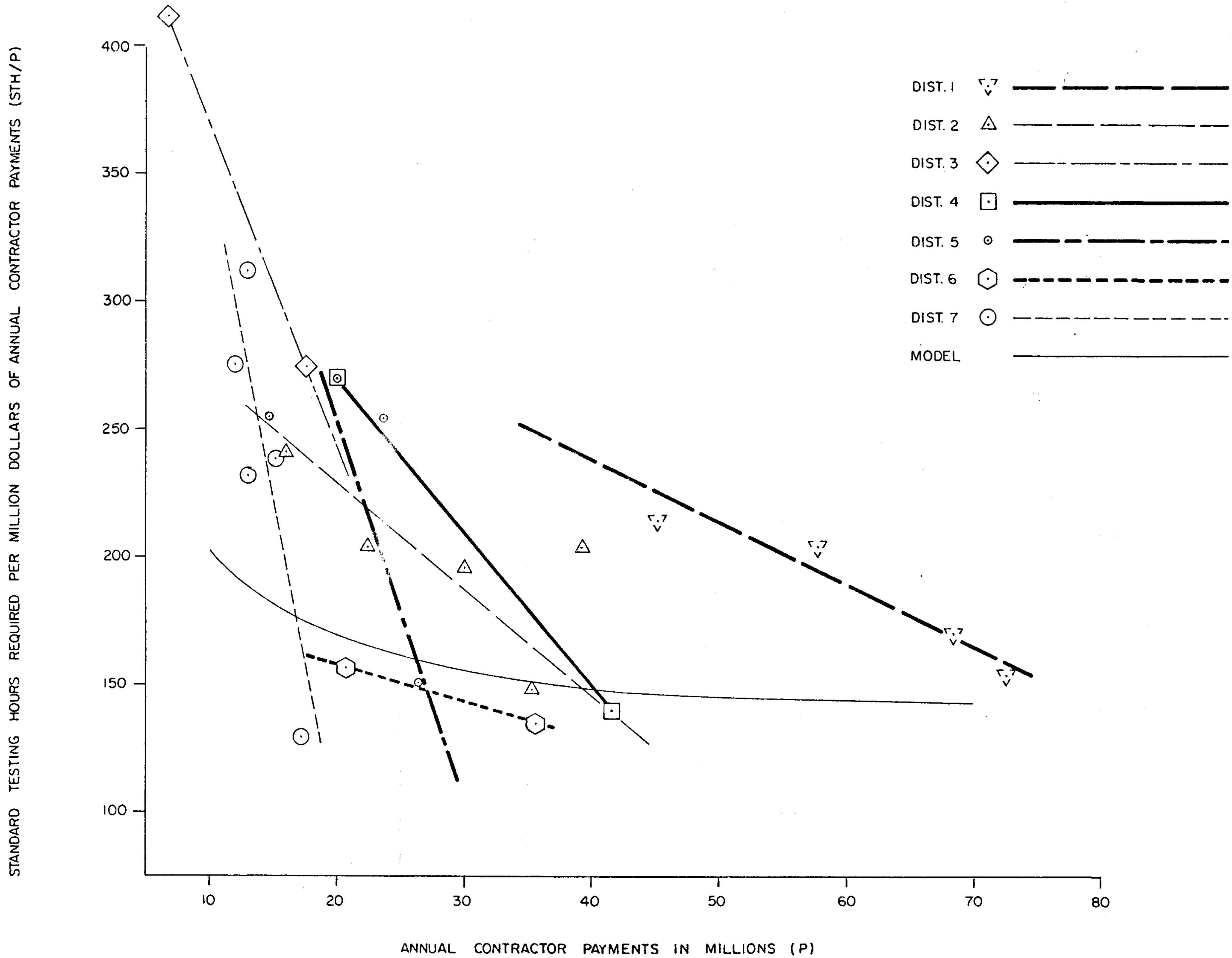
4. Make recommendations regarding rehabilitative needs, working with the Maintenance Supervisor and the District Staff.

5. Help locate and sample material sources for Maintenance.

6. Advise and consult with City and County personnel on matters involving local government projects.

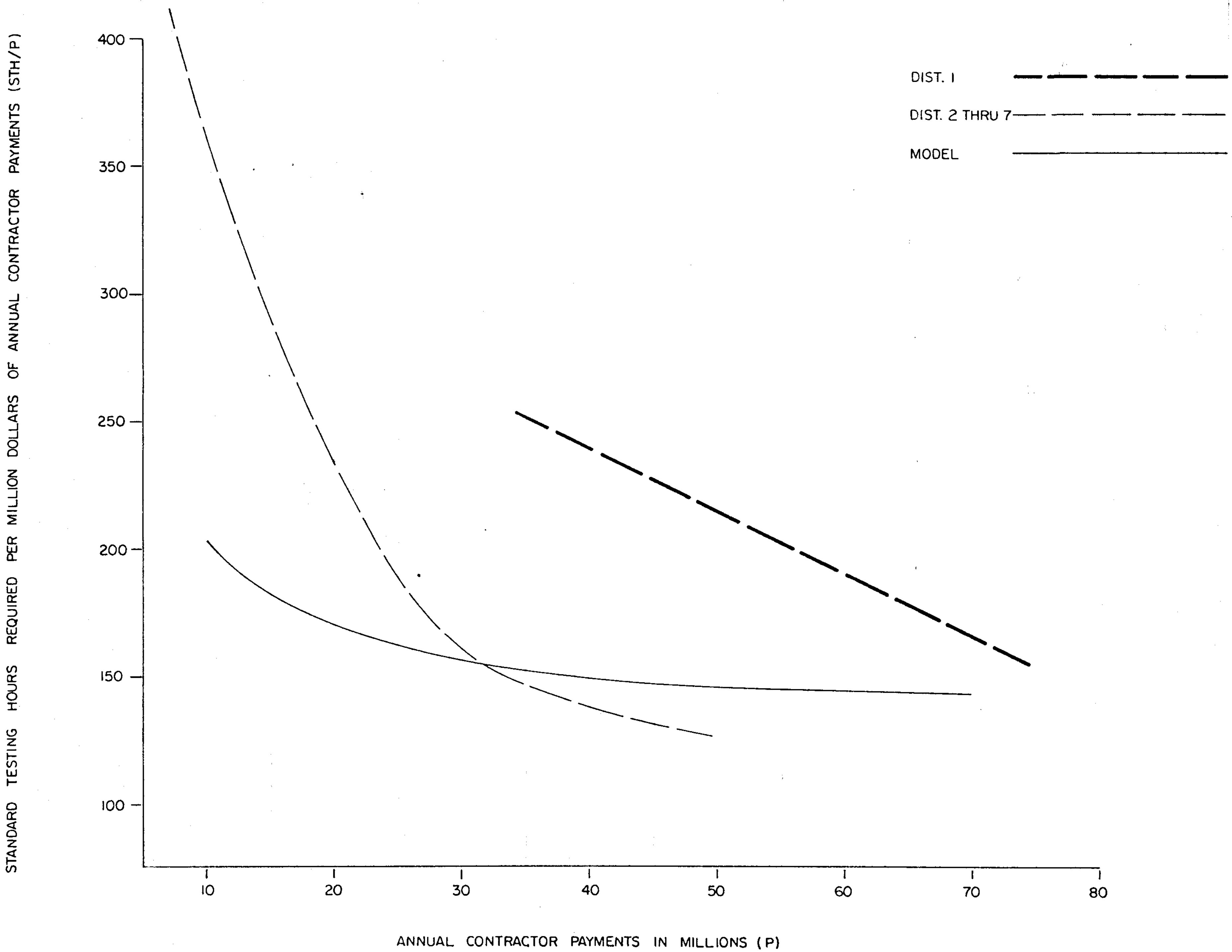
7. Assist central laboratory in testing products and materials for prior approval.

GRAPH I



STANDARD TESTING HOURS REQUIRED PER MILLION DOLLARS OF ANNUAL CONTRACTOR PAYMENTS (STH/P)
400
350
300
250
200
150
100
10
20
30
40
50
60
70
80
ANNUAL CONTRACTOR PAYMENTS IN MILLIONS (P)
DIST. 1
DIST. 2
DIST. 3
DIST. 4
DIST. 5
DIST. 6
DIST. 7
MODEL

GRAPH 2



DIST. 1
DIST. 2 THRU 7
MODEL
STANDARD TESTING HOURS REQUIRED PER MILLION DOLLARS OF ANNUAL CONTRACTOR PAYMENTS (STH/P)
400
350
300
250
200
150
100
10
20
30
40
50
60
70
80
ANNUAL CONTRACTOR PAYMENTS IN MILLIONS (P)

APPENDIX I

STAFFING PROJECTION MODEL FOR ADOT DISTRICT MATERIALS LABS

STAFFING PROJECTION MODEL FOR DISTRICT LABS

The staffing projection model used in Finding I consists of three main elements:

1. Productivity standards expressed as total number of testing hours per employee per year,

2. A statistical formula for projecting total lab testing hours or work load on the basis of the estimated highway construction program for each district, and

3. Conversion of projected lab work load (a product of element 2) into FTE requirements by applying the productivity standards in element 1.

Each of these elements is described more fully below.

Selecting Productivity Standards

Productivity standards used in the model are based on productivity rates achieved in recent years by the district labs. Productivity data was not available at the beginning of the audit, however, and had to be developed by audit staff.

We used annual testing hours per employee as an indicator of lab productivity. Lab personnel do not keep records which allow us to reconstruct the exact number and types of tests performed during given periods of time. However, lab logs show the number and types of samples processed by the lab each day. Therefore, we estimated total annual testing hours per lab by using the following information:

1. Number and types of samples processed by each lab annually. We gathered this data by reviewing lab logs.
2. Typical set of tests performed on each type of sample. Typical tests were identified by ADOT materials personnel.
3. Standard time to perform each type of test. Standard times were provided by ADOT and are known as Standard Testing Hour (STH).

This information allowed us to estimate total annual testing hours for each lab. After determining the number of lab employees for each period, we were then able to estimate the annual productivity of each lab expressed as standard testing hours per employee.

Past productivity rates provided the basis for the productivity standards used in the projection model. Table 3 (see page 12) shows the range of productivity achieved by each district lab during a six-year period where data could be obtained. In general, labs in the metropolitan districts (Phoenix and Tucson) historically achieved higher productivity rates than labs in the rural districts. This difference can be attributed to at least two factors: 1) employees in the rural district labs spent more time traveling than employees in the metropolitan labs and 2) economies of scale are possible in high-volume labs. Traveling distance becomes even more important as a factor when selecting productivity standards for the four new districts because three of these districts will have enlarged geographical areas to service. With this in mind, we adopted a productivity standard of 800 STHs per employee per year for new Districts 2, 3 and 4 and a standard of 1,150 STHs per employee per year for District 1. We believe these standards are achieveable, as evidenced by the historical rates shown in Table 3, and still allow adequate time for vacations, illness and the performance of other lab duties.*

---

* There are approximately 2,000 hours per employee in a fiscal year, not including holidays.

Projecting Lab Work Load

The second element of the model is a statistical formula for projecting total lab work loads (testing hours) on the basis of the estimated highway construction program for each district. The formula involves two main steps:

1. Projecting the amount of construction likely to occur in each district expressed as payments to contractors and

2. Estimating the number of testing hours needed to support that construction.

Using statistical techniques, we developed a method for projecting the amount of construction likely to occur in each district as measured by payments to contractors. We analyzed the historical relationship between 1) annual construction estimates for each district and 2) contractor payments during the same and subsequent periods.* The first-year estimates of the five-year construction programs were used as the construction estimates in the model.** We found a very high correlation between the first-year estimates and the actual construction in the district the following year, as measured by payments to contractors.*** This high correlation allows us to predict contractor payments in a future year on the basis of the official construction estimates for the preceding year.

We also found a high correlation historically between payments to contractors and the number of standard testing hours performed by the district lab during the same period.**** Therefore, the number of standard testing hours needed to support construction can be estimated from contractor payments.

---

* All historical data was converted to 1982 dollars.

** In the analysis we used the first-year estimates of six consecutive five-year programs.

*** Coefficient of correlation (R) = .902
Coefficient of determination (R^2) = .814

**** Coefficient of correlation (R) = .845
Coefficient of determination (R^2) = .714

In summary then, we discovered strong relationships linking annual construction estimates, subsequent-year actual construction and subsequent-year standard testing hours. These relationships allowed us to develop a formula, using linear regression, for predicting a district lab's future annual work load based on the official construction estimate for the preceding year.

Converting Work Load to FTE Requirements

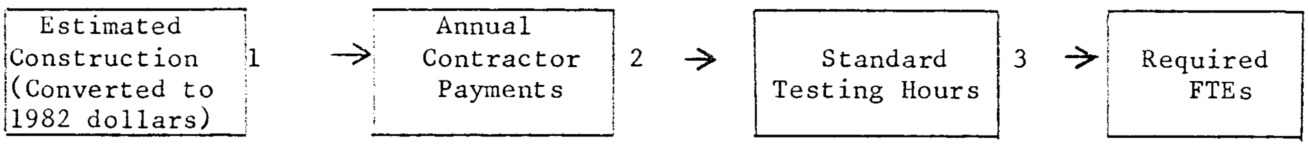
The final element of the model is the conversion of the projected lab work loads into FTE requirements. This conversion is done by simply dividing the projected annual work load, or standard testing hours, by the appropriate productivity standard (either 800 or 1,150 STHs per employee).

Summary and Regression Equations

Figure A summarizes the model graphically and presents the regression equations which were used to project contractor payments and standard testing hours for each district lab. To illustrate how the model works, Figure A also derives staffing requirements for the District 5 lab for fiscal year 1981-82.

FIGURE A

STAFFING PROJECTION MODEL FOR DISTRICT LABS



1. Annual Contractor Payments = 5,190,888 + .514 x (estimated construction for <u>prior</u> year converted to 1982 dollars)

2. Standard Testing Hours = 722 + .000133 x (annual contractor payments)

3. Required FTEs = $\frac{\text{standard testing hours}}{\text{productivity standard}}$ (800 or 1,150 STH/FTE)

   Or

   $$\text{Required FTEs} = \frac{722 + .000133\ [5{,}190{,}888 + .514 \times (\text{estimated construction})]}{800 \text{ or } 1{,}150 \text{ STH/FTE}}$$

To calculate District 5's fiscal year 1981-82 requirements, insert the estimated construction amount for fiscal year 1980-81 (after converting to 1982 dollars) into the formula:

$$\text{Required FTEs for fiscal year 1981-82} = \frac{722 + .000133\ [5{,}190{,}888 + .514\ (22{,}943{,}200)]}{800 \text{ STH/FTE}}$$

Required FTE for fiscal year 1981-82 = 3.7 or 4 FTEs