ARIZONA DEPARTMENT OF TRANSPORTATION

REPORT NUMBER: FHWA-AZ94-318-1

LANDSCAPE INVENTORY AND MANAGEMENT SYSTEM TECHNOLOGY FOR HIGHWAY TRANSPORTATION

Final Report

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April 1994

Prepared for:
Arizona Department of Transportation
206 South 17th Avenue
Phoenix, Arizona 85007
in cooperation with
U.S. Department of Transportation
Federal Highway Administration

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FHWA-AZ-94-318	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle LANDSCAPE INVENTORY AND MANAGEMENT SYSTEM TECHNOLOGY FOR HIGHWAY TRANSPORTATION		5. Report Date April 94'
		6. Performing Organization Code
7. Author(s) Harlow Landphair, Terry Larsen and Cliff Perry		8. Performing Organization Report No. Research Report 7180-RF
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, TX 77843-3135		10. Work Unit No.
		11. Contract or Grant No. HPR-PL-1(41)318
12. Sponsoring Agency Name and Address Arizona Department of Transportation Transportation Planning Division 206 South Seventeenth Avenue Pheonix, Arizona 85007-3213		13. Type of Report and Period Covered Final December 1990-June 1993
		14. Sponsoring Agency Code

15. Supplementary Notes

Research performed in cooperation with the United State Department of Transportation and the Federal Highway Administration
Research Study Title: Landscape Inventrory and Management System for the Arizona Department of Transportation.

16. Abstract

The application of computer based, spatial information technology (GIS) to the management of transportation facilities is becoming increasingly important. This porject was for the development of spatially referenced system for management of roadside landscape and irrigation development in Arizona.

Texas Transportation Institute, Environmental Management Program with ADOT's assistance completed the research activities associated with the identificatiion of needs, an assessment of the Arizona Department of Transportation's computing environment, conceptual design of the management system, evaluation of hardware and software, the pilot demonstration and subsequent trial implementation activities.

The research focused on the development of a "paperless" management system where the integration of technologies is the key to effective system consisted of the development of a spatially referenced mapping system for highway landscape and irrigation inventory, integration of intelligent maps into handheld data collection devices, collection of information into handheld devices and incorporation of these new technologies into existing data management systems.

Upon completion of the trial implementation period the evaluations suggest that the system, because of its limited focus and high degree of complexity is porbably not cost effective. This judgement is based on the fact that this system is a highly specialized system serving a very small segment of the overall maintenance mission of the Department. To be efficient and cost effective, a wider range of maintenance activities would have to be integrated into a single system framework. In the final analysis, the research successfully established a conceptual framework around which a new maintenance management system can evolve.

17. Key Words Pen Based Computing, Management Information System, Paperless Managemetn System, Geographic Information System (GIS)	18. Distribution Statement No restrictions. This document is available to the public through the: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	94	

Form DOT F 1700.7 (8-69)

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	6.452	centimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3.

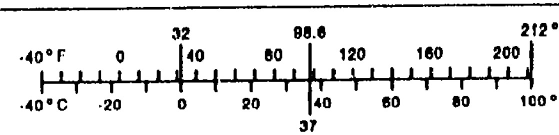
Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	millimeters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Disclaimer

"This report was prepared in cooperation with the U.S. Department of Transportation, Federal Highway Administration". "The contents of this report reflect the views of the author who is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Arizona Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification or regulation. Trade or manufacturer names which may appear herein are cited only because they are considered essential to the objectives of the report. The United States Government and the State of Arizona do not endorse products or manufacturers."

Benefits of Implementation:

The benefits suggested in the following paragraphs a·e anticipated to accrue, as a result of administrative efficiencies which will provide small, but long-term , cumulative, cost reductions in landscape maintenance. Administrative benefits are attributed to more effective planning, better cost and quality control. Cost savings would be a function of more effective planting and irrigation design, better material selection and reduced maintenance costs.

On the maintenance side supervisory personnel will be able to plan their work more effectively because they will have ready access to accurate field information. The increased detail available in the transaction files of PIMa will also assist in the development and tracking of actual costs and performance ratings of various equipment and materials.

A particularly important benefit of implementing the PIMa system is the issue of quality control. In an effort to increase its resource efficiency the Department is utilizing a higher percentage of private sector contractors to accomplish highway and landscaper maintenance. While it can usually be demonsrated that the reduction in overhead expense results in a significant savings to the state, the actual responsibility for providing a safe and efficient highway stystem still lies with the Department and not the private contractors. For this reason the Department must have a uniform system for tracking and assuring quality control.

The PIMa system when implemented will provide solid platform for tracking inidvidual contractor performance and ensuring the quality of maintenance is maintained at a level specified by the Department. The information base and analytical capabilities of the system will allow continuous, objective monitoring of contractor performance and ensuring optimum value per dollar. Without a strong monitoring system it will be very difficult to establish any form of defensible quality standard for future contracts.

PHASE I: TASK 1 THROUGH TASK 4

Introduction

Development of the Landscape Inventory and Management System (PIMa)[1], was accomplished in a series of 9 tasks and numerous sub-tasks. Tasks 1 through 4 were a sequence of interrelated activities that could be described as discrete units but, had to be accomplished concurrently to effectively recognize the relationships between raw data, informational needs, conceptual structure of the PIMa system and appropriate implementation technology. Tasks 5 through 7 focused on the development, demonstration and refinement of the PIMa system. Some activities, were added to the original contract to ensure that the issues of compatibility and interrelationships between the existing PeCosII system could be met prior to moving toward full development and implementation. Tasks 8 and 9 include preparation of the draft and final reports and trial implementation of the PIMa system.

This report is presented in sections that reflect the task structure of the work accomplished. Phase I included: Task 1; Needs Survey, Task 2; Preliminary Concept for PIMa, Task 3; Review of Available Hardware and Software, Task 4; Ranking and Recommendation of a Development Environment. Phase II of the project included: Task 5; Development of the Pilot Application for PIMa Including Automated Input, Task 6; Review and Demonstration of the Pilot PIMa System, Task 7; Revision of the PIMa System Applications per Demonstration and Review, Prepare the Implementation Plan. Phase III included: Task 8; Preparation of the Draft and Final Report and Task 9; Implementation of the PIMa, Landscape Inventory and Management System.

TASK 1 IDENTIFY ADOT'S LANDSCAPE MANAGEMENT REQUIREMENTS

Survey Development

The work described in this section describes the activities and findings of Task 1. It is important to recognize that the new generation of "Management Systems" being developed for transportation are "iterative" rather than "linear." That is, they do not follow a linear project path

[1] The acronym "PIMa" is being suggested as the identifying term for the Landscape and Inventory Management System. The initials stand for: Planting Inventory and Management

of: authorization, planning, design, construction and maintenance. These new systems are designed so they cycle information back into all parts of the process. In this case the information from PIMa will cycle between Roadside Development Services and Maintenance. For this reason a broad range of informational needs had to be considered.

To adequately recognize the differences in informational needs of Roadside Development Services and Maintenance, a four part survey instrument was developed with common sections to cover plant material and base plan (spatial reference) information needs. Separate sections dealing with design or maintenance considerations were developed to recognize specialized information needs. These specialized sections were administered to only the target groups.

In the initial meeting with ADOT advisory personnel, in December of 1990, a preliminary survey instrument was presented and comments were solicited. While nothing formal came from this meeting, later one-on-one conversations with design and maintenance personnel lead to some revisions in the technical wording and response options. These changes improved the "readability" of the instrument and simplified the administration. A copy of the survey instruments used is included in Appendix A.

Administration of Survey:

The two groups targeted for the needs survey were Roadside Development Services and Landscape Maintenance supervisors and crew chiefs from District 1. District 1 was targeted by ADOT as the pilot district since it has the greatest intensity of landscape development of all the districts in the state. Input from these two groups was essential to be sure that the PIMa system would be flexible and meet all the identifiable requirements of the Department and District 1. Other districts were surveyed by telephone contact and on site visits to determine what informational needs might exist as a function of regional differences. This was done to ensure maximum transferability and utility state-wide.

The Roadside Development Services and District 1 Landscape Maintenance groups were surveyed at meetings in early February by TTI personnel. The survey was administered to each group in separate meetings in a one-on-one forum. Each individual surveyed received a package containing the survey and a diagram describing the PIMa concept. The interviewer gave a brief description of the project and described the PIMa concept. The respondents were then asked to complete the survey.

Survey Results:

The survey results were reviewed and the results compiled into 6 tables. Tables 1 and 2 summarize the results of the survey related to base plan and plant material information needs. This information is common to both groups. Tables 3 through 6 are summaries of the specialized information gathered from Roadside Development Services and District 1 Maintenance respectively.

The "Base Plan" section of the survey was necessary to determine what information was required to spatially reference the landscape and irrigation inventory. The survey included a list of 15 data attributes that are frequently used on plan sheets for highway landscape, irrigation and construction. Each respondent was asked to choose one of 3 responses: 1) Never necessary; 2) Useful but not essential for most projects; 3) Essential for all projects. The percent of the respondents answering in each category are shown in the columns to the right of each item.

TABLE 1. Base Plan Information Summary

BASE PLAN ATTRIBUTES COMPUTER BASE MAPS	ANSWERS BY % OF RESPONDENTS		
	1	2	3
ROW Lines			100
Center Lines		37	63
Center Line Geometry	37	63	
Center Line Stationing		12	88
Mile Posts Mile / Points		12	88
Pavement Edges		12	88
Driving Lane Layout	25	37	38
Center Line of Drainage Ways		50	50

BASE PLAN ATTRIBUTES COMPUTER BASE MAPS	ANSWERS BY % OF RESPONDENTS		
Primary Structures			100
Lighting Standards		63	37
Sign Standards and Markers		63	37
Guard Rails and Barriers		12	88
Contour Lines		25	75
Water Source			100
Power Supply			100

The survey instrument contained a list of 24 different plant attributes that could be included in a plant information library. This kind of information would be useful to designers and consultants in making plant material selections and to maintenance personnel in determining the cause of maintenance problems. The plant material information is divided into two sub-sections; environmental factors and plant characteristics. Each respondent was asked to give one of three possible responses: 1) Never necessary; 2) Useful but not essential for most projects; 3) Essential for all projects. The percent of the responses in each category is shown in the columns to the right of each plant material attribute.

TABLE 2a. PLANT INFORMATION: ENVIRONMENTAL FACTORS

PLANT INFORMATION ATTRIBUTES FOR DATA BASE	ANSWERS BY % OF RESPONDENTS		
	1	2	3
ENVIRONMENTAL FACTORS			
Soil P_h		25	75
Soil N Range		50	50
Soil P Range		63	37
Soil K Range		75	25
Soil Salt Tolerance Range			100
Soil Suction Range	12	63	25
Slope % Range	12	38	50
Slope Orientation (Aspect)		50	50
Light Reflection Limits	12	50	38
Aggressiveness Characteristics		12	83
Water Requirement			100
Air Pollution Sensitivity		50	50
Wind Sensitivity		63	37

TABLE 2b PLANT INFORMATION: PLANT CHARACTERISTICS

PLANT INFORMATION ATTRIBUTES FOR DATA BASE	ANSWERS BY % OF RESPONDENTS		
	1	2	3
PLANT CHARACTERISTICS			
Plant Type			100
Evergreen / Deciduous		12	88

PLANT INFORMATION ATTRIBUTES FOR DATA BASE	**ANSWERS BY % OF RESPONDENTS**		
	1	2	3
PLANT CHARACTERISTICS			
Leaf Texture	12	75	13
Leaf Color	12	13	75
Flower Type		25	75
Flower Season			100
Flower Color			100
Fruit Type		75	25
Fruit Color		75	25
Fruit Season	25	50	25
Applications		12	88
Constraints		12	88

The soil information section of the survey was intended to determine what, if any, soil information would be considered useful to design personnel. In this case soii information is being used in the context of its agronomic properties rather than the geotechnical characteristics. While this is not traditional information used by engineering design sections of transportation agencies nationally, the project description specifically asked that this be included as a part of the study. The soil portion of the survey provided a list of 12 soil attributes that could be of value in making appropriate plant material selections. The list was compiled from the information that is most often reported in standard agricultural soil tests and from information available in U.S. Department of Agriculture, Soil Conservation Service, soil survey reports. As in the previous sections, participants were given three response options: 1) Never necessary; 2) Useful but not essential for most projects; 3) Essential for all projects. The percent of responses in each category is shown in the columns to the right of each soil attribute.

TABLE 3. SOIL INFORMATION

SOIL CHARACTERISTICS AND ATTRIBUTES COMPUTER BASE MAPS	ANSWERS BY % OF RESPONDENTS		
	1	2	3
Soil Profile to 3 Feet by Type and Texture		50	50
Soil P_h for Selected Areas		37	63
Soil Salts for Selected Areas		25	75
Soil Nitrogen (N)for Selected Areas	12	38	50
Soil Phosphorous (P) for Selected Areas	12	63	25
Soil Potassium (K) for Selected Areas	12	63	25
Soil Trace Elements for Selected Areas	12	38	50
Soil Compaction for Selected Areas	12	38	50
Soil Infiltration for Selected Areas	25	25	50
Soil Ash for Selected Areas	25	63	12
Soil Plastic Index (PI) for Selected Areas		75	25
Soil Available Moisture by Percent for Selected Areas	12	88	

In addition to the objective data variables, Roadside Development Services staff were asked about the need for additional site based information. This is somewhat subjective information that might effect the overall design and selection of plants and other materials. The survey included a list of 6 site based influences common to the roadside environment. For each case, respondents were asked to select one of three possible responses: 1) Never necessary; 2) Useful but not essential for most projects; 3) Essential for all projects.

TABLE 4. SITE CONSIDERATION

SITE CONSIDERATION ATTRIBUTES COMPUTER BASE MAPS	ANSWERS BY % OF RESPONDENTS		
	1	2	3
Flow Limit and Depth of Drainage Way	25	25	50
Assessment of Wind Exposure of Plants	12	63	25
Assessment of Reflected Heat Hazard to Plants		37	63
Aspect Orientation / Exposure Hazard to Plants		25	75
Assessment of Air Pollution Hazard to Plants	12	63	25
Assessment of Dust Hazard to Plants / Appearance	25	63	12

Roadside Development Services was not asked to respond to this portion of the survey because it focused on the spatial (map), information necessary for location, identification and the original base data that goes into the system. Maintenance personnel must have the appropriate instrument for collecting the information required to update the landscape irrigation inventory. Roadside Development Services will have an occasional reference to this information and it will be their responsibility to generate the original base data that goes into the system.

The survey instrument provided a list of eighteen different kinds of information related to a plan or tabular display. Each respondent was asked to consider the item and determine whether it could potentially increase the efficiency or quality of their daily work responsibilities. In this case a simple yes or no response was requested. The results are shown by percent in the columns to the right.

This part of the survey was intended to obtain information about any common problems related to plants or irrigation systems. This is the kind of information that can be reported back to designers to ensure that problems are not unwittingly designed into a project.

The survey listed nine potential maintenance problems. Each participant was asked to respond with one of four choices: 1) No problem in my area; 2) Minor problem; 3) Common problem; 4) Major problem. These results of this are shown in Table 6.

TABLE 5. LANDSCAPE INVENTORY DATA

LANDSCAPE INVENTORY ATTRIBUTES COMPUTER BASE MAPS	ANSWERS BY % OF RESPONDENTS	
	YES	NO
Location of Water Taps and Meters	100	
Location of Controllers and Power Source	100	
Location of Valves and Filters for Irrigation	100	
Location of Irrigation Mains	100	
Location of Irrigation Mains and Laterals	100	
Number of Emitters per Valve and Lateral	100	
Number and Type of Emitters per Valve per Lateral	78	22
Number and Type of Emitters per Valve	78	22
Plant Beds and Kinds of Plants in Beds	100	
Locations of all Individual Trees	100	
Location and Kinds of Shrubs in the Beds	100	
Location of all Plants and their Types	78	22
Plant Lists with Quantities and Common Plant Names Only	56	44
Plant List with Quantities, Common and Scientific Names	78	22
Plant Lists by Scientific Names Only	33	66

LANDSCAPE INVENTORY ATTRIBUTES COMPUTER BASE MAPS	ANSWERS BY % OF RESPONDENTS	
	YES	NO
Plant Dictionary or Manual with Pictures for Identification	89	11
Plant Dictionary with Information on Diseases and Pests	100	
Plant Dictionary with Information on Diseases	67	33
Plant Dictionary with Maintenance Information	100	

When answers to the questions were affirmative respondents were asked to name plants, locations or equipment that were not giving satisfactory service. The primary concern in this area was Acacia redolens, a large, aggressive plant that will take over large areas. It is a particular problem when planted too close to the driving lane where it can encroach on the traveled way and act as a visual obstruction. Other problems seemed to be isolated cases of poor plant selection by design consultants and unusual site conditions that contributed to unsatisfactory performance. Little else could be generalized from the other problems cited.

TABLE 6. COMMON LANDSCAPE AND IRRIGATION PROBLEMS

QUESTIONS	ANSWERS BY % OF RESPONDENTS			
	1	2	3	4
1. Particular shrubs are planted near the driving lanes and seem to consistently collect more trash than would be expected		22	56	22
2. Certain shrubs and trees in my area seem to collect and show more dust than other plants.	33	67		
3. Particular shrubs when used on steep slopes and embankments seem to allow more soil erosion than others.	11	44	45	

QUESTIONS	ANSWERS BY % OF RESPONDENTS			
	1	2	3	4
4. Particular kinds of shrubs and trees grow so fast they frequently encroach on the driving lanes if not trimmed.	33	11	11	45
5. Certain plants seem to have constant problems with weed invasion.	22	45	33	
6. Some plants have had a tough time surviving when planted next to structures like bridge supports, walls, drainage structures, etc.	45	33	11	11
7. Some plants get to be real problems when they are planted near any drainage way or structure.	22	33	34	11
8. The leaves and or branches of certain plants seem to catch alot of trash.	33	34	22	11
9. Some trees and or palm trees cause problems when they drop fruit, seed stalks and or fronds on to the driving surfaces.	56	22	22	

Analysis of Findings:

The Roadside Development Services survey included the sections on base plan information, soil data, plant material data and site considerations. This was the information summarized in Tables 1. through 4. The District 1. Maintenance survey included the same sections on base plan, plant materials and soil information plus, sections on plant inventory, landscape and irrigation problems. The findings on base plan, plant material, and soil are combined with Roadside Development Services responses in Tables 1 through 3. The data on plant inventory and maintenance problems were summarized in Tables 5 and 6.

Based on the results reflected in each of the summary tables data, attributes were selected for inclusion in the PIMa data base. The selection of items was based on having a 50% or greater positive response to the "Essential to all projects" (response No. 3 sections 1-5), or where 90% of the respondents felt that the information was either useful or essential (responses 2 and 3 in sections 1-5). In a few cases these conditions were not met and the variable has still been included. In these cases it is believed that the omission of the attribute could have a bearing on the long-term utility of the system. Where this occurs the attribute is shown in bold face type. The following sections describe the data variables recommended for inclusion in the PIMa data base.

Base Plan Material:

It was anticipated that there would be some distinct differences between the plan information needs of design and maintenance interests. This was anticipated because of the difference in plans prepared for construction purposes and the "as-built" informational needs of field personnel . In tabulating the results this proved to be true, but not to the extent that had been expected.

Responses from Roadside Development Services suggest that thirteen variables should be included on the PIMa base maps. These generally agree with the responses from the maintenance group with one major exception, field control used for construction is standard center line control. Maintenance personnel, on the other hand, use mile post references for all records and field reference. Since mile posts are used as the primary reference system in reporting inventory information for all ADOT maintenance activities they were the logical choice for the reference system. Some consideration was given to incorporating some means of linking stations to mile post locations. However, this proved to be cumbersome and of questionable long-term benefit.

Based on the survey, the following information was selected for inclusion on base maps used for the PIMa system.

1) **ROW lines**
2) **Center lines**
3) **Water Sources**
4) **Mileposts/points**
5) **Pavement Edges**
6) **Drainage ways**
7) **Primary structures (bridges, etc.)**

FIGURE 1. BASE PLAN ENTITIES FOR PIMa MAPS

In the final data base only items shown in Figure 1 were actually included. The reason for omitting items was the lack of complete accurate data on the materials being used to capture the base information. It simply would not have been economically feasible to field verify all of the information suggested or to search the archives for plan materials. While it was not possible to include these items in the initial PIMa data set ADOT can require that this information be included on all new construction submissions and begin recording this information as it becomes available.

It should also be pointed out that light standards, signs and guard rails are elements of roadside hardware that all too frequently come in conflict with the highway landscape. When this information is not available on the base maps used for design, conflicts between plants and hardware are not readily apparent. The net result is that large growing plant materials are located in the distribution pattern of lighting standards or in the sight line of signs and information standards. These frequently lead to very hazardous conditions that could be avoided with better information.

Originally contours were an item considered of value in the data base. However, the long-term need for contours was not immediately apparent, nor was the means to implement their inclusion. There can be little doubt that contours have application in both the design and maintenance phases of a project. However, the labor costs associated with input, information availability and mass storage overhead of maintaining contour information in the computing environment, ultimately made the inclusion of contours unfeasible.

Plant Information Database:

The plant information section of the Roadside Development survey inquired about the type of plant material information needed by designers and maintenance personnel. The responses strongly suggest the need for a plant information library supplemental to the basic plant inventory information. Review of the responses suggested several characteristics be included in the plant material library. Figure 2 shows the information to be included in the plant data base and illustrates how the information will be presented.

Name Botanical: Cassia artemisioides	Type: Shrub-evergreen
Name Common: Feathery cassia	Cultivar:
Flower Time: Early spring	Temperature: Damaged below 20' F
Flower color: Yellow	Heat reflection: Damaged by direct afternoon sun.
Leaf: Gray-green needle-like	H2O requirements: 1 gpd/ft. to 3' and .5 gpd after 3' to 5 gpd at maturity.
Fruit: Flat pod	Slope Limits: none
Soil N Range: 4-6 ppm	Soil K Range: 1-2 lb./cu.yd.
P_h Range: 6.9-7.3	Soil Salt Tolerance: < 300 ppm

Applications: Specimen or mass planting, requires little maintenance

Constraints: Damaged by cold and beans result in litter and are a problem were neat, manicured effect is desired.

Pests: Few

Diseases: Generally hardy, but can suffer from rust. Die back is usually the result of lack of water.

FIGURE 2. PLANT LIBRARY INFORMATION EXAMPLE

Soil Information:

Soil information is not traditionally carried on highway base plans in Arizona. However, basic knowledge of the soil type is very important to making plant material selections and can be of even more value in planning and making maintenance decisions. For this reason ADOT required that soil information be considered as part of the project. In developing the survey an effort was made to determine the kinds of soil data that would be of use to design and maintenance personnel and included these as items in the survey. The results of the investigation suggest that the items listed in Figure 3 should be included in the soils information library three.

Upon further consideration of the soil library it was deleted from the final data set. The major consideration was that during highway construction the soil profile is drastically disturbed. This is particularly true in the vicinity of deep cuts, fills and in the construction of embankments associated with complex interchanges and wide highways. In cases like this an attempt to represent the soil condition from SCS information would be very misleading.

1) Soil profile by SCS type and texture
2) Soil Ph for selected areas
3) Soil salts for selected areas
4) Soil Nitrogen (N) for selected areas
5) Infiltration for Soil Type
6) Available moisture by % for selected areas
7) **Plastic Index (PI)**
8) **Internal drainage properties**

Figure 3. SOIL INFORMATION DATA BASE

These problems could be overcome by a program of soil testing, as part of landscape development, at selected locations after construction and before landscape design begins. There is no hard evidence for such programs in transportation literature but other literature in vegetation maintenance and establishment strongly suggest that such a program could be cost effective in both design and maintenance. In the final analysis, the inclusion of standard SCS information was seen as being of little use without some on-site verification. Given these constraints and the limited value of the soil information available it was not included in the final data set. The framework of PIMa does provided a means to handle soil information if ADOT elects to implement a soil testing program as a part of the landscape design process.

Site Analysis Information:

The site analysis section was administered to the Roadside Development Services group only. The responses to this section suggested three items for inclusion in the database from the original survey. These were: limits of drainage ways, reflected head hazard and orientation hazard. In addition to the three identified in the prepared survey materials five additional items were suggested by ADOT staff. These are included in Figure 4.

After much discussion of this data it became clear that Roadside Development Services concerns revolved around the ability to evaluate the decisions of consultants. There is a need to ensure that all consultants address the issues represented by these items during the design process. However, most of the information is subjective and can only be carried in the data base as informational fields. In the final analysis the considerations of cost for gathering and entering this kind of information was not considered cost effective.

1) Limits and depths of drainage ways
2) Assessment of reflected heat hazards
3) Special orientation or exposure hazards
4) **Visual analysis**
5) **Hazardous viewing areas**
6) **Assessment of wind exposure**
7) **Assessment of air pollution hazard**
8) **Assessment of special dust hazards**

Figure 4. SITE ANALYSIS INFORMATION

Landscape Maintenance Standards:

One concern that surfaced during discussions of site analysis was loss of the intent of design intent. The designers were concerned with field changes that often occur as a result of plant loss or changes made by maintenance personnel resulting in loss of design integrity. Some options were explored for including design intent text fields on plans to describe preferred maintenance procedures and design intent. The shell for including this feature was included in PIMa. However, since no information of this type exists for current projects it will have to be implemented by ADOT staff.

Landscape Inventory Data:

This section was developed to identify the information needs of maintenance personnel in day-to-day operations. This included plant material and irrigation maintenance considerations. It is important to note that while this section was administered to only maintenance interests it has significance to the all ADOT maintenance units because it is the framework for data acquisition and updating of the inventory portion of the data base. Roadside Development Services staff have very little contact with this system.

Plant Material Needs

1) Location of all plants with names
2) Plant list with quantities, scientific and common names

Irrigation Needs

1) Location of water taps and meters
2) Location of controllers and power source
3) Location of valves and filters for irrigation
4) Location of irrigation mains and laterals
5) Show number of emitters per valve/lateral
6) Show number and type of emitters per valve

Special Informational Needs

1) Plant dictionary or manual with pictures for identification
2) Plant list with information about insects that cause damage
3) Plant list with information about diseases and treatment
4) Plant list with information about basic maintenance needs

Figure 5. LANDSCAPE INVENTORY DATA STRUCTURE OF PIMa

A review of the responses clearly suggested that the ability to display information in plan form is very important. It was also apparent that they would like to have access to a wide variety of information in as much detail as possible. The desire for the level of detail indicated was not anticipated and had to be considered further with respect to cost and long-term utility. After several follow up sessions with maintenance crews and supervisors and Roadside Development Services the following level of information was incorporated into PIMa data set. The basic structure and level of detail is outlined in Figure 5.

Landscape and Irrigation Maintenance Problems:

The results of this section indicated that there were indeed some problems related to specific plants, locations, workmanship and materials. However, other than the Acacia redolens problem, there were no patterns that emerged from the investigation. The structure of PIMa does provide ADOT a means to examine trends in maintenance activities and, over time, to identify patterns and predict problems. Once PIMa is in operation it will lead to early detection of problems and actions can be taken to avoid more costly consequences. Figure 6 is a tabulation of the primary problems identified by respondents to the survey.

1) Erosion of decomposed granite
2) Motor vehicles driving on granite
3) Wrong types of plants planned - some won't grow in this area
4) Poor workmanship in laying of irrigation lines
5) Acacia redolens grow too large - many complaints
6) Erosion on unprotected slopes caused by rainfall drainage
7) Acacia unger plants spaced too close to each other
8) Rodents
9) Overplanting

Figure 6. MAINTENANCE PROBLEMS CITED BY RESPONDENTS

Review of ADOT'S Computing Environment:

An important consideration in completing Task 2 The Conceptual Development, was determining the compatibility with existing ADOT computer based systems. Since PIMa would very likely have some interaction with existing systems it was important that issues of compatibility and connectivity be addressed even though this was not specifically addressed in the original ADOT problem statement.

ADOT's Computing Environment:

The Arizona Department of Transportation's Computer System consist of an AMDAHL 5 990-790 mainframe computer, an IBM 3745-410 computer acting as communications front end. The machines drive a host of support peripherals such as disk drives, cartridge devices, printers and others, all interconnected via data lines, courier controllers and data circuits. These central computing facilities are maintained and operated by ADOT's Information Services Group, (ISG).

Parallel to this there are significant decentralized computing resources in the CADD Services area and for specialized computing operations among divisions and sections. While there is no evidence that this is a departmental commitment it is consistent with national trends in other transportation agencies and departments. Most information services planners suggest that functions such as accounting, inventory and records will remain in the centralized computing realm, while the design, construction, operations and maintenance functions will become increasingly specialized and housed in a desktop environment designed for a specific task.

Existing Systems Affecting Development of PIMa:

During the review, it was discovered that ADOT has two major systems that handle landscape related maintenance and operations activities. These are known by the acronyms PeCosII and VEGI. These systems are Mainframe resident programs that utilize IBM-PC programs written in dBaseIII+ as the data acquisition front end, between field and central administration. The existence and function of these systems had significant implications for the development and final structure of the PIMa system.

The PeCosII System:

The PeCosII is a "Management Decision Support Software" used by ADOT Maintenance and Operations. It is the primary management tool for collecting and processing data for maintenance work planning, efficiency control and budgeting functions.

The PeCosII system is a multi-platform resident application. The primary database and high level reporting functions reside on the AMDAHL 5990-790 mainframe computer, while the menu-driven data input and specialized reporting functions related to districts and "ORGS"[2], reside on field-based microcomputers supported in dBaseIII+. The mainframe is used as a repository for data, and to produce reports for all levels of management, from the individual org to state headquarters. No data input is performed directly in PeCosII. These functions are preformed at either area org terminals or the area. The data is then transmitted by modem to

[2] "Org" is a term used by ADOT to designate a functional maintenance unit or crew.

central processing. The data gathered for PeCosII is to general to be of use to the PIMa system but there is a significant overlap in concept. This suggested that PIMa should be developed in a way that would increase the detail of data acquisition at the field level while meeting the data requirements of PeCosII. Because of ADOT's investment in PeCosII and the limited mission of PIMa, PeCosII and its operating constraints had to be recognized.

The VEGI System:

The VEGI System is a mainframe database application used to manage ADOT's vegetation control program and track the use of herbicides throughout the state. VEGI was originally linked directly to the PeCos system. When PeCosII was brought on line the link between VEGI and PeCos was not implemented and at this time there does not appear to be any action scheduled to reestablish the link.

In the landscape maintenance section of PeCosII there are some functions that relate to herbicide use but they only cover very small scale use of herbicide materials. PeCosII has no provision for handling the detailed information necessary for records of herbicides use. The level of detail in VEGI includes factors such as weather, type of chemicals used, concentrations, type of plant treated, etc. VEGI also provides several report generation options and includes the capability of producing needed forecasts.

Integrating PIMa with Existing Systems:

Because PIMa required more detail and could not be attached to PeCosII, it had to be developed as a stand alone system. When finally conceived it was similar to VEGI, having the ability to produce reports and store information for specific design and landscape maintenance needs and at the same time furnishing PeCos II the necessary data records. In order to accomplish this meant that some provisions had to be made internal to PIMa to reformat raw data into PeCosII compatible files. Ultimately, the need to make PIMa compatible with the PeCosII system led to significant changes in the original scope of work. These changes will be discussed in conjunction with the individual tasks.

Field Review of Landscape Development

Along with the needs survey, a field inspection was made of the landscape development on the state maintained sections of the freeway system in District 1. This is roughly 60 lane miles of freeway including sections of East and West Papago (IH 10), Black Canyon (IH 17 North), Maricopa (IH 10 and IH 17 South), Agua Fria, Hohokam and Superstition freeways. These tours assess the character and condition of the landscape and how it related to the current paper records maintained by the Department. These reviews were important to decisions about the means of capturing, verifying and recording the inventory data for implementation.

CONCLUSION, TASK 1

The findings of Task 1 supported the concept of developing a landscape inventory and management system. It also appeared to be feasible within the limits of existing technology. The strong ties to plan based information also suggested that the concept of implementing the system in a spatially referenced environment was appropriate.

While the survey results supported the concept it was also deemed important to continue looking closely at the costs associated with implementation and maintenance of PIMa. Many data items and analytical capabilities were requested by Roadside Development Services and Landscape Maintenance. Nonetheless, the costs associated with each application and data base entity included in the system had to be weighed against its effectiveness in making maintenance and design decisions.

Concurrent with the development of PIMa, PeCosII was also undergoing review with respect to its data structure for activities in landscape and irrigation maintenance. While this effort was not a part of this contract steps were taken to stay abreast of all developments and changes as they were adopted. Unquestionably, any changes in the PeCosII reporting system had to be considered in the final development of PIMa since the maintenance of the inventory would depend on continuous access to field information.

TASK 2: CONCEPTUAL FRAMEWORK FOR PIMa

This section addresses the Task 2 requirements to develop the conceptual framework and operating parameters of PIMa and address technical issues associated with development and implementation of PIMa. The work accomplished in Task 1 were taken into account in developing this section.

Current Inventory and Management of the Highway Landscape: PeCosII and VEGI:

Management of highway landscape maintenance is tracked in a very general way through the PeCosII system. PeCosII tracks broad scope activities such as: mowing, tree trimming, fertilizing, repairing irrigation, etc., no data is specific to plants or irrigation equipment. More detailed information about vegetation management with herbicides, is recorded and processed in the VEGI system. Figure 7 is a diagram that represents the current flow of landscape and irrigation maintenance information within ADOT.

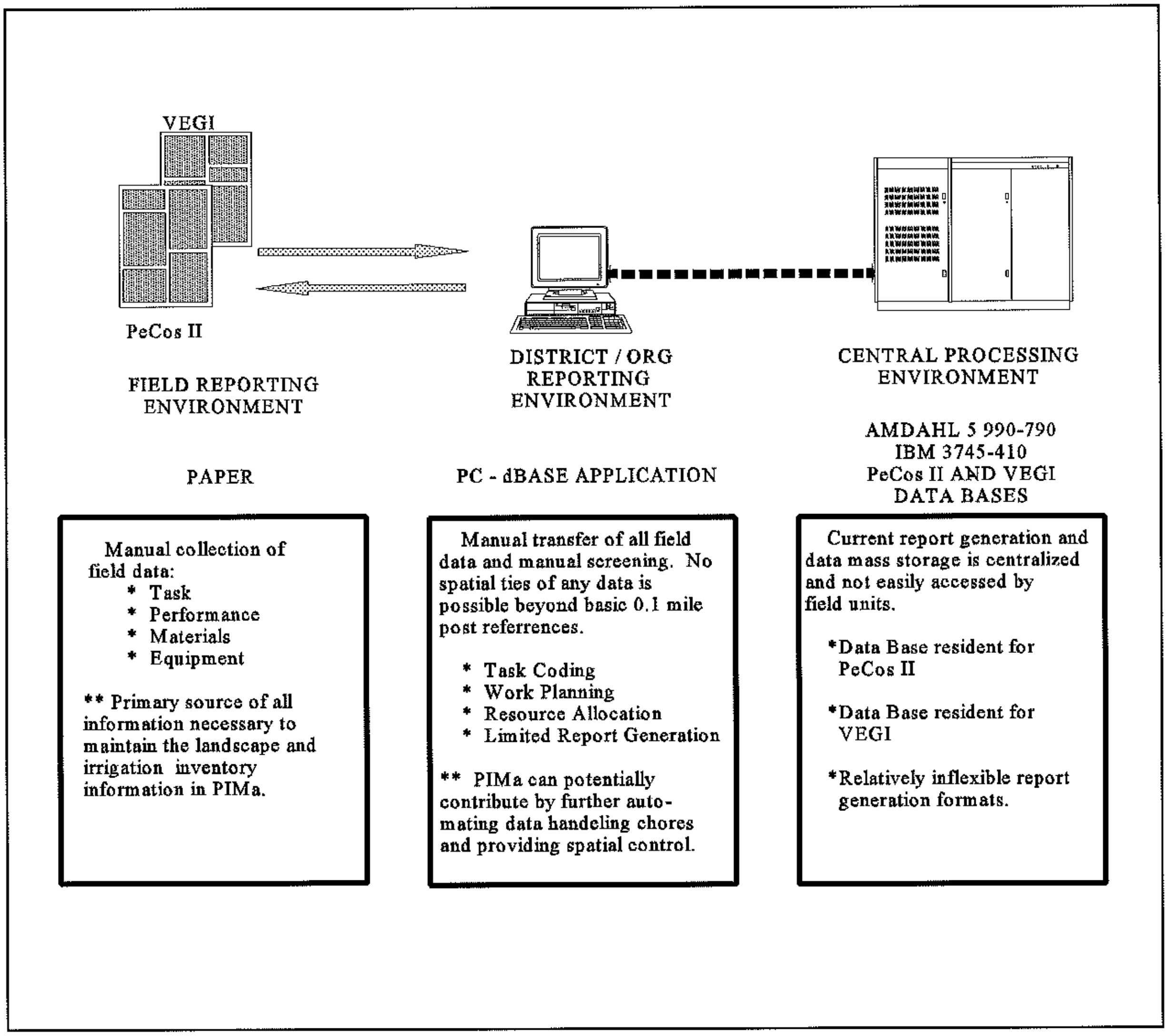

Figure 7. Current Landscape Management

Two very important considerations were noted. First, the field reporting of inventory and activity data is by manual execution of paper records. These records must be manually verified and manually transferred to the PeCosII and VEGI systems. This not only requires a considerable manpower commitment it also provides three contact points where error generation is possible. Secondly, the materials codes currently used to identify repair and replacement material do not provide sufficiently detailed information to make field level maintenance or design decisions.

Equally important was the question of how sufficiently detailed data could be acquired without unduly increasing the burden on field personnel. After meeting with the working group charged with recommending revisions to the PeCosII system it was agreed that every consideration would be given to the automation of field reporting procedures, and that this would be brought to the attention of the technical advisory group.

Data Organization:

Based on a review of the information needs, PIMa was organized into six basic data sets: spatial information (maps), graphic data (raster maps), landscape inventory data tables, irrigation inventory data table, transaction files and the plant material library, see Figure 8. The spatial data is a base map that locates all plant material and irrigation equipment on the maintained rights-of-way in District 1. The graphic data set was a late addition and is made up of bit-mapped images (raster images), of the vector base maps for use in the data collection devices. The landscape and irrigation inventories are tabular data sets that make up the working inventory. The transaction data is a record of all maintenance actions to the landscape and irrigation system on the right-of-way. The plant material library is a supplemental data base with more detailed information about specific plants used in the highway landscape.

These six data sets are used to support a variety of applications in design, maintenance and operations. A brief discussion of each data sets is provided to establish the relationships between the information and the computing environment that will be necessary to automate the data.

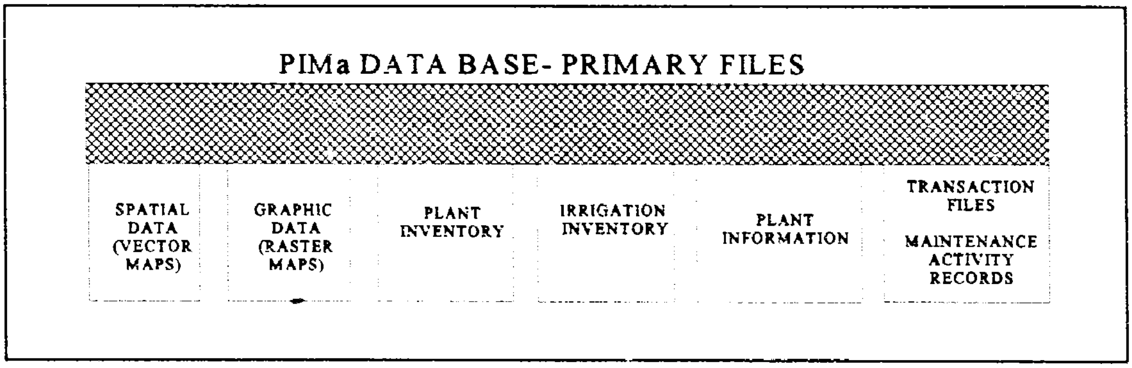

Figure 8. PRIMARY DATA FILES IN THE PIMa DATA BASE

Spatial Data:

The term spatial data is used here to avoid the narrow connotation of the term "map." A map, as the term is usually used, is a graphic representation of physical features or thematic information. This narrow definition does not adequately describe the variety of information that can be carried in a machine based spatial referencing system, more often called a Geographic Information System, (GIS). GIS as used in this document means a topologically structured graphics file of map primitives linked to a relational data base management system, (RDBMS). This type of system allows all tabular data in the system to be spatially referenced to its physical location as well as maintain the spatial relationships between all of data elements.

The use of a GIS environment was necessary to satisfy the need for spatial referencing of inventory information and the desire of the design and field personnel to produce a variety of map products. In order to efficiently maintain the spatial referencing needs, the map files were created in five layers: Physical Features; Shrubs, Surface and Ground cover; Trees; Soils; Irrigation Appliances and Irrigation lines. These layers carry all of the boundary and locational information necessary to maintain the inventory items and produce a variety of map products.

The geo-referencing was accomplished using the ADOT, ALISS center line data base. This was the most accurate, machine compatible, referencing system of ADOT's highways. The ALISS files provide current center line geometry for all pavements as well as mile posts. The tenth mile points were inserted after the initial data base was transferred into the PIMa environment.

Raster Graphic Data:

When the addition of an automated data collection feature was approved a set of "raster maps" were generated from the vector maps. This was done to avoid the need for paper maps in the field. Map information is down-loaded into the hand held devices used for data collection along with the work reports used in the field. These maps are equipped with reference links back to the inventory data sets that allow field personnel to identify all of the entities that appear on the maps.

Landscape and Irrigation Inventories:

The landscape and irrigation inventories are very general data sets resident in the RDBMS for tracking the number and type of plants in the landscape and the attendant irrigation equipment. These are the tabular data sets linked to the map data base. They include basic information such as: plant type or name of material, quantities, date of installation, slope aspect, tenth mile post reference, etc. Appendix B has examples of typical data files and maps for the data sets.

Transaction Data Set:

The transaction files are the means of tracking the history of work on the rights-of-way. Every time an action is taken affecting any item in the plant or irrigation inventory, a record is made of the action taken. These records can then be processed to establish trends, examine costs, determine the utility of materials and brands of equipment, and to identify successes and failures in the landscape.

Plant Material Library:

The plant material library provides detailed information about the ornamental plant materials used on the rights-of-way in District 1. The reason this is not included with the basic inventory data is that only one information file is required for each plant type. This data will be accessed by a relational link to the appropriate reference code in the inventory file. The development of reference code system will follow the expanded the alpha code scheme adopted for the VEGI system[3].

Data Acquisition and Maintenance:

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[3] The system used in VEGI follows the USDA Soil Conservation Service Technical Publication 159, National List of Scientific Plant Names, two volumes; Volume 1, List of Plant Names, Volume 2 Synonymy. The primary difference is that the SCS system uses a 4 alpha and one numeric character code and VEGI limited the field to four alpha characters. The need to recognize more species and their cultivars will probably require the adoption of the full 5 character system.

While the results of the needs survey made the determination of the data organization a reasonably straight forward task, the means for collecting the field information required to maintain the inventory was quite another matter. As noted in the discussion of current activities all records are executed manually and require a considerable time commitment to record, check and enter into the PeCosII data base. Consensus among district and central maintenance personnel was that it would not be feasible to expand or revise the paper data collection system to achieve the necessary level of detail needed for PIMa. Such a change would, in their opinion, add too much time to an already cumbersome paper records system. Maintenance Planning Services also rejected this idea because it could not be accommodated in the existing PeCosII framework. This meant that it would be necessary to streamline the data collection process to acquire the necessary information. What finally transpired was the development of a fully automated data collection system. This involved the development of specialized software and the use of a graphics based, pen-sensitive screen collection device.

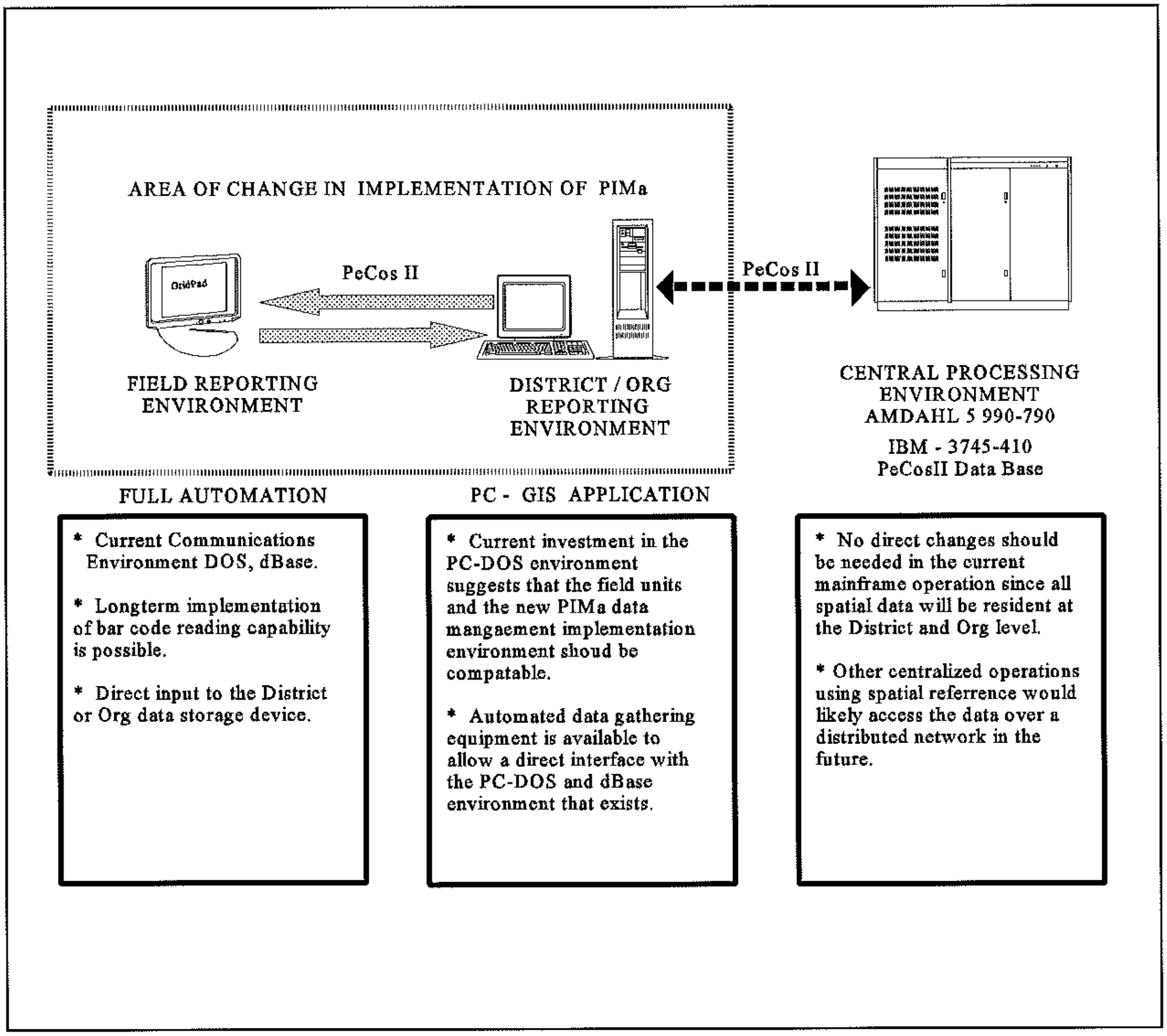

Figure 9 Automation of Field Data Collection

Figure 9 illustrates the relationship of the automated data collection device to the PeCosII system. The automated data collection for PIMa uses the field based device to ask for specific responses based on the tasks to be performed by a crew for the day. Most of the information necessary to make appropriate responses is resident in the machine including map references which provided each crew information on their specific area of responsibility. Appropriate information is input to the field device which is then processed into appropriate output units (.DBF files), for direct transfer into PeCosII and PIMa. At this time, verification of information, such as employee number and other cost data, necessary for PeCosII, remains on the district or org level machine. Some consideration was given to including the verification function in the field based unit. This is possible if sufficient mass storage capability is provided. However, further investigation of this alternative was beyond the scope of this project.

The Operational Concept for PIMa:

Figure 10 illustrates the Operational Framework (Task 2.1) and broad operational parameters (Task 2.2), for PIMa. It shows the general relationships of data units described earlier, the flow of data from the automated field device to the area and org level application and the ability to pass the appropriate information along to the PeCos II and VEGI system.

The user interface is divided into four functional units; mapping, reporting, data entry and informational libraries. The mapping unit (Arc/Info), houses the map analysis and thematic mapping functions of PIMa. The reporting module has automated report functions that utilizes the data base query functions of dBaseIV for developing specialized queries. The data entry module is used to filter data from the field units and format it for transfer to the PeCosII and PIMa systems. It is also the module used to enter new landscape projects in the system. The information libraries are files that provide detailed information about specific landscape plant materials.

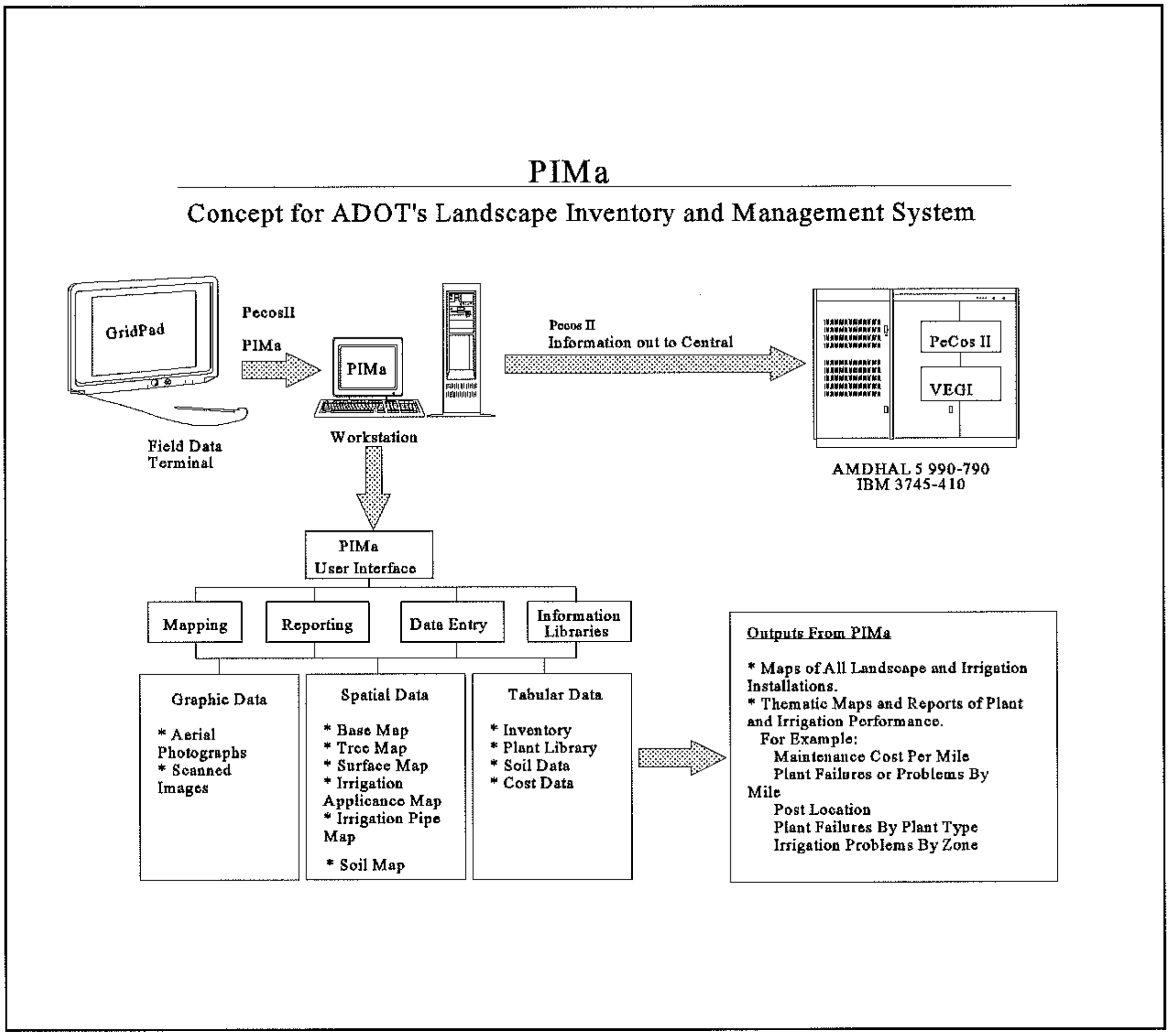

Figure 10 The PIMa Concept

Data Organization:

The boxes below the user interface block illustrate the individual data elements that are resident in PIMa. The spatial and tabular data units have been described previously. In the early design of the system some thought was given to the inclusion of aerial photographic information as part of the data base which could be used as one means of verification of inventory and tracking change. Upon further study this proved to be impractical due to the mass storage requirement and the lack of resolution available on the display devices to be used. In the end the photographic data set was used only as a tool to verify the base plans and inventory information. As implemented the PIMa system uses a raster graphic data set which was generated to support the hand held devices in the field. This proved a more valuable tool and more economically feasible. The contents of this data set was described earlier.

TASK 3: REVIEW OF SOFTWARE AND HARDWARE

Software Comparisons:

Task 3 required the evaluation of available hardware and software for the implementation of PIMa. In light of the findings in Tasks 1 and 2 the evaluation criteria became heavily influenced by the need for the PIMa system to be compatible with the PeCosII system. The following evaluation criteria were developed to guide the evaluation process and are reflected in the comparison matrices used for evaluation of hardware and software packages.

General (Hardware and Software) System Evaluation Criteria

1. Systems should be able to run in multiple environments and on a variety of platforms common to the ADOT units that will use PIMa.

2. The spatial graphics system should be compatible with ADOT's primary CADD system, and to the extent possible, other CADD systems used by ADOT's consultants.

3. The Data Base Management System (DBMS), should have a relational structure, capable of interfacing with other applications in the Department.

4. The DBMS should be compatible with the Ashton-Tate, dBaseIII+ application developed for support of PeCosII.

5. The DBMS should be able to run in an "off the shelf" configuration with the spatial data software selected.

6. The DBMS and spatial graphics system should have minimum requirement for RAM and mass storage space to operate efficiently. This criteria is to limit ADOT's need for further capital investment for implementation.

The basic criteria were deliberately broad. The aim was to avoid adopting any requirement that was not based on an identified operational need of ADOT. It was also important that the first round of evaluations not be biased by over emphasizing issues of existing infrastructure and cost, since this would defeat the objective of identifying the best options.

Matrix Comparison of Software Packages

To assist in the evaluation process a cross section of commercially available systems were compared in matrix form, Figures 11 and 12. The systems shown in the matrix are representative only. Other popular systems were also considered but not included in the matrix comparison. The other systems were System 9 (Computervision), Synercom (Synercom), GIS/AMS (GeoVision), GDS (McDonell Douglas), GRASS (U.S. Army Corps of Engineers), TransCadd and MapInfo. The five systems shown in the matrix are used to illustrate the range of software available and they are listed in alphabetical order. Inclusion in the matrix does not imply a relative ranking of a particular software package.

SOFTWARE: OPERATIONAL FEATURES MATRIX

GIS SYSTEM AND VENDOR	DATA STRUCTURES AND FEATURES	DBMS INTERFACE	MEASURE TYPE	USER INTERFACE	MAP OUTPUT	Raster with GIS MAP	SQL Capable	TCP/IP	User Custom Feature	Costom Menus
ARC/Info Env. Systems Research Institute,	VECTOR TOPOLOGY, RASTER, NON-TOPOLOGIC VECTOR, QUADTREE AND TIN	INFO, ORACLE, INGRES, SYBASE INFORMIX, DBL, Rdb, SQL, dBASE	STRAIGHT AND CURVED DISTANCE, PROXIMITY, AREA	COMMAND LANGUAGE, MENU, ICONS, MULTIPEL WINDOWS AVAIL.	RASTER AND VECTOR MAPS, B-D PLOTS, GEOREFERENCED	YES	YES	YES	YES	YES
Atlas-GIS Strategic Mapping Inc	NON-TOPOLOGIC VECTOR	dBASE III AND COMPATABLE DBMS FORMATS	STRAIGHT LINE DISTANCE AND AREA	MENU	VECTOR MAPS	NO	NO	NO	NO	NO
GIS-Plus Caliper Corp.	TOPOLOGIC VECTOR	1-2-3; GENERIC WITH ASCII EXPORT CAPABILITY	STRAIGHT AND CORVED DISTANCE, PROXIMITY AND AREA	MENUS	VECTOR MAPS	YES	NO	YES	YES	NO
MGE Intergraph Corp.	VECTOR TOPOLOGY, RASTER, NON-TOPOLOGIC VECTOR, TIN	ORACLE, INFORMIX, INGRESS, DBZ	STRAIGHT AND CORVED DISTANCE, PROXIMITY AND AREA	COMMAND LANGUAGE, MENUS, ICONS MULTIPLE WINDOWS	RASTER AND VECTOR MAPS, B-D PLOTS, GEOREFERENCED	YES	YES	YES	YES	YES
SPANS Tydac Tech. Corp.	VECTOR TOPOLOGY, RASTER, NON-TOPOLOGIC VECTOR, TIN	OS/2 DBMS, SQL/INTERFACE, PC ORACLE, dBASE IV	STRAIGHT AND CORVED DISTANCE, PROXIMITY AND AREA	COMMAND LANGUAGE, MENUS, ICONS MULTIPLE WINDOWS	RASTER AND VECTOR MAPS, B-D PLOTS, GEOREFERENCED	YES	YES	YES	YES	YES

Figure 11 Operational Features

Figure 11, Operational Features Matrix, allows a quick comparison of the sophistication and flexibility of the various software systems. There are eight areas of consideration noted across the top of the matrix. Each of these had a bearing on the utility of a software's suitability for development of PIMa as follows:

* Data Structures and Features: Graphic system will be primarily vector or raster based. Some of the more sophisticated systems as illustrated in the matrix will allow the simultaneous overlay and display of raster and vector graphics. None of the systems, at the time of evaluation could perform vector and raster analytic operations. For implementation of PIMa a vector graphics base was required.

  It was also important that the vector graphics system have full functional topology. That is, the system must be structured so that the relationships between zero, one and two dimensional graphic primitives are constantly maintained.

* DBMS Interface: One measure of the flexibility and overall utility of a system is its ability to access a variety of data base management systems. Some systems are built using a single data base management system while others allow access to two or more data bases via a System Query Language (SQL) link.

* Measurement Type(s): The means of describing the geometric properties of map primitives directly effects the accuracy and precision of measurements. Some systems are capable of providing only straight line measurements while more sophisticated systems are capable of more complex curved distance and area functions. The long-term utility of PIMa will require the ability to do complex curved distance measurements.

* User Interface: There are generally four types of user interface to a computer software; command line, menu, icon graphic, and multiple window graphic. In general the command line is considered the least friendly while the multiple window graphic interface is thought to be the most friendly. As demonstrated by Figure 4, some of the systems have all four interface types available.

* Map Output: The ability of a system to provide a variety of output such as, raster graphics, pen plots, and color graphics will add to the overall utility of a system. As a minimum PIMa will require raster and vector output capabilities.

* Raster with GIS Map: This column indicates the ability of the system to produce output that combines raster and vector information in a single document.

* SQL Capable: This column indicates if the system has SQL capabilities.

* TCP/IP: This column indicates if the system has built in Transmission Control Protocol (TCP), and Internet Protocol (IP) capabilities. These capabilities are necessary for systems that will be connected to a network environment.

* User Custom Features: This column indicates if the system has some built-in features that allow the user to custom tailor the operating features to the specific application. With one exception, all the systems reviewed claim some custom feature capabilities. However, there is considerable variation in the flexibility of these features among softwares. PIMa will not be as sensitive to flexibility in spatial referencing as it will be in the data base management area.

* Custom Menu Features: This indicates if the system will allow the user to modify the user interface, menus and icons, to suit a particular application. Some flexibility will be needed to develop the PIMa applications.

GIS SYSTEM AND VENDOR	COMPUTER PLATFORMS			INPUT SUPPORT		OUTPUT SUPPORT					PRICE[1]
	Computer Hardware	Minimum Memory Required	Minimum Disk Storage Required	Digitizers	Scanners	Pen Plotters	Electrostatic Plotters	Laser Printer	Dot Matrix	Other	Published lowest priced operating module
ARC/Info Env. Systems Research Institute,	Multiple Platforms Including: Intergraph, DEC, Prime, IBM, Data General and IBM PC Compatibles	640 Kb for DOS 8 Mb for Unix, Varies in other Mini and Mainframe Environments	12 Mb DOS 200 Mb Unix Varies in other Environments	CalComp, Altek, Kurta, Hitachi, GTCO, and Others.	YES	Hewlett-Packard, Houston Instruments, Brunning Zeta, CalComp, IoLine	Versatek, CalComp, Hewlett-Packard	YES	YES	Film SQR Map Cart.	$2,400
Atlas-GIS Strategic Mapping Inc	IBM PC-XT AT, PS/2, DOS, and all Compatables	640 Kb	10 Mb	CalComp, Altek, Hitachi.	NO	Hewlett-Packard, CalComp	Versatek, Hewlett-Packard	YES	YES		$2,495
GIS-Plus Caliper Corp.	IBM PC-XT AT, PS/2, DOS, and all Compatables	2 Mb	10 Mb	CalComp, Altek.	NO	Hewlett-Packard	Hewlett-Packard	YES	YES		$2,995
MGE Intergraph Corp.	Intergraph Workstations and IBM PC Comaptables, 80286 processors and higer	4 Mb DOS 8 Mb Unix	30 Mb DOS 50 Mb Unix	Intergraph, Altek, CalComp	YES	Hewlett-Packard, Intergraph	Hewlett Packard, Intergraph, Versatek	YES	YES	Film Ther. Plot	$8,300
SPANS Tydac Tech. Corp.	IBM PC-DOS and IBM PC-OS/2, W/ 80286 of higher processors. IBM RS 6000	2 Mb DOS 4 Mb OS/2 8 Mb Unix	15 Mb DOS 18 Mb OS/2 40 Mb Unix	CalComp, Altek, Kurta, GTCO	YES	Hewlett-Packard, CalComp, Houston Instruments, IBM	Versatek, CalComp, Hewlett-Packard	YES	YES		$6,000

[1] Prices quoted do not reflect equal features and operational capabilities.

HARDWARE REQUIREMENT MATRIX

Figure 12 Hardware Requirement Matrix

Figure 12, Hardware Requirements Matrix, provides a comparison of the hardware requirements of the various software systems. In general, the software selected should provide a reasonable level of flexibility in the hardware requirements and offer some choice in platform and operating system. While this might not be essential immediately, useful applications tend to expand over time and the ability to move between platforms usually results in a more efficient allocation of computing resources. In this matrix there are four broad categories with several sub-categories of comparison as follows:

* <u>Computer Platforms</u>: This is a measure of the systems ability to operate on a number of computer platforms and how the machines need to be configured. Some software systems run on proprietary platforms while others indicate that they will run on numerous platforms under a variety of operating systems.

  In reviewing this category of information it must be remembered that there are often considerable differences in the software characteristics and capabilities of the same product running in a different computer environment. In most cases the personal computer products are not as full featured as their counter parts running under a more sophisticated operating system. The primary advantage is that most systems will allow for relatively easy transfer of data sets between platforms.

* <u>Input Support</u>: Implementation and operation of PIMa will be best served by a system that will allow input from a variety of digitizing and scanning devices. This section notes the variety of digitizers supported and if it allows raster input from a scanning device.

* <u>Output Support</u>: Data and map output from PIMa will seldom require more than a dot matrix printer. However, over the long-term pen plots and other types of color mapping may be desired.

* <u>Price</u>: As noted in the matrix this column shows the lowest published price for the basic operating module. However, it is can only be used to give some general idea of the cost since all of the vendors package the software in modular work units. Thus, a true price comparison is almost impossible.

A cursory review of the matrices might suggest that there are some superior products. However, on closer examination characteristics that appear to be advantages in one category are off set by short comings in another area. A second factor that is not at all apparent, is that not all of the systems are developed to the degree that their promotional literature might indicate. In this regard there is such a wide variety of difference and that the technology is changing so rapidly that a detailed discussion of individual differences would be quickly dated and serve very little purpose.

In the final analysis it was suggested, and ADOT's advisory group agreed, that due to differences in the systems, the level of development and the influence of rapidly changing technology, that there is no meaningful set of objective criteria that would suggest that one system is clearly better than another. For this reason the recommendation of a system for implementation was dependent less on the differences between available technology and more on the needs and characteristics of ADOT's operational units that would use PIMa.

TASK 4: COMPARE, RANK AND RECOMMEND A SYSTEM

Data Base Management Systems:

As in the previous section, a meaningful and objective comparison of software packages, particularly the current geographic information system products, is not possible. A majority of the differences between systems tend to be matters of preference or related to factors of compatibility with hardware, other software and peripherals that a potential user might already have. Overall, almost all of the products reviewed could have been used to meet the current data base management needs of PIMa.

The differences in and among the systems, were mostly at the level of development and the operational sophistication. More specifically, each system has basic differences in the level of application development and approach to system components such as: the user interface, the size and sophistication of the operations library, the sophistication of the SQL feature, data format portability-compatibility, peripheral support and platform flexibility.

Spatial Data Management Systems:

Unlike the Data Base Management Systems there were some significant differences in the spatial data management systems. The most notable differences were in the user interface, the digitizing features, topologic structure and SQL features.

Some of the less developed products still utilize a command line interface or have very limited menu capabilities, while the more advanced systems utilize a very friendly menu and icon interface. There is also quite a bit of variation in the digitizing features of the vector graphics systems. In general those that have built on an existing well developed CADD package, ie. Ingergraph and Autocad, have very sophisticated digitizing capabilities. Some packages of the available packages do not use fully functional topologic structures in the mapping package. This is a deficiency, that for this application, would be severely limiting and would drop a system from consideration.

The SQL links are a measure of flexibility in a system. The SQL feature allows data in supported data base management systems to be attached to the spatial referencing system and used transparently. For example a system might be compatible with Oracle and Ingress, a second system might be compatible with dBase and Paradox, while a third system might be compatible with all four systems. The third system would be capable of accessing more data bases via the SQL feature and would provide a greater degree of flexibility.

Comparison of Systems:

Based on the six criteria outlined in Task 3, and the comparison matrices, no significant differences were found that would recommend one system over another. That is, from an operational point of view, with the exception of the non-topologically structured systems and the raster based systems, any of the others could be used to implement PIMa. This conclusion is based on the assumption that the each of the software systems remains in the market place and that it continues to be updated and developed over time to meet user needs and changes in technology. This does not mean that there are no differences between the software systems. If each system is evaluated only on the basis of its ability to satisfy ADOT's landscape inventory and management needs, immediate and future, any of the leading packages could accomplish the task.

Analysis of Development Needs and Other Options

Since Task 4 requires that a recommendation be made for a development system the research team looked closely at Task 1 and Task 2 analysis for additional criteria that could be used to narrow the field and make a final recommendation. The review of ADOT's computing infrastructure suggested that, with the exception of the mainframe environment, the selection of division-level hardware and software is the option of the operational units. More specifically, there is no department-wide standard for hardware platforms or software systems that would influence a recommendation. This being the case, the focus turned to the current status and specific needs of Roadside Development Services and District 1 Maintenance. PeCosII is the overarching maintenance management system for ADOT. For this reason compatibility with PeCosII became the primary influence guiding hardware and software evaluations for PIMa.

In all of ADOT's field units PeCosII is implemented on PC-DOS platforms using dBaseIII+ for the application driver. In District 1 Maintenance, and Roadside Development Services the PC-DOS machine is was also the dominant operational platform for other applications. Roadside Development Services does use an Intergraph, Inter-Pro drafting station as the primary drafting platform but other internal operations are generally PC-DOS based. Division 1 Maintenance utilizes all PC-DOS equipment, including the automated irrigation control system.

Given this information the following final selection criteria were suggested:

1. The system adopted for development of PIMa should be a proven, fully operational software product in the IBM, PC-DOS compatible environment.

2. Training and documentation in the operation and management of the system should be available from the vendor on a regular basis.

3. For reasons of data collection, the DBMS should be fully compatible with the dBase application of PeCosII.

4. The system should allow custom development of menus and screens that look similar to those used in PeCosII.

5. The system should require a minimum of new investment in capital equipment, software and personnel training/retraining.

6. The system should have a demonstrated ability to export and import data from a variety of different CADD and data base management systems.

In arriving at these criteria, several key influences from the previous sections were considered important. First, considerations of cost and manpower commitment suggested that the PIMa environment should, if possible, take advantage of existing ADOT data management tools. For this reason the software package should be one that is fully operational in the PC-DOS environment. It is also desirable to have a package that uses or is compatible with of one of the dBase products to ensure maximum compatibility between applications.

Secondly, it was important to recognize that the most costly part of implementing PIMa was the acquisition and maintenance of data. For this reason the system selected should allow maximum transferability of the data across platforms, operating systems and software systems so that, to the extent possible, future options are not limited. It is very clear that ADOT has made a substantial capital and personnel commitment to Intergraph systems in its engineering and design functions. Since construction documents are and will continue to be the origin of most new inventory information, compatibility with Intergraph drawing formats had to be a long-term consideration .

The question of PIMa's drawing format compatibility with ADOT's CADD system was, and remains to be an area of great concern. There can be little doubt that the Intergraph system is a superior product for highway engineering applications. However, their spatial information management software products for the PC-DOS environment have not reached the same level of development as their engineering software. At the time of this investigation Intergraph did not have an operational PC-DOS product developed that would support development of the PIMa system within the contract period.

System Recommendation:

Given the more specific evaluation criteria, related to the existing infrastructure and needs of Roadside Development Services and District 1 Maintenance, one system quickly emerged as the system of choice, ARC/INFO 3.4D. This is a fully developed and proven PC-DOS system using dBaseIV as the primary data base manager. In addition to this very important capability was the demonstrated ability of the ARC/INFO system to pass data between other hardware platforms and operating systems. This system allows data output in more standard data exchange formats than any other system. It also has a "live-link" to an image processing software package. Other systems offered similar capabilities or indicate that they would have within a year or so but, no other package offers all of these distinct advantages immediately.

Some final reasons for selecting this particular package over other candidate softwares had to do with ADOT's future development of this and other management applications. For example; sign management, pavement management, bridge management, etc. Experience with the design and development of similar spatially referenced managements systems suggests that over time the initial system will grow. New data sets will be added and new applications will be developed as overlays to the original spatial data base. The ESRI Family of software products offered, at that time, the greatest flexibility in data conversion and transfer capability across platforms and systems. This flexibility will help maintain options that might be lost with other software systems.

PHASE 2. TASK 5 THROUGH TASK 7

Introduction:

This portion of the report describes the activities involved in the PIMa Pilot, (Task 5); reviews the activities and findings of the Pilot Demonstration, (Task 6); and presents a Draft Implementation Plan, (Task 7).

During the first phase of the research, Tasks 1 through 4, it was determined that the Department's commitment to PeCosII so dominates the planning, organization, administration and budgeting of maintenance and operations activities that the PIMa system must provide a high degree of operational compatibility in order to be of economic benefit. This finding also resulted in a revision to the original contract adding two additional tasks, Task 5 - the PIMa Pilot and Task 6 - the Pilot Demonstration. The original tasks were revised and renumbered accordingly.

The major change in the overall scope of work focused on reviewing and recommending a means for automating the acquisition sorting, formatting of field data and providing for a more detailed pilot test program to ensure that all of the necessary data linkages could be implemented in a cost effective manner. The pilot was completed in early October and presented to over 30 Department employees in Phoenix, October 16 to 18.

Task 5: THE PIMa PILOT

Because it was necessary to automate the data collection, sorting and distribution as a part of developing PIMa an intermediate pilot was considered prudent. The conditions that contributed this decision were:

1. The Department's financial and long-term commitment to the PeCosII system so dominates the record keeping procedures compatibility with PeCosII became an overriding consideration. More specifically, Compatibility with PeCosII took precedence over other considerations of hardware and software environments.

2. The research also revealed that the data collected for PeCosII was not of sufficient detail to accomplish the goals of the project. This fact coupled with the mandate

not to increase paper work, necessitated automating the data collection, formatting and input process

During the pilot numerous decisions had to be made regarding the formatting of the data; spatial and tabular appropriate geographic referencing; source and form of plan information for data input; expansion of data codes and linkages to PecosII codes; development of new codes for inventory items, review of available data collection technology and numerous other details. The following narrative will deal with the broad based issues involved in generating of the pilot. Detailed examples are provided as appendices to this document.

The Pilot Data Base:

The goal of the pilot was to ensure that the data base contained appropriate information. It was also needed to prove that the selected format met the needs of the systems and that it could be entered and stored efficiently.

The pilot data base was developed for a continuous section of Interstate 10 between Buckeye and 7th Avenue, approximately 4.5 miles. This section was selected because it has a variety of interchanges and reasonably complex landscape and irrigation development. The variety and complexity provided the necessary test of the graphic base, the symbology, data entry, data dictionary, and analytical functions of the system.

Base data: The landscape features are divided into three different classifications; Trees, Shrubs and Surface covers. Each classification is represented on the plan by a closed series of lines (polygons), that generally represent the area covered by the canopy or material being depicted. Irrigation equipment and pipe are shown by lines and appropriate symbols. Each of the features is referenced by a unique identification code that allows associated data base information to be linked to the graphic element of the map. Coding and organization of the tabular data is described in more detail in the sections that follow.

Data Organization:

The organization of the tabular data base is essentially transparent to most system users. On the other hand, it is important to understand how the information is grouped within the system and how the organization relates to performing various tasks.

As outlined in the discussion of the PIMa concept the system is made up of both graphic and tabular data sets, see Figure 8. There are two graphic data sets; topologically structured vector graphics used to support the Data Analysis and Management module and a raster graphics set used to support the hand-held data collection system. The topological structure of the vector graphics allows information in the tabular data base to be attached to the graphics so that the relationships between various elements are maintained regardless of how the data is manipulated. The raster data set is used to achieve economies in data storage in the limited space of the field data collection device and also to take full advantage of sketch capabilities in the "GridPad" system for direct feedback communication from the field.

The tabular information is divided into three different categories; inventories, libraries and transactions. Inventory files are the primary data reference files that track all of the landscape and irrigation features on the roadside. The Library files are used to maintain more detailed information about landscape and irrigation elements. The Transaction files maintain a historic record of all actions performed on a plant, plant group, irrigation line or irrigation appliance. Every time a maintenance action is taken a permanent record is inserted in the Transaction file for that particular feature.

Geographic Reference:

All geographic data (maps), in the PIMa System utilize the ADOT, ALISS system. This reference base was used because it is ADOT's most complete and accurate geographic reference of the state maintained highway system. All mile posts in the ALISS system are referenced to the state plane coordinates with an estimated accuracy of plus or minus ten feet horizontal. Transformation of the ALISS data set into PIMa was via a Drawing Exchange Format (.DXF) conversion. Subsequent manual checks validate the registration of the maps with other ADOT map products. The ALISS mile post references were further divided into tenth mile increments. It is important to note that the distance between mile posts is not necessarily one mile. Tenth mile references were generated by dividing the distance between mile posts into ten equal parts. Given current practice this was the most utilitarian means of field reference.

Future Geographic Reference:

The lack of a uniform tie or a means to adjust the reference system is a matter of some continuing concern since conversion of the PIMa data set could be expensive if the mile post system is adjusted during the metrication process. It will be possible to revise the basic mile post system because there is a state plane coordinate reference to each mile post and the tenth mile points can be derived by simply dividing the distance by ten. However, the data polygons used in the system cannot be converted by simple arithmetic means. All of these adjustments will have to be done manually in order to sort the tabular data and re-segment the planner references to match the new system.

The expense for conversion of data will depend on the size and complexity of the mapped data base at the time the adjustments are made. By comparison to many state-wide data sets the PIMa data base will likely be quite small since it will cover only the landscaped freeway system in District 1. If PIMa is expanded beyond District 1 prior to making adjustments in the highway geo-referencing system, changes to the data base will be costly. Further discussion of revisions to the mile post reference system is beyond the scope of this project. PIMa, notwithstanding, if ADOT is going to continue the trend toward more GIS-based management applications there will be an immediate need to develop some basic standards for geo-referencing of information that corrects the deficiencies of the mile post reference system.

Data Codes:

The data codes adopted for PIMa utilize the PeCosII coding conventions as a beginning point. In other words, all PIMa codes are extensions of existing PeCosII codes. For example, the PeCosII code for a "Native Tree" is 23L. Since PIMa needs to know the actual name of the tree, the PIMa code would be 23LPRGL (**Pro**sopus **gl**andulosa) for common Mesquite. This system allows PIMa to interrogate the incoming data and capture the information needed to support PeCosII and put it into an appropriate ".dbf" format. The PeCosII codes incorporated into the system include:

1. All 300 and 600 series activity codes and appropriate 100 and 200 codes
2. All employee designation codes
3. All equipment codes with descriptors
4. All applicable material codes

The employee and equipment codes required no supplemental expansion for PIMa. These codes are simply picked up by PIMa's data conversion module and sent to the PeCosII system. The activity and material codes were expanded to provide more detail as noted earlier.

Activity Planning and Collection of Field Data:

A feature that had to be automated that was not anticipated earlier was the work planning activity. This was needed to facilitate the transfer of information into the data collection devices. In the current paper system the org supervisor fills out the "Crew Day Cards" with work assignments. Using PIMa, this task is accomplished by filling out a similar form on the computer screen. This step eliminates all paper from the work assignment, data collection and record keeping process. This also resulted in a net increase in the time required for planning activities because the supervisor now has to type the forms into the computer and then down load the forms into the GridPad. The time saving, noted in the benefit cost analysis would occur as a result of allowing automation of the PeCosII data entry process.

After forms are loaded on to the GridPad field personnel validate the planned activities, org, locations, personnel and verify or enter the equipment and materials used. The program in the data collection device provides menus and lists similar to those used in planning. To make changes an item is simply crossed out and an appropriate response is picked from a scrolling list or entered from a pop-up key pad. When the forms are complete the crew chief down-loads the information to an appropriate workstation where it is formatted and transmitted to the appropriate system.

In the pilot special software frameworks were created for the planning process and the data collection device to demonstrate the utility and practicality of the automated data gathering process. The final features of PIMa were not fully developed at this stage pending ADOT's acceptance of the principles and the operational features of the system.

All planning forms used actual activity, org, employee and equipment codes along with the new codes for materials and irrigation equipment. The "Transaction Files" were all hypothetical data since there was no way to capture historic information in the pilot area.

Data Analysis and Management:

To demonstrate the utility of the system, several scenarios were developed that used the data base and mapping capabilities of PIMa. Example reports and maps were generated to illustrate the output. The report formats were somewhat different than those finally included in the system. Two levels of application were developed and demonstrated; data base dependent functions and graphics dependent functions.

Data base dependent functions are those that require intensive use of the data base management system (DBMS). These are typically operations that require sorting the tabular information and performing arithmetic or logical operations on this data to generate a new order of information.

Graphic dependent functions are those that require intensive use of the spatially referenced information. An example of a graphics dependent function would be a query that involved knowing how close or far certain plants or features were from the edge of the driving lane.

Task 6: THE PILOT DEMONSTRATION:

The PIMa System, as demonstrated, consisted of four operational modules; Planning, Field Information, Data Management and Data Analysis. The planning module is written in dBaseIV and takes the place of the manually executed "Crew Day Cards" used for work assignments. The Field Data Collection device recommended was a "pen sensitive" hand-held computer (GridPad). The Spatial Information Management - Data Management and Analysis package is PC-based using dBaseIV and ARC/INFO 3.4/D

Work Planning Module:

The "Work Planning" feature of the PIMa system is another operational feature that had to be added to the overall concept of the original system in order to make it more practical to use. Planning using the PIMa system is accomplished by filling out forms on a computer screen organized to look the same as the paper crew day cards. The entries are the same as those required for PeCosII. The primary feature that distinguishes this application from other PeCosII operations is the use of pull down menus to accomplish the data entry rather than requiring the user to type in information. This feature is faster for the user and minimizes the possibility of entering inappropriate information.

Field Information Module:

Two different types of devices; a small screen keyboard device and the large "pen-sensitive" screen device, were considered for this operation. The "pen-sensitive" screen was recommended and finally utilized because it allows the crew day cards to be displayed in a form similar to the current paper forms. In addition it offers the flexibility to include map graphics. This feature, while requiring a major programming effort, completely eliminated the need for utilizing paper inventories or maps for field reference. The graphic sketch capabilities also allow field personnel to make notes and comments directly on the map graphics as a means of communicating problems back to the schedular's and designers.

The field information software module "down-loads" information prepared in the planning module. These are displayed as typical crew day forms on the screen of the hand-held device. The forms are divided into four sections that follow the PeCosII requirements for reporting activities, equipment, labor and materials. In addition to the standard information required by PeCosII more detailed information is collected such as specific plant types and plant beds or the specific irrigation appliance and appliance location being maintained. All of the entries are accomplished on a "pen-sensitive" screen using maps, "pop-up" menus and scrolling lists of options where possible.

Data Analysis and Management:

The Data Analysis and Management module is a dBaseIV, PC-ARC/3.4D application. The primary data management operations are accomplished on the dBaseIV side of the system while ARC/INFO handles the graphics and spatial relationships. When information is returned from the field the hand-held device is connected to the PIMa terminal and the information is "up-loaded." The information comes into the system as a simple ASCII text array which is then processed into appropriate formats for use by PeCosII or PIMa.

The data sent to the PIMa system is specific to the route and the mile post location eg, Interstate 10, Mile Post 147.6. In addition each plant mass, trees or shrubs, irrigation appliances and lines are referenced within that tenth mile. This is accomplished by touching the features on the screen that were repaired or maintained. No manual entry of location or description is necessary since the maps are linked to the data base. The information collected from the field in this unique way, is transferred to the PIMa system and held as a transaction record for each inventory element within the tenth mile. For example, a typical transaction might involve the removal of several shrubs that died due to irrigation failure. The transaction file would indicate that shrubs had been removed, the number removed, the cause or need for removal eg. irrigation failure, and the date of the transaction. If at the same time shrubs were replaced and the irrigation system repaired these would be shown as separate transactions consistent with the form of entry in PeCosII.

The advantage of keeping records in this way becomes very clear when questions about specific plant or irrigation performance arise. Because the information is referenced spatially the data can be processed in a way that will highlight high rates of failure and it will also provide clues as to why the failures occur. For example, one factor that is frequently associated with plant failure in a desert environment is reflected heat from structures which is often aggravated by slope orientation. Using PIMa patterns of plant loss in certain conditions will be quickly identified. Recurring patterns generally indicate a problem. These analytical functions are not available in data management systems that do not have spatial data referencing.

The Data Analysis and Management Module, like the others, is menu driven from either the data base management (dBaseIV) side or the graphics, (ARC/3.4D) side. Most simple queries such as the identification of plant materials, irrigation lines or appliances are handled simply within the graphics (ARC/3.4D) side of the application. More complex queries such as the one described above would require a two step process. The first step would be to generate one data set in ARC, finding all the west facing slopes within 300' of a bridge or wall, and one in dBase to find all the plants that had been removed from west facing slopes. These files would be used as the basis for a regular dBase query. Once the query file is produced and saved it would be sent back to the graphic side and plotted in map form.

Several example queries ranging from simple to complex were demonstrated as part of the pilot presentation. During the demonstrations, ADOT staff raised no questions that suggested that the system, as it was presented, would not be able to handle their needs.

Recognizing that this is a relatively new technology to most of the ADOT staff and that they only had limited time to asses how the system might impact their duties, members of staff were encouraged to offer comments and suggestions anytime during the remaining project period. In addition to this formal solicitation other suggestions were made as part of the implementation plan to help ensure the maximum utility of the system.

Results of the Pilot Presentation:

The pilot system was demonstrated in three sessions held on 17th and 18th October. A final review of the pilot was held with the Technical Advisory Group on the afternoon of 18th of October. This section provides an overview of the reactions of ADOT personnel to the pilot. It describes weaknesses identified in the system and discusses requested improvements and additions to the system.

Impressions from ADOT Personnel: Based on the reaction of ADOT personnel it appeared that the development of PIMa was meeting the expectations of ADOT staff. Roadside Development Services personnel seemed to be satisfied with the direction of the system requiring only minor changes, these changes will be discussed later. Maintenance personnel from District 1 2 and Tucson, were complementary and seemed to feel that the system would serve their needs. The org level supervisors that attended the presentations and demonstrations had very few questions. This was a matter of some concern that was followed up with direct contact in the field. In one-on-one conditions we found that their major concern was with the possibility of increasing the paper work load Once they had some hands on experience with the GridPad they seemed to be satisfied.

At the demonstrations and in the field the menu driven interface was well received. Everyone familiar with the PeCosII system quickly recognized the planning and crew day forms. They seemed less sure of the pen-sensitive pad device than originally expected but after 15 minutes or so their hesitation seemed to abate. They also appeared to understand how to use the pop-up menus and lists associated with each field in a form without much coaching. Everyone seemed excited about the maps and graphic capabilities of the GridPad.

Representatives from other areas of ADOT including; Information Services Group, CADD services, Contract Maintenance Services, Transportation Planning and others, expressed interest in the system and suggested numerous application potentials that could be used in their areas of work.

Problems or Deficiencies Identified: Several deficiencies were noted as a result of the pilot demonstration. Each of these is noted separately along with the actions taken to correct the deficiency.

1. Recording Model Numbers of Irrigation Equipment: There was a strong desire on the part of ADOT to have the capability to track the long-term performance of irrigation equipment by brand and model. This information had not been included in the pilot nor in the initial implementation because there is simply no economical way of developing an accurate inventory from the available information. To accommodate the need to track this information an additional field was added to the irrigation appliance inventory records for recording model numbers of equipment. This extra field will allow ADOT to develop the data over time.

2. Verification of Activity Records: This concerns how field personnel can be sure of their location within a given mile segment. In this case there is no easy answer. The problem was explored with field personnel and for the most part they indicated that, since they only cover very limited sections of highway, generally less than 15 miles, they usually know where they are. This later proved not to be the case.

   The graphics system has the ability to list a particular location and the contents of a particular plant bed. However, it is still not always clear where the division between tenth mile points really is on the ground. This can ultimately have been corrected using painted reference marks in the field.

3. System Security: There were several questions regarding the security of the data base and its maintenance. Clearly there needs to be some hierarchy of access to the data to ensure its safety and integrity. This was brought to the attention of the Technical Advisory Committee and they asked for a recommendation as part of the Implementation Plan, Task 7.

4. Design and Maintenance Advisory Notes: Roadside Development expressed, on a

number of occasions, the desire to communicate special maintenance or design related considerations to maintenance. This desire on the part of designers to continue their involvement in the project is a link in what should become a two-way communication process.

The means to implement this particular request is not as straight forward as others request. It would have been possible to add an additional memo field to the plant material library describing normal maintenance procedures and trimmings. On the other hand, it would be difficult to attach special notes to the vector map base for all special situations.

What was suggested at the time was to use the graphic capabilities of raster data set as the primary means of communicating special conditions. Field personnel could make notes about design conflicts or special problems and up-load the graphic files to the Roadside Development Services workstation. Likewise, Roadside Development Services personnel could make notes about special conditions or field observations and transmit them to the Maintenance workstation as a sort of graphic "E-mail." Depending on the importance of the information permanent notes could be added to the permanent raster graphics data base. Final implementation of these features will be an administrative decision beyond the scope of this work.

5. <u>Data Updates:</u> There were several questions about how data would be updated and new information put into the system. The recommendation was that the Department should, in the future, require that all plan work and "As-Built" drawings be submitted in digital format. The standard suggested was the Drawing Exchange Format, (.DXF) which can be produced by most leading CADD softwares.

This was questioned by the CADD services representative who indicated that they were recommending a policy that all information submitted to them had to be in the Intergraph, ".DGN" format. This could be a problem if it is adopted as a standard because it limits work to consultants with the Intergraph system. Since the .DXF format allows the broadest option and can be read by all Intergraph systems, it is suggested that this policy be given further consideration.

6. Contractor Reporting: A major concern in maintaining the inventory files in PIMa is how appropriate information will be obtained from maintenance contractors. There are a number of options open for collecting and entering the data into PIMa but how this is handled in the contract is not at all clear.

   Concern was also expressed about the value of the PIMa system if ADOT should contract most of its landscape maintenance work. The amount of data reported back to the system may be reduced along with the frequency of the reporting cycles. However, the PIMa system was initiated to facilitate two-way communication between design and maintenance personnel and to track the performance of landscape and materials. Regardless of the method of performing maintenance operations the questions of material performance, cost and more importantly, issues of quality control remain. In short management concerns related to maintaining a safe, attractive and cost effective landscape remain regardless of how maintenance services are provided.

Conclusion: The positive reception of the pilot was gratifying but there was some concern that sufficient time had not been allotted to fully review the features of the system. Every effort was made to make the system user-friendly. On the other hand, the PIMa system is a very complex software application that will take some time to master.

Given the short duration of the demonstration coupled with the complexity and number of different parts involved in the PIMa system, some deficiencies may have been overlooked. This concern was shared by ADOT's contract supervisor and others on the Technical Advisory Committee.

Task 7: APPLICATION REVISIONS and IMPLEMENTATION PLAN

Introduction

The implementation plan presents a strategy for accomplishing the final development of PIMa and outlines the work necessary to bring the system on line. The implementation plan is intended to address a variety of concerns including: Manpower requirement; Hardware and Software; Administration and Maintenance; Implementation Strategy; and Detailed Budget. Each of these considerations is addressed in the following sections.

Manpower Requirements:

The PIMa System as designed will serve the needs of Roadside Development Services and landscape maintenance personnel in participating districts. Under this contract the system was to be implemented in District 1 only, even though, the overall design of the system can be applied to all districts in the state.

It was recommended that during the first year of implementation, District 1 and Roadside Development Services each allocate one employee approximately 50% time to the project. The individual designated by Roadside Development Services was to have been a computer literate, professional level employee authorized to make administrative decisions related to the operation and maintenance of PIMa. The District 1 employee was to have been a supervisory level, computer literate employee, with a strong working knowledge of PeCosII and needed good written and spoken communication skills. This individual will be responsible for communicating the needs of maintenance personnel to Roadside Development Services, reviewing and approving operational features of PIMa and to coordinate day-to-day training of field personnel. After the initial implementation of PIMa it was estimated that annual maintenance and supervision would require the commitment of one employee 25% time for each unit and approximately 10% of one employee year from ISG for data base and program maintenance oversight and advisory support.

Equipment and Software:

The PIMa system is designed for the IBM, PC-DOS compatible environment. In this initial configuration it requires the following equipment and software: Two identically configured PC workstations. One workstation to be based in District 1's maintenance offices, the second, based in the Roadside Development Services offices. Communication between machines would be established by modem.

The software required is; PC-ARC/3.4D. The dBaseIV software is not included as part of the ARC/3.4D license. In addition to the ARC/3.4D licenses the system will require a "paint" program, an image capture routine, Lap-Link" software for transferring information between the hand held data collection devices and the maintenance workstation, a simple text editor and the modem communications package for data transmission. Recommended specifications for the equipment and software are given in the detailed budget estimate.

Administration and Maintenance:

During the 18th of October meeting, the Technical Advisory Committee asked for specific recommendations regarding the administration and maintenance of PIMa. This section is provided in answer to that request. It is based on very limited knowledge of ADOT's long-range automation plans and policies and should be read in that context.

Recommendations are based on the following assumptions.

1. The computing environment of ADOT will become increasingly decentralized with respect to hardware, software and applications. Central computing facilities will be increasingly devoted to mass data handling, mass processing, data conversion and data storage. The Information Services Group will become less involved in specific operational tasks and more concerned with training, evaluation, development, support and policy.

2. Data will become increasingly graphic, spatially referenced, GIS based, and

standardized across the Department. For example, ALISS or some preferably metric based geo-referencing system will become the standard spatial control. All information including construction documents, right-of-way records, planning maps, maintenance records and inventories, photogrametric records, traffic management records, etc. would be referenced to this single base.

3. Use of paper records will continue to decline in favor of digital and electronic communication conventions.

Given these assumptions it is suggested that the primary responsibility for operation and data base maintenance of PIMa reside with Roadside Development Services. This recommendation is consistent with the assumption that computing will become more decentralized based on specific missions and that Roadside Development Services is the primary generator of base data and ultimate consumer of PIMa transaction records. Roadside Development Services has the equipment and manpower necessary for maintenance and archiving of map, inventory and transaction files. Maintenance and operations personnel are primary users and suppliers of raw data. Policy effecting the overall administration of the system should be by consensus between Roadside Development Services, Central Maintenance and participating districts, advised by ISG.

Technical support and direction will be needed from ISG based on the assumption that they will have policy and oversight responsibilities in matters that effect the department-wide computing environment. Issues of concern for ISG would generally be matters of major changes in, or acquisition of software, compliance with ADOT standards, security and transmission of data across the systems or "Local Area Networks" (LANs). Primary systems such as PeCosII and VEGI would for the immediate future remain the province of ISG. Over the long-term it is anticipated that VEGI and even PeCosII will merge into a GIS-based environment.

It is believed that PIMa is the forerunner of a new generation of spatially referenced, (GIS-based) management systems for ADOT. As these systems grow the Department will necessarily move to standardize the data sets to minimize data acquisition costs and ensure maximum compatibility between applications. As this occurs ISG will likely be charged with administrative oversight of the data base while individual units will be charged with actual maintenance of various data sets. For example, right-of-way records will be the responsibility of that section. Right-of-way personnel would have the responsibility for maintaining the Department's right-of-way data base and transmitting this information to ISG for distribution to other ADOT units needing right-of-way data. PIMa anticipates this to allow this eventuality and, within the limits of current technology, provides maximum flexibility and transferability of data.

Implementation Strategy:

PIMa is the first fully operational GIS-based management tool developed by ADOT. Since this was essentially all new technology for the personnel that will use PIMa, an integrated implementation strategy is recommended. Integration in this context meant intensive user participation in the final development and implementation of the system.

Early envolvement of appropriate ADOT personnel in the implementation process was intended to accomplish two important objectives:

* Allow the individuals ultimately responsible for operation and maintenance of the system to become fully literate in its structure and, through their participation in the implementation process they can more readily influence the operational features to be sure they meet the needs of the Department.

* Allow field personnel more contact with the system as it evolves to ensure that the system meets their needs. This early involvement will also spread and ultimately reduce the training required to bring the system into full operation.

Specific steps recommended were as follows:

1. Manpower: One individual should be appointed from Roadside Development Services and District 1 Maintenance to participate in, and coordinate the implementation activities related to their unit. Each person should be the one within the administrative unit that will be responsible for training new users and for overseeing the maintenance of the system after it is turned over to ADOT.

2. <u>PIMa familiarization:</u> The unit coordinators would receive about a week in intensive use and familiarization with the TTI staff in PIMa and the structure of the system.

3. <u>Equipment acquisition:</u> During the initial training period ADOT would acquire the hardware and software for implementation of PIMa. A detailed list of equipment was provided with the budget detail.

4. <u>Incremental review:</u> As data units and operational units of the system are brought on line these would be forwarded to the appropriate individual for review and testing in the field. This was to set up an important feedback loop not possible without the approach suggested. More importantly, ADOT would be building an experience base that to support the system beyond the expiration date of this contract.

5. <u>Training materials:</u> As the data base and the application modules near completion TTI and ADOT will collaborate on the contents and order of training including the appropriate kinds of documentation. This will ensure more orderly implementation and minimize time losses related to draft submissions, reviews and revisions.

6. <u>Field training:</u> In the final stages of implementation TTI would collaborate with the ADOT representatives to provide appropriate training sessions and documentation materials.

The approach suggested was to ensure that ADOT received the highest level of service and maximum utility from the system being developed. More importantly, since this was the Department's first venture into this technology, the methodology provides a vehicle to evaluate how this same technology may serve other needs of the Department.

Specific tasks that were to be completed during implementation included:

1. Complete the conversion of plan information (approximately 60 miles), to machine readable form.

2. Complete the entry and attachment of inventory data including links to PeCosII.

3. Perform inventory verification and validation tasks.

4. Finalize and test the standard reports and data queries.

5. Finalize the data input from maintenance contractors.

6. Establish the data entry format for new project work and finalize all data base design.

7. Finalize and test the programming for the data collection devices.

8. Finalize a communications convention between Roadside and Maintenance.

9. Acquire necessary hardware and software for PIMa system.

10. Prepare documentation and training materials.

11. Conduct training sessions.

Benefits of Implementation:

The benefits suggested in the following paragraphs are anticipated to accrue, as a result of administrative efficiencies which will provide small, but long-term , cumulative, cost reductions in landscape maintenance. Administrative benefits are attributed to more effective planning, better cost and quality control. Cost savings would be a function of more effective planting and irrigation design, better material selection and reduced maintenance costs.

On the maintenance side supervisory personnel will be able to plan their work more effectively because they will have ready access to accurate field information. The increased detail available in the transaction files of PIMa will also assist in the development and tracking of actual costs and performance ratings of various equipment and materials.

A particularly important benefit of implementing the PIMa system is the issue of quality control. In an effort to increase its resource efficiency the Department is utilizing a higher percentage of private sector contractors to accomplish highway and landscaper maintenance. While it can usually be demonsrated that the reduction in overhead expense results in a significant savings to the state, the actual responsibility for providing a safe and efficient highway stystem still lies with the Department and not the private contractors. For this reason the Department must have a uniform system for tracking and assuring quality control.

The PIMa system when implemented will provide solid platform for tracking inidvidual contractor performance and ensuring the quality of maintenance is maintained at a level specified by the Department. The information base and analytical capabilities of the system will allow continuous, objective monitoring of contractor performance and ensuring optimum value per dollar. Without a strong monitoring system it will be very difficult to establish any form of defensible quality standard for future contracts.

Budget Detail:

Manpower Commitment First Year:[4]

0.5 Employee year, Roadside Development Services
0.5 Employee year, District 1 Maintenance (Central Maintenance)
0.1 Employee year, Information Services Group

Estimated Cost $63,360.00

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[4] Manpower costs were based on an average annual salary of $45,000 plus fringe benefits equal to 28% of the annual salary.

Equipment Requirements:

Computers: 2 / IBM-PC/DOS Compatible 80486 processor, 33Hz, with 16 MB RAM expandable to 64 Mb with 2 Mb SIMMS chips and minimum 128K RAM cash, 1-1.2Mb 5.25" FDD, 1-1.44Mb 3.5" FDD, 1-315Mb HDD, with EISA disk controller, VGA graphics card and high resolution (<.21) color graphics monitor. Buss shall be full 32 Bit with a minimum of 6 expansion slots, 1-parallel and 3 serial ports with db 24 connectors, Ethernet or Token Ring card. DOS 5.0 shall be provided and the machine shall be loaded and configured at delivery. $3.900 ea.

$7,800.00

Peripheral Equipment: 1 A-E Size pen plotter ($6,500), 1 36" x 48" Digitizer w/16 button cursor ($4,800), 1 External 8mm tape backup system or similar optical disk component ($2,800).

$14,100.00

Field Data Collection Units: 5 GRID Pad 8088 based devices with 4 RAM cards, 640K RAM. $2,400/unit — $12,000.00

Software Requirements:

2-ARC/3.4D, price includes copies of dBaseIV.	$16,000.00
2-Lap-Link modules	$300.00
2-Image Capture modules	$50.00

E-Mail Package	$600.00
Paint Program	$125.00
Network Communication Software (PC-NFS)	$900.00
	$115,235.00

Total Initial Commitment

Annual Maintenance Expense:

Software Maintenance, Annual Estimate $800/unit	$1,600.00
Equipment Maintenance, Annual Estimate $900/unit	$1,800.00
Field Device Maintenance, Annual Estimate $300/unit	$1,500.00
Manpower Costs, Annual Estimate w/o escalation	$34,000.00
Estimated Annual Maintenance:	**$39,900.00**

It should be noted that the equipment finally acquired for the trial implementation added 5

GridPad units and deleted the pen plotter shown originally. Two graphics laser printers were added to generate report and graphic output.

TASK 7a: BENEFIT COST ANALYSIS

BENEFITS

This section outlines the benefits in the form of savings that might be anticipated from the implementation of PIMa. Suggesting direct benefits in the form of cost savings requires a great deal of subjective speculaton on the part of the authors. However, based on many years of experience with landscape construction and maintenance operations, in a variety of climates allows some reasonable basis of judgement. This, coupled with significant input and advice from ADOT staff, supervisors, technitionns and field personnel, provide the best estimates possible considering the scope and limits of the project. We are not suggesting that there was a consensus reached between all parties to this project, since there was considerable difference in opinion between staff on certain items. For this reason, the authors simply had to exercise their best judgement which in most cases ment taking the middle road between differing points of view.

The base line cost are taken from the information developed in the previous on implementation. These costs reflect the market values of the hardware, softwar, preipherals and incidental costs at the time of writing. The manpower costs were set high to reflect the uncertainty in these costs associated with implementing a totally new system. The maintenance costs were taken directly from ADOT records for District 1, Org 4172 , for Fiscal Year 1991. Every effort has been made to be realistic in all values used in the analysis.

Savings Associated with Implementation of PIMa: Since the amounts that might reasonably be expected to accrue from the implementation of PIMa vary from no possible saving to substantial amounts each maintenance activity is treated separately in the paragraphs that follow. In each case the logic for any savings attributed to implementation of PIMa are described. As indicated earlier, the rational is based on input from ADOT personnel and our best professional judgement. Any more exaustive means of determining cost reductions was simply not within the scope of the project.

369 Other Landscape Maintenance: Maintenance activities such as the removal and replacement of shrubs and trees are currently lumped into this very general activity. Because it is difficult to be precise about the distribution of costs conservative figures were used. No effort was made to account for the cost of replacement plants or other materials inventory. Only labor costs are considered.

The savings in this area would result from maintenance personnel having strong backup for removal or alternative replacement of materials that create undue maintenance hardships. The savings would be expected to increase slightly over time due to better design as well as more informed replacement of plant materials. Clearly if plants that perform poorly are eliminated from the design palette a savings in basic maintenance as well as removal and replacement can be expected. However, since it will take some time to identify the patterns of poor performance a figure of 5% is estimated for the first year and 10% in all subsequent years.

374 Trim Trees: At this point tree trimming tends to be uniform over the entire right-of-way. This is not desirable from either a design point of view or for maintenance efficiency. Many trees currently in use should not be trimmed except for reasons of traffic safety, irrigation visibility or to remove foliage and structure damaged by storms or vehicles. Over trimming results in inefficiency in two ways: First, the labor spent on unnecessary trimming is lost. Second, removal or thinning of the upper canopy allows light to penetrate to the ground which leads to weed intrusion in the irrigated area at the base of the tree.

Not all ADOT personnel agree with this particular item. The argument for uniform trimming has to do with the ease of irrigation inspection which is a consideration. However, this need could be met with selective trimming for visibility which rather than broad brush method that is currently employed. The estimate here attempted to reflect a balance in the two schools of thought.

The ability to pass on basic information about trimming needs and the availability of more detailed maps of the vegetation should allow better planning and less trimming overall. The actual savings are estimated to be 10% the first year and increase gradually to a plateau of around 15% in the 5th year. Depending on department policy and what the public may be willing to accept this figure could be reduced by as much as 30%

379 Irrigation Maintenance: Irrigation maintenance will likely experience an increasing rate of savings beginning at about 5% in the first year of implementation escalating gradually to 15% in the fourth and fifth year. After this plateau we would expect the saving to climb to around 20% after about ten years. Again, the table only reflects the first five years.

Implementation of facility management systems similar to PIMa for buildings reflect similar rates of saving between 30% to 40% on the average. Since these systems are less complex than buildings a more conservative figure was suggested.

The savings accrue from the ability to: plan activities more efficiently, identify the products and procedures that are most efficient, provide ready access to plan information and the ability to develop preventative maintenance techniques that reduce overall maintenance cost. The overall savings under this activity would also account for fewer plant losses due to irrigation failures over the long term.

382 Trim Shrubs: The savings that would accrue under this activity are the same as for 374 Tree Trimming. Possibly more of the total saving in this category would be derived from better design and consultant oversight than would be the case for trees. For example, Acacia redolens quickly becomes a pest if planted in the wrong place, too close to the driving lanes or if it is planted on too close a spacing.

363 Manual Weed Control: Manual weed control is the third most costly item after 379, Irrigation Maintenance and 369, Other Landscape Maintenance. A portion of this weed problem can be attributed to the over-trimming of trees and shrubs as mentioned above. Other reasons for

manual weed control, ie. weeds around sign bases, pools, near guard rails and walls and in expansion joints will not likely be reduced measurably by implementation of PIMa.

The estimated savings in this area will not likely show up until the third year of implementation since it will lag behind the reduced trimming of trees and shrubs. As indicated in Table 1 we expect a modest 5% reduction in the third year with a plateau of 10% in the fifth year.

377 Chemical Weed Control: This item would benefit for the same reasons as manual weed control. However, the overall savings would be somewhat less than expected from manual weed control methods. Here we believe we would see some reduction in cost by the second year of implementation quickly reaching a plateau of only 5% of current cost.

380 Irrigation Inspection: The ability to better manage irrigation maintenance will also lead to a modest reduction in maintenance expense. However, the decreased cost as a percent would be considerably less than that for 379, Irrigation Maintenance. Here it is believed that there would be a 5% reduction in cost for the first three years increasing to approximately 8% in the last two years. Very little increase in savings would be expected beyond this since inspection activities are an integral part of the preventive maintenance program.

Other Maintenance activities performed would receive no significant benefit from implementation of PIMa. These include:

371 Mow Weed Areas
383 Repair Berms and Basins
385 Fertilize Trees and Shrubs
373 Edge and Trim Lawns
378 Manual Irrigation

TABLE 7

Estimated Annual Savings for Typical Landscape Maintenance Org (4172) by Year and Activity for Five Years[5]

ACTIVITY DESCRIPTION CODE	FY 91 Cost	Est % Saving Year 1	Total Year 1	Est % Saving Year 2	Total Year 2	Est % Saving Year 3	Total Year 3	Est % Saving Year 4	Total Year 4	Est % Saving Year 5	Total Year 5	**5 Year Total**
369 Other Landscape Maintenance	$52,594	5%	$2,664	10%	$5,400	10%	$5,472	10%	$5,544	10%	$5,618	**$24,698**
374 Trim Trees	$12,477	10%	$1,247	12%	$1,537	14%	$1,187	15%	$1,972	15%	$1,999	**$7,942**
379 Irrigation Maintenance	$73,176	5%	$3,707	8%	$6,010	10%	$7,613	12%	$9,257	15%	$11,725	**$38,312**
382 Trim Shrubs	$24,226	10%	$2,453	12%	$2,983	14%	$3,527	15%	$3,829	15%	$3,880	**$16,672**
363 Manual Weed Control	$44,708	0%		0%		5%	$2,325	5%	$2,356	10%	$4,776	**$9,457**
372 Mow Weed Areas	$1,233	0%		0%		0%		0%		0%		**$0**
377 Chemical Weed Control	$29,207	0%		2%	$599	5%	$1,519	5%	$1,539	5%	$1,560	**$5,217**
380 Irrigation System Inspection	$19,996	5%	$1,013	5%	$1,026	5%	$1,040	8%	$1,686	8%	$1,708	**$6,473**
383 Repair Berms and Basins	$13,015	0%		0%		0%		0%		0%		**$0**
385 Fertilize Trees and Shrubs	$0	0%		0%		0%		0%		0%		**$0**
373 Edge and Trim Lawns	$0	0%		0%		0%		0%		0%		**$0**
378 Manual Irrigation	$5,612	0%		0%		0%		0%		0%		**$0**
Totals	**$276,244**		**$11,084**		**$17,555**		**$22,683**		**$26,183**		**$31,266**	**$108,771**

5 All activity costs are escalated at a rate of 1.33% per year over the actual cost for Fiscal Year 1991.

Labor Costs Associated with the Use of PIMa: In addition to the direct savings accrued from implementation of PIMa there will be some additional savings in labor costs associated with the use of PeCosII. The cost analysis shown in Tables 2 and 3 reflect the estimated labor costs currently associated with the use of PeCosII in a typical Landscape Maintenance Org. Table 2 is a tabulation of costs for: transmitting information to District and to the PeCosII mainframe system; preparation of "Crew Day Cards" (planning); recording field data on "Crew Day Cards"; entering data into PeCosII from the "Crew Day Cards"; and verification of the "Crew Day Card" information. Table 3 is cost for the same process using PIMa and the automated data collection system.

Based on the comparison there is an estimated $2,927 annual saving using PIMa with the automated data collection system. It is important to note the savings are not a result of the plant inventory, irrigation and analysis features of PIMa. The additional information required for PIMa would increase the data collection and entry expense if the process were not automated.

The savings are attributed to:

1. **The speed and efficiency of data entry using the intuitive GridPad interface which will result in a modest reduction in the time required to enter all information.**

2. **The reduced chance of errors in entering the data.**

3. **The most significant saving is the direct result of eliminating the manual entry of data from the "Crew Day Cards" now required using PeCosII. This is an estimated saving of $1,925/year per Org.**

4. **Savings on paper and printing of crew day card forms and other office consumable.**

TABLE 8
Estimated Annual Labor Cost for Operation PeCosII[6]

LABOR COSTS (System Use)	Hr/Month	Rate/Hr	Man Months Per Year	Monthly Cost
Up/Down Loading of PeCosII Data. Sup-05	3	$18.22	12	$655.92
Planning Daily Activity Sup-05	8	$18.22	12	$1,749.12
Field Data Recording Tech-02, 8 in Org	5	$10.44	96	$5,011.20
Data Entry to PeCosII System From Crew Day Cards. Sup.Asst.-04	12	$13.37	12	$1,925.28
Verify Data Sup.Asst.-04	20	$13.37	12	$3,208.00
Total Annual Cost				**$12,549.52**

TABLE 9
Estimated Annual Labor Cost for Operation of PeCosII/PIMa

LABOR COSTS (System Use)	Hr/Month	Rate/Hr	Man Months Per Year	Monthly Cost
Up/Down Loading of PeCosII Data. Sup-05	3	$18.22	12	$655.92
Planning Daily Activity Sup-05	8	$18.22	12	$1,749.12
Field Data Recording Tech-02, 8 in Org	4	$10.44	96	$4,008.96
Verify Data Sup.Asst.-04	20	$13.37	12	$3,208.00
Total Annual Cost				**$9,622.00**

6 The costs reflected in Tables 2 and 3 are based on interviews and discussions with District 1 Maintenance personnel attached to Org 4172.

COSTS:

This section tabulates the costs in terms of man power commitments, capital expense and system development. In this case the estimates are made based on implementation of PIMa District-wide and then apportioned on the basis of 5 Orgs.

Table 4 lists all of the capital costs for computer hardware, software, initial training and fees for system development. All equipment necessary to support PIMa is included in these costs even though PIMa will take some advantage of existing computer resources and peripherals.

Hardware Costs: The primary hardware expense is for the purchase of the GridPads to automate the data collection process. For implementation in the landscape maintenance orgs it will require an estimated 40 individual machines. This amounts to an initial investment of about $120,000. Other expenses are for two large PC's and two laser printers capable of producing text and graphics. (See Table 4)

Software Costs: Software needs are also minimal. Using the recommended implementation strategy, the org offices will only require a dBaseIV license to support the data interface to the PIMa system. This minimizes the software acquisition costs. Only two full licenses will be required for PC-ARC/3.4D.

Other Costs: This category includes the expense of the consulting contract for developing PIMa and the additional costs associated with initial training of key personnel in the use and maintenance of the PIMa system.

TABLE 10

Capital Costs for PIMa Development and Implementation

Item Description	Cost / Unit	Number of Units	Total Cost
Hardware			
Computer (486 IBM-PC compatible)	$5,000.00	2	$10,000.00
GridPads (8 Per Org average)	$3,000.00	40	$120,000.00
Printers (Laser/Graphics)	$1,800.00	2	$3,600.00
Software			
ARC/INFO 3.4D	$5,900.00	2	$11,800.00
dBaseIV (upgrades)	$100.00	7	$700.00
LapLink	$150.00	2	$300.00
Other System Expenses			
Consulting Fees (TTI Contract	$180,000.00	1	$180,000.00
Initial Training of Personnel	$19.00[7]	960	$18,240.00
Total Capital Cost			**$344,640.00**

Amortization of Capital and Operating Costs: Table 5 shows the derivation of the annual operating cost estimated for PIMa. The basis for the Capital Costs enumerated here are:

$$\frac{CapitalCost}{5years} + AnnualMaintenance \times 5years$$

[7] The initial employee training is based on training primary personnel in Roadside and Maintenance in the operation, maintenance, input and use of the system. This was based on a total of 960 Man-hours at an average cost of $19.00 per Man-hour.

TABLE 11

Summary of Annual Operating Costs and Capital Amortization[8]

Operating Cost Description	Estimated Annual Cost	5-Year Operating Total
Computer Related Maintenance and Depreciation		
Computers (2)[9]	$2,200.00	$11,000.00
GridPads (40)	$25,600.00	$128,000.00
Printers (2)	$1080.00	$5,400.00
Software Maintenance		
ARC/INFO (contract maintenance)	$3,860.00	$19,300.00
dBaseIV (7 software upgrades per year)	$350.00	$1750.00
Estimated Annual Personnel Commitment		
Roadside .20 M/Yr (416 Hr @ $20.00)	$8,320.00	$41,600.00
District Maintenance .25 M/Yr (520 Hr @ $20.00)	$10,400.00	$52,000.00
ISG .10 M/Yr (208 Hr @ $20.00)	$4,160.00	$20,800.00
Other Costs to be Amortized		

[8] These figures reflect the estimated total cost for implementation and operation of PIMa in the 5 Landscape Maintenance Orgs of District 1.

[9] Computers currently based at the Org level are not included because they are currently used by the PeCosII system and PIMa does not change or replace PeCosII functions in such a way that different equipment would be required now or in the future.

System Development (TTI Contract)	$36,000.00	$180,000.00
Initial System Training	$3,648.00	$18,240.00
Total Operating and Amortization	**$93,258.00**	**$466,290.00**

Computation of Benefit/Cost: If the annual operating and amortization costs of the system are apportioned equally over the 5 Landscape Maintenance Orgs of District 1 the annual operating cost per Org for PIMa would be:

$$\frac{\$93{,}258}{5Orgs}=\$18{,}652 PerOrg$$

Based on an estimated average savings of $2,500 in labor costs associated with the data entry of information from "Crew Day Cards" for each Org the adjusted operating and amortization cost of PIMa by Org would be:

$$\$18{,}652-\$2{,}500=\$16{,}152$$

Taking the total estimated benefits from Table 1 the benefit/cost ratios by year would be as follows:

Year 1

$$\frac{\$11{,}084}{\$16{,}152}=0.69$$

Year 2

$$\frac{\$17,555}{\$16,366} = 1.07$$

Year 3

$$\frac{\$22,683}{\$16,583} = 1.37$$

Benefit-Cost Continued:

Year 4

$$\frac{\$26,183}{\$16,803} = 1.56$$

Year 5

$$\frac{\$31,266}{\$17,027} = 1.84$$

The overall benefit/cost for the first 5-year implementation period would be:

$$\frac{\$108,771}{\$82,931} = 1.31$$

Based on this evaluation there is a positive benefit to cost ratio in favor of implementing the PIMa system. On the other hand, it must be recognized that the first significant savings from implementation of PIMa are not realized until the fourth year. The positive ratios reflected in years 2 and 3 are due to savings from data automation and can not be attributed to PIMa. It must also be acknowledged that the total dollar savings is only a very small portion of the overall maintenance budget.

While the hypothesis has not been tested, it seems probable that if all landscape maintenance activities, including VEGI, and other spatially dependent maintenance activities were phased into this system over time, the combined savings would be most significant.

TASK 8: DRAFT AND FINAL REPORT

This task covers the activities associated with the preparation of this report and its associated documentation. The report is intended to cover the research and development activities involved in the development of PIMa. Detailed documentation of the PIMa system, software, hardware and operation is provided in separate documents.

TASK 9: IMPLEMENTATION

Introduction

As development of the PIMa system moved into the final stages of development, ADOT elected to move more cautiously into implementation of the system. This decision has been the result of several considerations which are beyond the scope of this current contract to address fully. The concerns are as follows:

1. While the benefit to cost ratio seemed positive by the forth year of operation no consensus opinion was reached about the validity of benefit values or the assumptions used to derive the values.

2. The PIMa system is a complex, expensive and highly specialized system that only serves the needs of one very small unit within ADOT maintenance and operations. Other activities, such as signs and stripes, pavement and bridge maintenance are far more significant in terms of percent of work and budget allocation.

3. As currently written PIMa does not replace or communicate with VEGI, the

vegetation management program used to track herbicide and other roadside vegetation control activities. This is a matter of some concern since PIMa becomes a third system involved in tracking roadside maintenance activities. This clearly complicates the maintenance reporting process rather than simplifying it.

4. The durability of the field based data collection units is a concern in terms of its ability to withstand the harsh climatic conditions of Arizona summers.

5. An increasing percentage of the landscape maintenance in District 1 is being let to private contractors. This is part of the ADOT effort to meet the state mandate for more utilization of private sector contractors. There are some concerns that the use of PIMa, on contract maintenance sections, would increase contract costs and be of limited value.

6. The ability of field personnel to effectively use the data reporting devices has been questioned since many individuals in the labor force do not have english as a first language.

Given these concerns and the limited time and resources, ADOT opted for a "Trial Implementation" of PIMa.

Trial Implementation Org

Based on the recommendation of the District 1 maintenance supervisor and the District Engineer, Org 4170. This org is one of more established landscape maintenance orgs in the district and is responsible for the Superstition Freeway from mile post 5.4 to 16.4. This section of freeway includes a range of landscape development from old overgrown plantings to newly established projects. It was also felt that the personnel in this org would have the least trouble in adapting to the new system of reporting.

Trial Implementation Activities

Training: Approximately two weeks before the trial implementation was to begin the primary supervisors and individuals to be involved in the implementation trial were given a 5 day period of intensive training. The purpose of the training was to familiarize all of the involved personnel with the operating units of PIMa, the data base management system, the GIS system, and the GridPad modules. The focus was on gaining a good understanding of the system interface and a general knowledge of the operating structure of the system to be implemented.

Installation: During the training sessions with ADOT personnel several needs for operational changes were identified. Some of the changes were to facilitate the use of the software and make it more compatible with ADOT routine while others were operational difficulties with the software that needed correction.

The installation of the PIMa system began on October 5, 1992. The initial setup process was plagued by communication compatibility problems. The combined effect of these problems took approximately four days to correct and the system finally went into the field on the 9th October.

Field Operations

Problems: The trial implementation has proved to be a very good shakedown period for the system. As could be expected with a system made up of so many different modules and units several bugs began to show up by the third or fourth day of operation. Some of the more significant problems were:

1. Data would be lost if a machine was turned off prior to the files being saved to the cards. This was corrected by adding internal save features to the software.

2. The "RAM Cards"[10] used in the GridPad could only handle 112 files in the root directory. This limited each RAM Card to approximately 12 miles of maps. Originally this was not considered a problem since it was believed that a three mile segment would be sufficient for one day's work. This was quickly shown not to be the case. Since the directory limit was software dependent and not a problem of actual space on the card the problem was solved by simply creating a directory for each mile. This allowed the device to store up to 12 miles with no problem.

3. The communication link to the district and PeCosII were not established. There

[10] RAM cards are utilized as the mass storage device in the GridPad instead of a hard disk. The RAM card is not as subject to damage by rough handling or climatic variation.

have been continuing problems with the communication conventions used by the data transfer modems. These problems are still being resolved.

4. As expected, map accuracy has been a problem in some of the older more established areas. The problem with the inaccuracy of maps is the result of the lag in field verification of the data input from plans. For example, plant materials and irrigation have been completely removed from some of the older sections of Superstition Freeway's medians. These changes were not recorded as planned by the as built materials provided by ADOT. For this reason major changes such as this have to be noted and corrected after field verification.

5. The original program had not made provision for revising fields on the crew day forms that would usually be entered by the supervisor. This was solved by adding routines that allowed the user to delete a field and provided access to a popup keyboards or calculator pad to insert the appropriate information.

6. Some additional features had to be added to facilitate the collection of removal and replacement of information about plant beds and irrigation appliances for PIMa and PeCosII. This involved the addition of popup menus to reduce the need for using the keyboards. Some problems with correcting error messages during data input were also resolved.

7. There have been nagging problems with the GridPad devices battery life. The battery's are rechargeable nickel-cadmium (ni-cad), batteries. Ni-cad batteries have a problem of recharge memory. If the batteries are not completely discharged during each use the battery becomes fixed at that level of discharge and will no longer accept charge beyond that capacity. The problems experienced seem to be related to this weakness. The district has acquired a discharger/recharger which fully discharges the battery before beginning the recharge cycle. As soon as this is in place the GridPad representative replaced the batteries and ADOT has experienced little problems.

8. The transfer of data from the GridPad to PeCosII still requires manual transfer. The down loading program written for the GridPad, creates and formats all of the data into the .dbf files used by PeCosII for activity, equipment, personnel and materials. What remains is a software routine that will query the fields of these files for verification purposes and transfer it into the PeCosII system.

   It has been suggested that storage capacity of the GridPad should be sufficient to allow the verification routines of the PeCosII system to be resident in the field. If information could be verified directly in the field it would certainly reduce the overall time of data entry.

The means to capture the basic information required by PeCosII has been affected and the .dbf files are created. The method of verification and uploading to the PeCosII system is the prerogative of ADOT's Maintenance Planning Services office and the Information Systems Group. Decisions in this regard rest with these units of ADOT and were beyond the scope of this project.

Field Personnel Evaluations: To provide a fitting conclusion to the research objectives of this project all employees that have participated in the trial implementation of the system were interviewed to determine their reactions and opinions of the PIMa system. These interviews were informal telephone conversations that focused on: the ease of utilization, problems or errors, opinions of long-term utility and preferences.

1. Org Supervisor

The overall reaction of the org supervisor has been most favorable. He feels that the crews have become more involved with the goals of the Department and the org. In general the crews seem to feel that they have been able to participate in the decision making process of the Department.

On the operational side the supervisor believes the system works well and is operationally sound. At this time he indicates that it requires about 3 hours per two week cycle to input the crew work reports. In the evening it requires about ten to fifteen minutes to transfer the information from the GridPad onto the base PC. The major time consuming activity is still the transfer of information from the field forms to the PeCosII forms. As pointed out earlier this step has not been automated so no time economies have actually been achieved.

2 Assistant Org Supervisor

The assistant org supervisor is much less optimistic about the utility of the system. The fact that the transfer of data into PeCosII is not automated simply adds time to the administrative work load. In his opinion, it has also taken a lot of time to get everyone used to using the equipment and using it properly. Overall, it seems that he would agree that the scope of the project is in the right direction. Particularly if all of he automation features are made operable.

3. Crew Leaders

Among the crew leaders the opinions vary. A majority of the crew leaders expressed a desire for more explanation on how to use the maps for reporting information. They have some trouble understanding how to pick which areas or features they worked on during the day. They feel that the use of the maps take more time than the paper forms. In addition the problems with batteries and some of the early bugs made using the maps rather frustrating at first. They have seen some improvement in the system as the bugs have been corrected, but map use is still very limited & isolated.

Overall the crew leaders were very non committal about using the system. Some thought that it was a good idea while others quite candidly indicated that they would just as soon continue using the paper forms.

Conclusions and Recommendations

Introduction and Overview

The PIMa system began with the simple concept of spatially referencing and tracking ADOT's plant and irrigation inventory on the developed freeway system in District 1. In the initial scope of work, the system was to be designed independently of any existing ADOT information management system(s). It was assumed that the information needed to maintain a current inventory could be identified by a survey of needs and then operationalized as part of a data collection system in the field. Each of these assumptions proved faulty.

The first step in developing the inventory system was an assessment of landscape design and maintenance information needs, Task 1. This assessment activities focused on determining what information would be of value to design and maintenance personnel and how plant material and irrigation inventory data could be collected from the field.

This was the first contact with the PeCosII maintenance planning and information system which already had rudimentary data collection features for plant materials and irrigation. The only problems with the features of PeCosII are that its ability to handle locational information are limited and the coding for inventory items is far to general to provide any useful feedback for making detailed design and maintenance decisions. At this point some consideration was given to how the existing PeCosII system might be expanded to handle the landscape and irrigation inventory and management functions. Discussions were held with Maintenance Planning Services and the Information Services Group, who indicated that the structure of the existing system would be so impacted by such a change that it would not be an economically feasible alternative.

However, further examination of ADOT's Roadside Development Services and Operations and Maintenance units demonstrated the departmental commitment to the PeCosII and VEGI systems would have to be reckoned with since it was the established system for continuous data collection. Any new data collection procedures were going to have to fit within the data collection requirements of PeCosII system. This substantially changed the scope of work and the degrees of freedom open to the design of the PIMa system.

Communication with PeCosII was absolutely essential if cost effective data collection was to be achieved. Hardware and software compatibility became a matter of much greater concern and the organization of data needed to be developed in a way that would recognize the structure and conventions of PeCosII. In Task 2, the conceptual development of the system had to be molded in a way that recognized the need for sorting general date and sending it to PeCosII and extracting more detailed information and sending it to PIMa. It was at this point that the need to automate data collection became apparent. There were provisions for manual, paper based data collection but it simply did not make good economic sense given the capabilities of the new data collection technologies.

These discoveries greatly impacted the evaluation criteria ultimately used to review and rank hardware and software and recommend a system for development of PIMa, Tasks 3 and 4. The issues of the best software and hardware environments for PIMa were very much influenced by the need to be compatible with current field practices and the PeCosII system. Issues of personnel familiarity with the operating environment, compatibility and ease of data transfer between systems and the ability to utilize the existing computing infrastructure became issues of the greatest importance.

To address the changes revealed as the result of accomplishing Tasks 1 through 4, the scope of work was modified and two additional tasks were added. Task 5 was changed to a Pilot application to include the exploration and recommendation of a suitable device for automated data collection. Task 6 was the pilot demonstration, Task 7 was the preparation and presentation of an implementation plan, Task 8 was the draft and final report and Task 9 was implementation.

Over the course of bringing the project to a close there were further modifications to the actual work accomplished. Tasks 5 and 6 were generally completed in accordance with the original description. The pilot demonstration was presented and a recommendation for implementation was made. At this point several issues were raised about the overall utility of the system and the fact that it had a very limited scope in relation to the cost. This led to a request for a benefit cost analysis of the systems utility. While this was not a part of original scope of work it was accomplished. Upon review and discussion of the benefit cost analysis ADOT elected to move ahead with a Trial Implementation only. Thus, Task 9 was only trial implementation not full implementation as in the original scope of work. Even though the area of coverage was less, the trial implementation required that the system be brought to full operational status which was accomplished.

At this writing there has been no final decision about expansion of the implementation. It would appear that ADOT will keep the trial implementation in force for some extended period for further internal evaluation. In closing out this project all of the data files generated for the landscape and irrigation development in ADOT District 1, will be turned over along with the system documentation, executable programs, training, and verification materials.

Concept Feasibility of Spatially Referenced Maintenance Management Systems

The development and successful trial implementation of PIMa has served to demonstrate the feasibility of spatially referenced management systems. The development of PIMa has successfully demonstrated a completely paperless management system and it has illustrated how spatially referenced data sets can be structured to capture, store, manipulate and display information in support of design and maintenance decision processes.

What is most significant about this system is that it begins to provide feed back from the field to the design process. Feedback from the field is the most neglected link in the overall management of highway system in the country. Current practice and the systems used for design decision support tend to be linear. That is, information flows from design to construction to maintenance and operations and ends. No link is provided to feed information about design related successes and failures back into the design process. Systems like PeCosII provide cost-based information to the management level. On the other hand, almost no qualitative information is flowing from the field back to the design process. The basic system structure demonstrated in PIMa will allow this link to be made. And while PIMa was designed to capture landscape and irrigation information the same structure could apply to pavement, bridges, congestion and safety.

Operational Utility and Value of the PIMa System

PIMa is an operational system and, if used as it is designed will provide the information necessary to track the landscape and irrigation inventory of ADOT. Likewise if it is improved over time to perform the functions of the VEGI system and other roadside activities it will be very effective. However, when taken in context of the full scope of maintenance activities that must be performed to ensure the utility and safety of the ADOT maintained system and the existing PeCosII and VEGI systems, PIMa has limited utility. It is as an independent system that will have to be maintained over and above the existing systems.

On the other hand PIMa does provided a framework for moving to a new method of data collection for PeCosII. The crew day card software currently written for the GridPad, with minor modifications, is capable of collecting the base data for all PeCosII functions. Likewise, the spatial data structure established in the PIMa design can easily be overlaid to add different kinds of inventory information such as signs, light standards or guard rails.

Conclusion

PIMa is a highly specialized system that is dependent on uniform reporting of field data that cannot be controlled by the ultimate consumer of the end information, Roadside Development Services. In its current state it operates fully independent of the other two major information management systems of ADOT. Thus, regardless of its simplicity and efficiency, it is an additional time and cost burden. Therefore if there is no commitment on the part of ADOT to continue the development of a new generation of spatially referenced management systems, continued support for PIMa probably cannot be justified.

Recommendations

While operation of PIMa may not be cost effective at this time there are parts of the system that have much broader application to the Department that should be pursued independently of their association of PIMa project.

Automated Data Collection Technology: The primary feature that does have wide spread application immediately is the use of the GridPad pen sensitive device for data collection. All information input into the PeCosII system is currently done by paper " Crew Day Cards." Work assignments are manually executed, activity, labor, equipment and material reports are all generated on paper and then manually transferred to the PeCosII system. PIMa has clearly demonstrated that this procedure can be successfully automated. The software already written for the GridPads can be used as a foundation to automate all field data collection for all operations.

It is recommended that the Department give serious consideration to further evaluating the data collection features developed in the PIMa project and take steps to adapt these to all data collection activities of ADOT. During the course of the study the area of Signs and Stripes was often mentioned as an area of work that could possibly benefit immediately from this technology. The new mandates in the ISTEA requiring development of more responsive management systems for pavement, bridge, safety and congestion also suggest that it will be to the Department's benefit to move toward more universal application of automated data collection technology.

Plan Data and Consultant Submissions: ADOT should give serious consideration to requiring that all plan submissions from consultants, engineering, landscape architects and others, be in digital format. The ".dxf" format is being suggested because it can be picked up by all major CADD and GIS software packages including Intergraph and ARC/INFO. This should be implemented at the earliest possible date, regardless of the ultimate decision regarding the implementation of the PIMa system. By adopting this policy now it will measurably reduce the overall data capture costs to ADOT when GIS technology is finally adopted into the data management structure of the Department.

Hands-on Experience in the Development of Map Files: A recommendation was made in the implementation plan to involve ADOT in the preparation of digital base files for the PIMa system. This was to have been done parallel to the work being conducted by the consultants. The reason for this was to build some institutional memory into the data base creation process rather than rely on short training sessions and documentation. These resources will be available but it is almost impossible to train an individual in the preparation of spatially referenced data sets without some extended period of hands on training. Prior to turning over the digital data files ADOT should give some further consideration to this type of training.

Development of a Spatial Data Structure for ADOT: PIMa demonstrates the broad capabilities of spatially referenced information systems which are usually called "Geographic Information Systems". This technology is the future framework for information management for all spatially oriented service providers and more particularly transportation interests. Thus it is reasonable to assume that the work pioneered by PIMa will have value at some future date.

One very important problem that surfaced in the work on PIMa is the current spatial referencing system ALISS, used by ADOT. At this point the state inventory and the safety records are all referenced to the ALISS centerline system. ALISS has good geo-reference ties which allow it to be converted to a variety of datum standards and map projections. However, the primary points of reference in ALISS are mile posts. Use of mile posts has numerous draw backs since it does not relate to any system of true measure. Not having a true measure reference complicates the structure of any spatial data base. The lack true measure references will make the conversion of data bases very complicated and costly if the mile post designations are ever changed.

It is reasonable to assume that in the near future it will be necessary to convert the existing mile post referencing systems from english to metric units, since it is mandated by law. How this is done should also take into account the most efficient structure for spatial referencing of all physical development of the state maintained transportation system. For this reason it is recommended that ADOT undertake a study of its design, planning, maintenance operations and information needs and develop a spatial referencing structure that will not be change sensitive.

APPENDIX A

Needs Survey Instrument: Arizona Department of Transportation, Landscape Inventory and Management System

Part I: Information needs of field and management personnel with responsibilities for maintenance and installation of roadside landscape and irrigation. The purpose of this section is to determine what information is of the greatest value to field personnel and what forms of information are most useful in day-to-day activities.

Directions: For each of the following kinds of information please rank each one on the following scale:

1 Information would be of no use to me

2 Interesting but I really do not need it

3 Only needed on special occasions

4 Absolutely necessary for every day duties

1. Plans that show locations of water taps and water meters.

   1 Information would be of no use to me
   2 Interesting but I really do not need it
   3 Only needed on special occasions
   4 Absolutely necessary for every day duties

2. Plans that show the location of controllers and power source.

   1 Information would be of no use to me
   2 Interesting but I really do not need it
   3 Only needed on special occasions
   4 Absolutely necessary for every day duties

3. Plans that show location of valves and filters for irrigation system.

   1 Information would be of no use to me
   2 Interesting but I really do not need it
   3 Only needed on special occasions
   4 Absolutely necessary for every day duties

Part II. Common landscape and irrigation maintenance problems encountered by field personnel with responsibilities for roadside landscape and irrigation. The purpose of this section is to identify recurring landscape and irrigation maintenance problems that might be corrected by changing design practices or unique habitat problems that have been noticed by experienced field personnel.

Directions: Rank each of the following statements on the following scale:

1 No Problem in my areas

2 Minor problem

3 Common problem

4 Major problem

If there is a problem note the name of the plant or item that you feel causes the problem. EG: red fountaingrass invading drainage ditches, Brand M single port emitters clog more often, etc.

1. A particular shrub(s), planted near the driving lanes seem to consistently collect more trash than would be expected.

   1 Can not think of a problem in my areas
   2 Minor problem
   3 Common problem
   4 Major problem

   If there is a problem please give name of shrub:____________________

2. A certain shrub(s) and tree(s) in my areas seem to collect and show dust much more than other plants.

   1 Can not think of a problem in my areas
   2 Minor problem
   3 Common problem
   4 Major problem

   If there is a problem please give name of plant, material or part:____________________

3. Particular shrubs when used on steep slopes and embankments seem to allow more soil erosion than other kinds of shrubs.

   1 Can not think of a problem in my areas
   2 Minor problem
   3 Common problem
   4 Major problem

   If there is a problem please give name of plant, material or part:____________________

4. A particular kind of shrub(s) or tree(s), grow so fast that they frequently encroach on the driving lanes if not trimmed.

1 Can not think of a problem in my areas
2 Minor problem
3 Common problem
4 Major problem

If there is a problem please give name of plant, material or part:____________________

5. Certain plants seem to have constant problems with weed invasion.

1 Can not think of a problem in my areas
2 Minor problem
3 Common problem
4 Major problem

If there is a problem please give name of plant, material or part:____________________

6. Some plants have had a tough time surviving when planted next to structures like; bridge supports, walls, drainage structures, guard rails, etc.

1 Can not think of a problem in my areas
2 Minor problem
3 Common problem
4 Major problem

If there is a problem please give name of plant, material or part:____________________

7. Some plants get to be a real problem when they are planted near any drainageway or structure.

1 Can not think of a problem in my areas
2 Minor problem
3 Common problem
4 Major problem

If there is a problem please give name of plant, material or part:____________________

8. The leaves and or branches of certain plants seem to catch a lot of trash.

1 Can not think of a problem in my areas
2 Minor problem
3 Common problem
4 Major problem

If there is a problem please give name of plant, material or part:____________________

9. Some trees and or palm trees cause problems when they drop fruit, seed stalks or fraunds on to the driving surfaces.

1 Can not think of a problem in my areas
2 Minor problem
3 Common problem
4 Major problem

If there is a problem please give name of plant, material or part: ____________________

10. Other Problems: in the space below or on the back of this sheet note any other problems you have with specific kinds of plants, irrigation equipment or site conditions.

12. Project plant lists with quantities and common names only.

1 Information would be of no use to me
2 Interesting but I really do not need it
3 Only needed on special occasions
4 Absolutely necessary for every day duties

13. Project plant lists with quantities, scientific and common names.

1 Information would be of no use to me
2 Interesting but I really do not need it
3 Only needed on special occasions
4 Absolutely necessary for every day duties

14. Project plant lists by scientific name only.

1 Information would be of no use to me
2 Interesting but I really do not need it
3 Only needed on special occasions
4 Absolutely necessary for every day duties

15. Plant dictionary or manual with pictures for identification.

1 Information would be of no use to me
2 Interesting but I really do not need it
3 Only needed on special occasions
4 Absolutely necessary for every day duties

16. Plant list with information about insects that cause damage.

1 Information would be of no use to me
2 Interesting but I really do not need it
3 Only needed on special occasions
4 Absolutely necessary for every day duties

17. Plant list with information about diseases.

1 Information would be of no use to me
2 Interesting but I really do not need it
3 Only needed on special occasions
4 Absolutely necessary for every day duties

18. Plant list with information about basic maintenance needs, (watering, trimming, fertilizer, etc.).

1 Information would be of no use to me
2 Interesting but I really do not need it
3 Only needed on special occasions
4 Absolutely necessary for every day duties

Part III: Special or unusual problems with landscape or irrigation maintenance. In the daily discharge of your job responsibilities there may be particular problems and or places that seem to always give you a problem that are not really described in any of the preceding sections.

Directions: If you can think of a situation or want to share your most nagging maintenance problem please provide a description of the problem in the space(s) below. Use the back of the page if necessary.

1. Specific Location of Problem:

   Description of the Problem:

2. Specific Location of the Problem:

   Description of the Problem:

Part IV: Information types, formats and access needed by roadside personnel. The following questions deal with the determining what information you feel is most useful to you in the day-to-day performance of your work and what form is the most convenient for you.

Directions: For each of the following statements rank the responses in the order of their importance to you simply place a 1 by the most important, a 2 by the second most important, 3 by the next and so on.

1. If you were at the shop or your office preparing to go into the field for the day which of the following forms of information resources would be of the most use to you <u>in the office</u> in making your preparations?

   __ a. A map file or hanging file of blueprints of the projects in my area.

   __ b. A book of plans and maps of the projects in my area.

   __ c. A library of rolled blueprints of all projects in my area that can be checked out and taken into the field.

   __ d. A computer terminal that would allow access to plan libraries and could provide hard copy of small plans of specific areas.

   __ e. A computer terminal that would provide plans as above but also allow me to get information about the plants or irrigation materials on the job.

   __ f. A computer terminal that would provide maps and other information noted above but could also show me a photograph of the specific site.

2. In your field activities what would be the most useful information format for you to take with you to the job site?

   __ a. Full scale plans and materials lists (blueprints), on standard size sheets.

   __ b. Half scale plans and materials lists.

   __ c. Small plan sheets, 8.5" x 11" xerox sheets of areas where there are specific problems.

3. Other than plan information what is the most important written information you need on a landscape project?

__ a. Plant names

__ b. Disease information

__ c. Insect information

__ d. Plant quantities

4. Other than basic plan information what is the most important written information you need on irrigation jobs.

__ a. Type(s) of emitter

__ b. Controller program and station assignment

__ c. Model numbers of emitters

__ d. Technical information on pressure regulators and filters.

__ e. Technical information on emitter repair and replacement.

__ f. Technical information of valve repair and replacement.

5. Is there some kind of information that would help you do your job better that just never seems to be available? If you can think of something please note it briefly in the space below.

Part IV. Current Information Use: These questions are intended to find out what types of information you currently use as a matter of daily routine, where and how it is accessed.

Directions: Simply circle or check those information items that you currently use in your day-to-day work.

1. What items on the following list do you usually or always try to have with you in your vehicle.

   a. An irrigation plan of the projects in my work area for the day

   b. A controller program or diagram

   c. Technical sheets on the irrigation equipment we use

   d. A plant list of the projects in my area

   e. A planting plan of the projects in my work area for the day

   f. A maintenance schedule for the daily work area.

   g. A maintenance check list for the maintenance reporting cards

2. What kinds of information do you keep in the office for reference?

   a. Irrigation plans of all projects in the work area

   b. Planting plans of all projects in the work area

   c. Technical data sheets on all irrigation equipment used within the work area

   d. Plant lists of all the landscape materials used in the work area

   e. Electrical plans of all controllers in the work area

   f. Water meter plan locations for all irrigation water meters in the work area

   g. Maintenance schedules for the work area

3. Are there other types of information you use in your day-to-day work that is not covered in this list. If you can think of some please not them on the back of this page.

Part V: Design Information Needs: This section is intended to identify those kinds of information that are needed by the Landscape Architects and ADOT personnel charged with the design, installation and continued management of the roadside landscape development.

Directions: For each of the items listed below rank it according to the following scale:

1 Never necessary

2 Useful but not essential for most projects

3 Essential for all projects

Place the number of your ranking in the blank to the left of each item in the list.

1. Rank each of the following types or categories of information with respect to their significance to base plan materials. ie, how important are these items to a good base map?

___a. ROW lines
___b. Center line
___c. Center line Geometry
___d. Center line Stationing
___e. Mile posts/points
___f. Pavement edges
___g. Driving lane layout
___h. Center line of drainage ways
___i. Primary structures (bridges, supports, riprap, walls, drainage structures, etc.)
___j. Lighting standards
___k. Sign standards and markers
___l. Guard rails
___m. Contour lines
___n. Water source
___o. Power supply

2. Rank each of the items in the following list as to their importance in keeping inventory and maintenance records

___a. ROW lines
___b. Center line
___c. Center line Geometry
___d. Center line Stationing
___e. Mile posts/points
___f. Pavement edges

___g. Driving lane layout
___h. Center line of drainage ways
___i. Primary structures (bridges, supports, riprap, walls, drainage structures, etc.)
___j. Lighting standards
___k. Sign standards and markers
___l. Guard rails
___m. Contour lines
___n. Water source
___o. Power supply

3. Rank each of the following soil characteristics as to their importance in developing landscape plans and project specifications.

___a. Soil profile to 3 feet by type and texture
___b. Soil P_h for selected areas
___c. Soil salts for selected areas
___d. Soil Nitrogen (N) for selected areas
___e. Soil Phosphorous (P) for selected areas
___f. Soil Potassium (K) for selected areas
___g. Soil trace elements for selected areas
___h. Soil compaction for selected areas
___i. Soil infiltration rate for selected areas
___j. Soil ash% for selected areas
___k. Soil plastic index (PI) for selected areas
___l. Soil available moisture by percent for selected areas

4. Rank each of the following additional site considerations with respect to their relative importance and need to be recorded as a part of the planning and design process.

___a. Flow limit and depth of drainage ways.
___b. Assessment of wind exposure
___c. Assessment of relative reflected heat hazard
___d. Assessment of special orientation or exposure hazard
___e. Assessment of special air pollution hazard
___f. Assessment of special dust hazard

5. Rank each of the following plant material characteristics as to their importance for inclusion in the plant information library.

___a. Soil P_h range
___b. Soil N range
___c. Soil P range
___d. Soil K range
___e. Soil salt tolerance range

___f. Soil suction range
___g. Slop % limitation
___k. Slope orientation limits
___l. Light reflection limits
___m. Aggressiveness characteristics
___n. Water requirement
___o. Air pollution sensitivity
___p. Wind sensitivity

6. Rank each of the following as to their importance for inclusion in a plant information data base.

___a. Plant type (tree, shrub, gc, etc.)
___b. Evergreen/Deciduous
___c. Leaf texture
___d. Leaf color
___e. Flower type
___f. Flower color
___g. Flower season
___h. Fruit type
___i. Fruit color
___j. Fruit season
___k. Applications
___l. Constraints

APPENDIX B

I. Example of Maps and Tables Generated from the Pilot Data Base

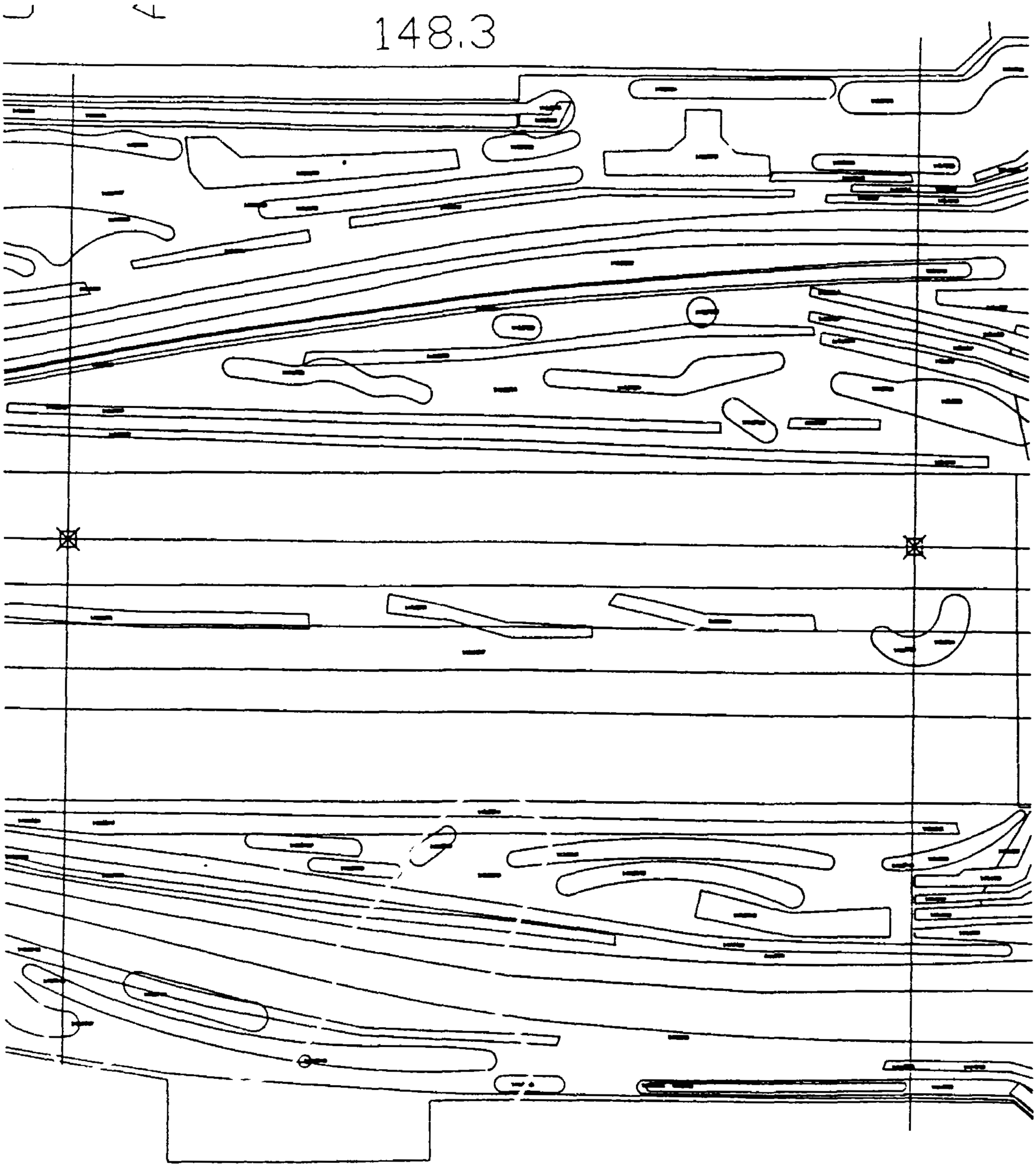
A. Map of vegetation for milepost 148.3

B. Vegetation database information for milepost 148.3

C. Map of irrigation applicances and lines for milepost 148.3

D. Irrigation applicance database information for milepost 148.3

A. Map of Vegetation for Milepost 148.3



B. Vegetation Database Information for Milepost 148.3

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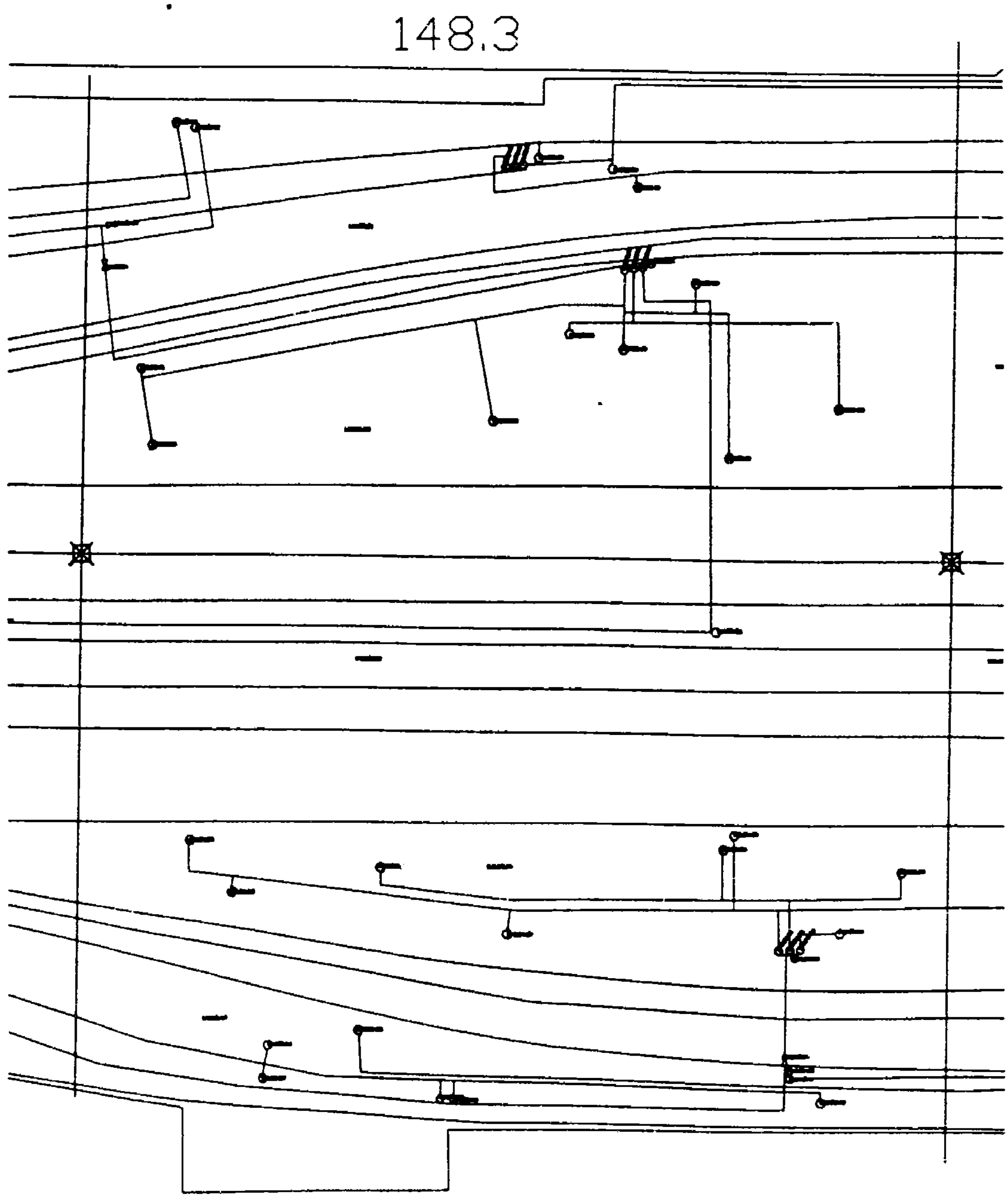
ROUTE	IDCODE	ID	QUAN	FACE	PLANTED	SIZEPLANTE
I10	148.3S01	NEOLS	32	East	8/89	1 gal
I10	148.3T02	PRAL	12	East	8/89	5 gal
I10	148.3S03	SAGR	18	East	8/89	1 gal
I10	148.3T04	PRAL	5	East	8/89	5 gal
I10	148.3S05	ACRE	27	East	8/89	1 gal
I10	148.3T06	PRAL	2	East	8/89	5 gal
I10	148.3S07	ACRE	12	East	8/89	1 gal
I10	148.3S08	ACRE	31	East	8/89	1 gal
I10	148.3T09	PRAL	4	East	8/89	5 gal
I10	148.3S10	CAPH	3	East	8/89	1 gal
I10	148.3S11	NEOLS	18	East	8/89	1 gal
I10	148.3T12	PRAL	6	East	8/89	5 gal
I10	148.3S13	NEOLS	46	East	8/89	1 gal
I10	148.3T14	ACSM	3	East	8/89	5 gal
I10	148.3S15	CAPU	9	East	8/89	1 gal
I10	148.3S16	SAGR	20	East	8/89	1 gal
I10	148.3S17	VEPE	35	East	8/89	1 gal
I10	148.3S18	NEOLS	30	East	8/89	1 gal
I10	148.3S19	CAPH	54	East	8/89	1 gal
I10	148.3S20	NEOLS	82	East	8/89	1 gal
I10	148.3T21	CEFL	6	East	8/89	5 gal
I10	148.3S22	CAPH	38	East	8/89	1 gal
I10	148.3T23	CEFL	2	East	8/89	5 gal
I10	148.3T24	EUMI	5	East	8/89	5 gal
I10	148.3T25	CEFL	1	East	8/89	5 gal
I10	148.3T26	CEFL	2	East	8/89	5 gal
I10	148.3S27	CAPH	7	East	8/89	1 gal
I10	148.3S28	SAGR	37	East	8/89	1 gal
I10	148.3S29	ENFA	13	East	8/89	1 gal
I10	148.3S30	CAPU	8	East	8/89	1 gal
I10	148.3T31	ACSM	3	East	8/89	5 gal
I10	148.3S32	CANY	21	None	8/89	1 gal
I10	148.3S33	CANY	17	None	8/89	1 gal
I10	148.3S34	CANY	17	None	8/89	1 gal
I10	148.3T35	CEFL	1	None	8/89	5 gal
I10	148.3S36	LELA	59	West	8/89	1 gal
I10	148.3S37	LELA	70	West	8/89	1 gal
I10	148.3T38	EUMI	4	West	8/89	5 gal
I10	148.3T39	ACSM	3	West	8/89	5 gal
I10	148.3T40	EUMI	2	West	8/89	4 gal
I10	148.3T41	ACSM	16	West	8/89	5 gal
I10	148.3T42	EUMI	5	West	8/89	5 gal
I10	148.3S43	ACRE	23	West	8/89	1 gal
I10	148.3T44	ACSM	1	West	8/89	5 gal
I10	148.3S45	NEOLS	58	West	8/89	1 gal
I10	148.3T46	ACSM	21	West	8/89	5 gal
I10	148.3T47	EUMI	1	West	8/89	5 gal
I10	148.3T48	PRAL	4	West	8/89	5 gal
I10	148.3T49	PRAL	5	West	8/89	5 gal
I10	148.3T50	PRAL	2	West	8/89	5 gal
I10	148.3T51	EUMI	4	West	8/89	5 gal
I10	148.3S52	ACSM	5	West	8/89	1 gal
I10	148.3S53	SAGR	9	West	8/89	1 gal

C. Map of Irrigation Appliances and Lines for Milepost 148.3



D. Irrigation Appliance Database Information for Milepost 148.3

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ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA01	PRR	0	0		1	5	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	23	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA02	PRR	0	0		1	5	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
113	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA03	GV	0	0		1	5	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA04	GV	0	0		1	5	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA05	RCV	0	0	SHRUBS	1	5	3	3

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA06	RCV	0	0	SHRUBS	1	5	4	4

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA07	RCV	0	0	TREES	1	5	2	4

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA08	PRR	0	0		1	5	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
58	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA09	PRR	0	0		1	5	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	11	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA10	PRR	0	0		1	5	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
64	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA11	PRR	0	0		1	5	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
53	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA12	PRR	0	0		1	5	0	0

NUMSINEMIT NUMMULTI3 NUMMULTI5

D. Irrigation Appliance Database Information for Milepost 148.3

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ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM	NUMSINEMIT	NUMMULTI3	NUMMULTI5
I-10	148.3IA13	PRR	0	0		1	5	0	0	75	0	0
I-10	148.3IA14	RCV	0	0	SHRUBS	1	5	6	6	0	0	0
I-10	148.3IA15	RCV	0	0	TREES	1	5	1	2	0	0	0
I-10	148.3IA16	RCV	0	0	SHRUBS	1	5	2	2	0	0	0
I-10	148.3IA17	QC	0	0		1	5	0	0	0	0	0
I-10	148.3IA18	PRR	0	0		1	5	0	0	0	7	3
I-10	148.3IA19	PRR	0	0		1	5	0	0	47	0	0
I-10	148.3IA20	PRR	0	0		1	5	0	0	79	0	0
I-10	148.3IA21	PRR	0	0		1	5	0	0	59	0	0
I-10	148.3IA22	PRR	0	0		1	5	0	0	0	13	1
I-10	148.3IA23	PRR	0	0		1	6	0	0	34	3	0
I-10	148.3IA24	PRR	0	0		1	6	0	0			

D. Irrigation Appliance Database Information for Milepost 148.3

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ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA25	PRR	0	0		1	6	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
37	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA26	PRR	0	0		1	6	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	4	6

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA27	PRR	0	0		1	6	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
38	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA28	PRR	0	0		1	6	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	16	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA29	PRR	0	0		1	6	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
54	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA30	PRR	0	0		1	6	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	7	5

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA31	RCV	0	0	SHRUBS	1	6	3	3

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA32	RCV	0	0	TREES	1	6	2	4

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA33	RCV	0	0	SHRUBS	1	6	1	1

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA34	PRR	0	0		1	6	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
50	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA35	QC	0	0		1	6	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA36	PRR	0	0		1	6	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5

D. Irrigation Appliance Database Information for Milepost 148.3

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA37	PRR	0	0		1	6	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	8	2

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA38	PRR	0	0		1	6	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
56	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA39	RCV	0	0	TREES	1	6	3	5

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA40	RCV	0	0	SHRUBS	1	6	2	2

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA41	RCV	0	0	SHRUBS	1	6	1	1

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA42	QC	0	0		1	6	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	0	0

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA43	PRR	0	0		1	6	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	13	5

ROUTE	IDCODE	ID	NUMSTA	NUMVAL	VALVETYPE	SIZE	CNTRLNO	FLOWGPM	MAXGPM
I-10	148.3IA44	GV	0	0		1	6	0	0

NUMSINEMIT	NUMMULTI3	NUMMULTI5
0	0	0

APPENDIX C

I. Detail List of Expanded Codes with Diagrams of Data Entry Sequences

- A. Example of expanded code with definitions
- B. List of new labels for expanded code

II. Sample Screens of Portable Data Collection Unit (PDCU)

- A. Sample screen of raster map image on (PDCU)
- B. Sample screen of employment report

III. Examples of Menus and Screens for Automated Data Queries and Reports

<u>dBase</u>

- A. Six views of the main menu in dBase IV for PIMa
  - 1) Report menu
  - 2) Query menu
  - 3) Database Display menu
  - 4) Transfer to Arc/dBase option
  - 5) Activities menu
  - 6) Print menu
- B. Examples of pregenerated query screens
- C. Examples of pregenerated report screens
- D. Scheduling menu for daily work reports

<u>ARC 3.4D</u>

- A. ARC 3.4D menus for the graphics portion of the PIMa system
  - 1) Main Menu
  - 2) Specific milepost input menu
  - 3) Specific route selection menu
  - 4) Selection menu for intersection
  - 5) Color selection for polygon identification and queries
  - 6) Menu listing trees for identification of query
  - 7) Selection for single or multiple queries
  - 8) Menu for ground maintenance activities
  - 9) Menu for irrigation activities
  - 10) Irrigation appliance type selection menu

Detailed List of Expanded Code System for PIMa

Example of Expanded Code with Definitions

Typical Code: 146.5IA27

146.5- Milepost post marker plus tenth mile increment

IA- Inventory code to describe an Irrigation Appliance

27- Unit Number for the irrigation appliance located within this tenth mile

List of New Labels for Expanded Code

Inventory Coding System

146.7IA27

T= Tree

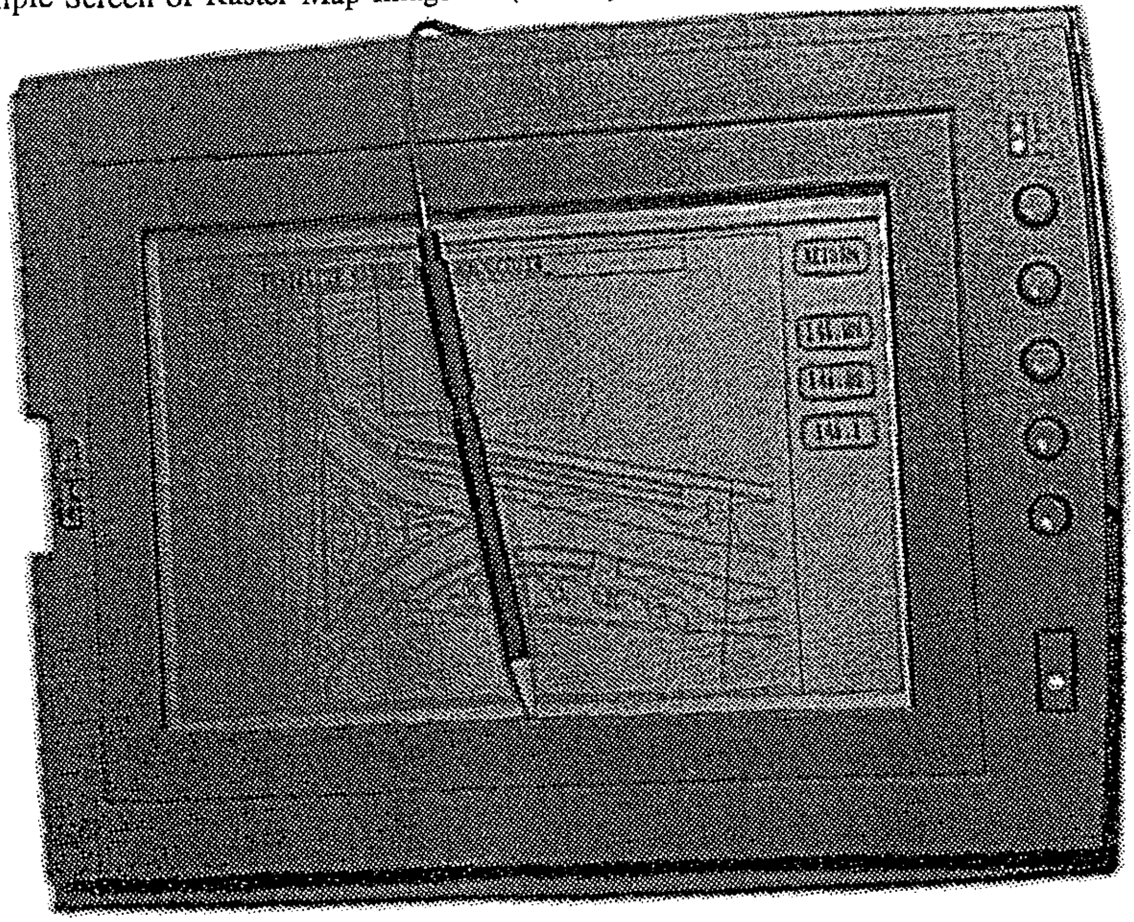
S= Shrub

G= Surface Coverage: Granite Mulch, Rock Mulch, etc.

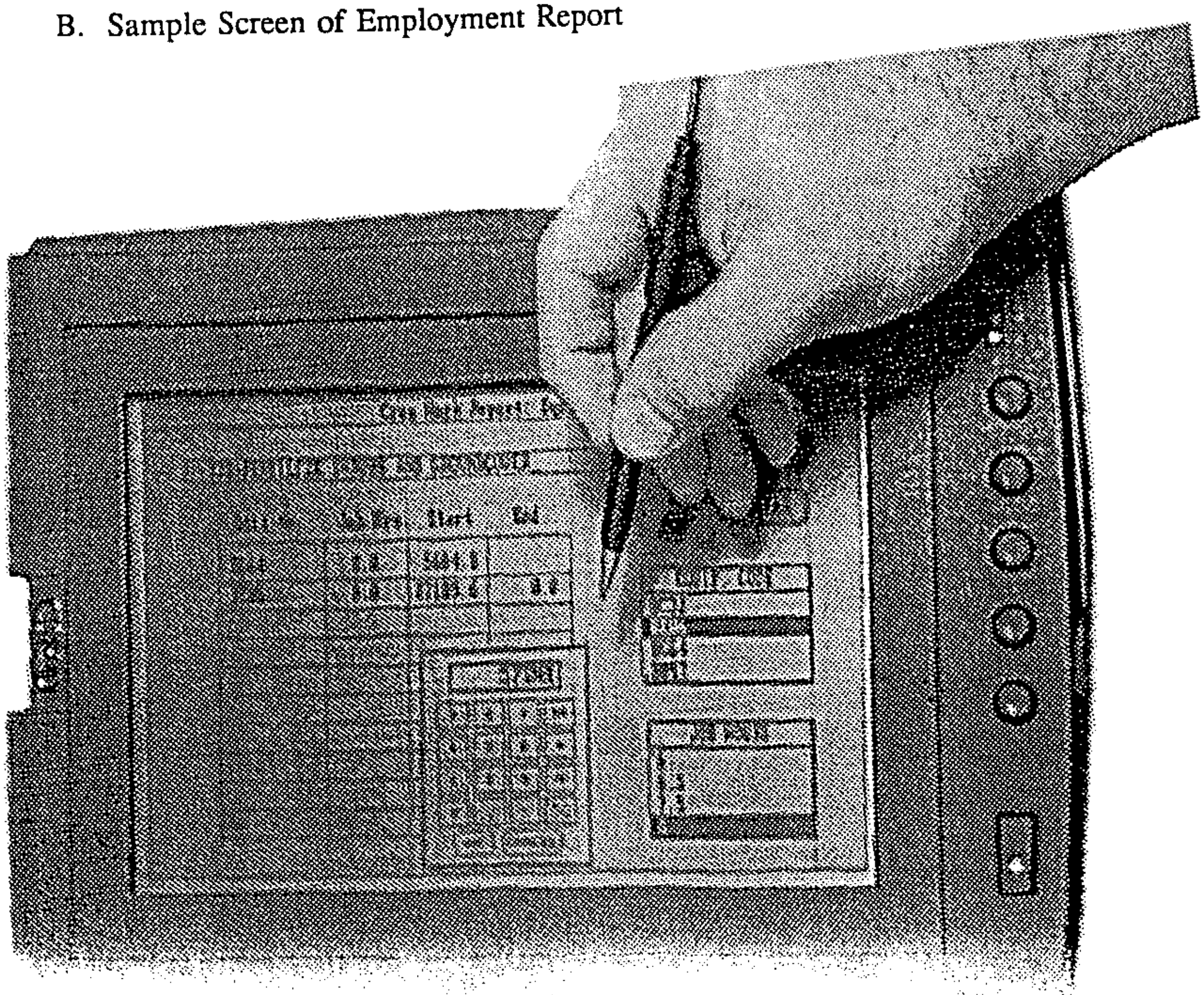
IA= Irrigation Appliance

IL= Irrigation Line

A. Sample Screen of Raster Map Image on (PDCU)



B. Sample Screen of Employment Report



P I M a   M A I N   M E N U

REPORTS   QUERIES   DATA FILES   ARC/DBASE   ACTIVITIES   PRINT   EXIT

View Report
Create Report
Modify Report
Print Report

1) Report Menu

P I M a   M A I N   M E N U

REPORTS   QUERIES   DATA FILES   ARC/DBASE   ACTIVITIES   PRINT   EXIT

Show Query Files
Create Query
Modify Query

2) Query Menu

A. Six Views of the Main Menu in Dbase IV for PIMa

P I M a   M A I N   M E N U

REPORTS | QUERIES | DATA FILES | ARC/DBASE | ACTIVITIES | PRINT | EXIT

View Data:
- VEGETATION
- VEG. DICT.
- IRRIG. APP
- IRRIG. LINE
- SURFACE
- SOIL DICT.
- TRANSACTION
- ACTIVITIES

3) Database Display Menu

P I M a   M A I N   M E N U

REPORTS | QUERIES | DATA FILES | ARC/DBASE | ACTIVITIES | PRINT | EXIT

Go To Arc/dBase

4) Transfer to Arc/Dbase Option

A. Six Views of the Main Menu in Dbase IV for PIMa

```
P I M a   M A I N   M E N U

REPORTS   QUERIES   DATA' FILES   ARC/DBASE   ACTIVITIES   PRINT   EXIT

                                              WORK REPORTS:
                                                New Work Report
                                                Revise Existing
                                                Input Crew Reports
                                              CATALOGS:
                                                Create New Monthly
                                                Review Catalog List
                                                Remove Old Catalog
```

5) Activities Menu

```
P I M a   M A I N   M E N U

REPORTS   QUERIES   DATA FILES   ARC/DBASE   ACTIVITIES   PRINT   EXIT

                                                          Database File
                                                          Query Report
                                                          Work Report
```

6) Print Menu

A. Six Views of the Main Menu in Dbase IV for PIMa

Layout Fields Condition Update Exit 11:17:30

Tran.dbf	↕IDCODE	↕ID	↕ACT_NO	↕ACTIVITY	↕DESCRIP	↕QUAN	↕CST_TRA
	"146.2T06"						

View

TREE	Tran-> DATE	Tran-> ROUTE	Tran-> IDCODE	Tran-> ID

Query | D:\dbase4\pilot\TREE | Field 3/9 | |
Prev/Next field:Shift-Tab/Tab Data:F2 Size:Shift-F7 Prev/Next skel:F3/F4

Layout Fields Condition Update Exit 11:19:5(

Tran.dbf	↕DATE	↕ROUTE	↕IDCODE	↕ID	↕ACT_NO	↕ACTIVITY	DESCRIP	↕Q(

CONDITION BOX
((A->ACT_NO=312))

View

STAKING	Tran-> DATE	Tran-> ROUTE	Tran-> IDCODE	Tran-> ID

Query | D:\dbase4\pilot\STAKING | Field 7/9 | |
Prev/Next field:Shift-Tab/Tab Data:F2 Size:Shift-F7 Prev/Next skel:F3/F

B. Examples of Pregenerated Query Screens

```
Layout   Fields   Bands   Words   Go To   Print   Exit              11:00:59
[·······▼·1·····▼···2···▼······3·▼·······▼·······▼·5·····▼···6···▼·····7·▼····
Page     Header  Band
Page No. 999
MM/DD/YY
DATE     ROUTE IDCODE   ID   ACT_NO ACTIVITY  DESCRIP      QUAN   CST_TRAN
Report   Intro   Band
Detail           Band
MM/DD/YY XXXXXX XXXXXXXXX XXXXX XXXX  XXXXXXXXXX XXXXXXXX 99999.9 9999999.99
Report   Summary Band
                                                          99999.9 9999999.99
Page     Footer  Band

Report  |D:\dbase4\pilot\TRANS    |Band 1/5          |File:Tran    |
          Add field:F5  Select:F6  Move:F7  Copy:F8  Size:Shift-F7
```

```
Layout   Fields   Bands   Words   Go To   Print   Exit              11:04:39
[·······▼·1·····▼···2···▼······3·▼·······▼·······▼·5·····▼···6···▼·····7·▼····
Page     Header  Band
Page No. 999
MM/DD/YY
ACT_NO   CST_TRAN
Report   Intro   Band
Detail           Band
XXXX    9999999.99
Report   Summary Band
Page     Footer  Band

Report  |D:\dbase4\pilot\ACT_AVG  |Band 1/5          |File:Tran    |
          Add field:F5  Select:F6  Move:F7  Copy:F8  Size:Shift-F7
```

C. Examples of Pregenerated Report Screens

```
Exit
                         Work Report Menu

Program:100  Activity:311  Suffix:W      Job No:100         Date:10/21/91
Activity Description:TRIM TREES
Org: 4170 Route:I-10 Begin MP: 146.0 End MP: 146.1 Dir:NORTH    Road: R
---------------LABOR-----------Exit Employee---------EQUIPMENT----------
Emp No.     RT     OT     CT    TRF    TRV    TRN| Unit
BRUGEM                                           |
```

D. Scheduling Menu for Daily Work Reports

ARC 3.4D MENUS FOR THE GRAPHICS PORTION OF THE PIMa SYSTEM

MAIN MENU

SELECT FROM THE FOLLOWING:

LOCATION	INVENTORY	MAINTENANCE	DATABASE FILES
MILEPOST	TREES	VEGETATION	RESULT_QUERY
ROUTE	SHRUBS	SURFACE	DATAFILE
INTERSECT	GROUND	IRRIGATION	
MAPEXTENT	APPLIANCES		
	LINES_IRRIG		

HIDE_MENU   ZOOM   KEYBOARD   DBASE   QUIT

SPECIFIC MILEPOST INPUT MENU

SELECT THE MILEPOST LOCATION:

FROM :
TO :

OK   CANCEL

SPECIFIC ROUTE SELECTION MENU

SELECT THE DESIRED ROUTE:

PILOT STUDY AREA
AGUA FRIA (LOOP 101)
BLACK CANYON (I-17 NORTH)
E. PAPAGO (LOOP 202)
HOHOKAM EXPRESSWAY (SH 143)
MARICOPA FROM I-17 SOUTH TO SUPERSTITION
PAPAGO (I-10 WEST)
PIMA I-10 SOUTH OF SUPERSTITION
SQUAW PEAK (SH 51)
SUPERSTITION (SH 360)

CANCEL

SELECTION MENU FOR INTERSECTIONS

SELECT THE DESIRED INTERSTATE SECTION:

1 I-10 from 7th AVENUE to 7th STREET
2 I-10 from 7th STREET to 16th STREET
3 I-10 from 16th STREET to VAN BUREN
4 I-10 from VAN BUREN to BUCKEYE

CANCEL

COLOR SELECTION FOR POLYGON IDENTIFICATION AND QUERIES

SELECT THE COLOR NUMBER TO REPRESENT THE SELECTED ITEMS:

1 WHITE	2 RED	3 GREEN	4 BLUE	5 YELLOW
6 CYAN	7 MAGENTA	8 DK GRAY	9 LT GRAY	10 LT RED
11 LT GREEN	12 LT BLUE	13 LT YELLOW	14 LT CYAN	15 LT MAGENTA
66 RED HAT	68 BLUE HAT	53 WHITE SQ	55 GREEN SQ	44 BLUE DIAG

CANCEL

MENU LISTING TREES FOR IDENTIFICATION OR QUERY

SELECT THE TREE ID YOU WANT TO IDENTIFY

'ACMI'	Acacia minuta	Southwest Sweet Acacia
'EULE'	Eucalyptus leuconylon 'Rosea'	White Ironbark
'EUPA'	Eucalyptus papuana	Ghost Gum
'EUTO'	Eucalyptus torquata	Coral Gum
'PHDA'	Phoenix, dactylifera	Date Palm
'PIEL'	Pinus eldarica	Afghan Pine
'PRAL'	Prosopis alba	Argentine Mesquite
'SOSE'	Sophora secundiflora	Mescal Bean
'VIAN'	Vitexangus-castus	Chaste Tree
'WAFI'	Washingtonia filifera	California Fan Palm

SELECTION FOR SINGLE OR MULTIPLE QUERIES

SELECT THE TYPE OF QUERY

SINGLE MULTIPLE CANCEL

ENTER A VALUE FOR THE ITEM:

QUAN	FACE	PLANTED	SIZEPLANTE
10	'NORTH'	'1/89'	'1GAL
20	'SOUTH'	'8/89'	'5GAL
30	'EAST'	'1/91'	'10FT
50	'WEST'		'15FT
100	'NONE'		'20FT
200			'25FT
300			'30FT
400			'35FT
500			'40FT
		CANCEL	'45FT

MENU FOR GROUND MAINTENANCE ACTIVITIES

SELECT THE GROUND MAINTENANCE ACTIVITY

'341' GRANITE EROSION CONTROL - MAJOR
'342' GRANITE EROSION CONTROL - MINOR
'343' NON-GRANITE EROSION CONTROL
'344' CHEMICAL SOIL STAB.APPLI. - LANDSCAPE
'345' REPAIR BERM SAND BASINS

'351' MAJOR L/S VEG.CONTROL - HERBICIDES
'352' MAJOR L/S VEG.CONTROL - GROWTH REGULATOR
'353' MINOR LANDSCAPE VEGETATION CONTROL
'354' LANDSCAPE INSECT CONTROL
'355' LANDSCAPE RODENT CONTROL - CHEMICAL

'361' LANDSCAPE LITTER CONTROL
'362' BLUE STAKE MARKING
'363' MANUAL WEED CONTROL
'369' OTHER LANDSCAPE MAINTENANCE

CANCEL

MENU FOR IRRIGATION ACTIVITIES

SELECT THE IRRIGATION ACTIVITY CODE

#331 IRRIGATION INSPECTION - MAJOR
#332 IRRIGATION INSPECTION - MINOR
#333 MAJOR IRRIG. APPLI. REPAIR/REPLACEMENT
#334 IRRIGATION LINE REPAIR

CANCEL

IRRIGATION APPLIANCE TYPE SELECTION MENU

SELECT THE TYPE OF APPLIANCE

'GV' GATE VALVE
'RCV' REMOTE CONTROL VALVE
'BP' BACK FLOW PREVENTION
'WM' WATER METER
'FS' FLOW SENSOR
'PRR' PRESSURE REDUCTION RISER
'ARC' ANTENNA/RADIO COMMUNICATION
'QC' QUICK COUPLER

CANCEL

APPENDIX C (Continued)

IV. Examples of Automated Data Queries and Reports

<u>dBase</u>

A. Query of the average cost per activity
B. Query of activity: staking trees from mile 146.0 to 146.9
C. Query of activities performed on <u>Washingtonia</u> <u>filifera</u> from mile 146.0 to 146.9
D. Query of activities costing greater than $ 100.00 performed after 09/01/91
E. Screen for reviewing the scheduling of daily work reports

<u>Arc/3.4D</u>

A. Arc/3.4D map- simple query of graphics database

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ACT_NO	CST_TRAN
311	127.50
312	194.03
313	34.32
314	60.92
315	33.81
321	70.96
322	136.24
323	65.36
324	34.83
331	1.01
332	10.00
333	77.93
334	21.50
341	79.73
342	114.81
351	48.33
352	52.38
353	35.00
354	185.38
355	126.92
361	40.00
362	202.50
363	40.00
369	29.67

A. Query of the Average Cost Per Activity

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DATE	ROUTE	IDCODE	ID	ACT_NO	ACTIVITY	DESCRIP	QUAN	CST_TRAN
11/16/90	I10	146.4T01	ACMI	312	Stake Tree	N/A	10.0	117.00
11/18/90	I10	146.4T18	VAFI	312	Stake Tree	N/A	5.0	79.00
11/24/90	I10	146.5T05	EUTO	312	Stake Tree	N/A	12.0	134.00
11/29/90	I10	146.5T02	VAFI	312	Stake Tree	N/A	5.0	77.00
12/03/90	I10	146.5T06	EULE	312	Stake Tree	N/A	22.0	330.00
12/15/90	I10	146.5T25	EULE	312	Stake Tree	N/A	3.0	50.00
12/15/90	I10	146.5T35	EUTO	312	Stake Tree	N/A	8.0	132.00
12/18/90	I10	146.5T18	LTTH	312	Stake Tree	N/A	5.0	77.00
12/19/90	I10	146.5T32	EUTO	312	Stake Tree	N/A	6.0	87.00
12/23/90	I10	146.5T20	PRAL	312	Stake Tree	N/A	1.0	15.00
12/30/90	I10	146.5T14	VAFI	312	Stake Tree	N/A	4.0	65.00
01/03/91	I10	146.5T16	PIBR	312	Stake Tree	N/A	22.0	330.00
01/05/91	I10	146.5T24	EUTO	312	Stake Tree	N/A	5.0	78.00
01/05/91	I10	146.5T34	EUTO	312	Stake Tree	N/A	1.0	15.00
01/07/91	I10	146.6T06	SOSE	312	Stake Tree	N/A	5.0	80.00
01/09/91	I10	146.5T19	EULE	312	Stake Tree	N/A	3.0	54.00
01/11/91	I10	146.5T36	EUTO	312	Stake Tree	N/A	2.0	32.00
01/11/91	I10	146.5T31	EULE	312	Stake Tree	N/A	5.0	75.00
01/12/91	I10	146.6T05	PIBR	312	Stake Tree	N/A	12.0	190.00
01/14/91	I10	146.6T15	EUTO	312	Stake Tree	N/A	14.0	225.00
01/17/91	I10	146.6T16	EULE	312	Stake Tree	N/A	19.0	340.00
01/17/91	I10	146.5T29	PRAL	312	Stake Tree	N/A	1.0	16.00
01/19/91	I10	146.5T30	PIBR	312	Stake Tree	N/A	30.0	520.00
01/22/91	I10	146.7T01	SOSE	312	Stake Tree	N/A	53.0	793.00
01/24/91	I10	146.7T06	EULE	312	Stake Tree	N/A	3.0	54.00
01/24/91	I10	146.5T26	ACMI	312	Stake Tree	N/A	9.0	170.00
01/25/91	I10	146.7T12	EULE	312	Stake Tree	N/A	18.0	354.00
01/27/91	I10	146.6T08	SOSE	312	Stake Tree	N/A	58.0	913.00
01/30/91	I10	146.6T14	EULE	312	Stake Tree	N/A	20.0	310.00
01/30/91	I10	146.8T09	SOSE	312	Stake Tree	N/A	48.0	786.00
02/03/91	I10	146.8T15	VAFI	312	Stake Tree	N/A	3.0	54.00
02/04/91	I10	146.5T17	EULE	312	Stake Tree	N/A	2.0	34.00
02/05/91	I10	146.5T25	EULE	312	Stake Tree	N/A	3.0	57.00
02/07/91	I10	146.7T02	PIBR	312	Stake Tree	N/A	23.0	311.00
02/07/91	I10	146.9T06	VAFI	312	Stake Tree	N/A	8.0	165.00
02/08/91	I10	146.9T18	VARO	312	Stake Tree	N/A	6.0	111.00
02/09/91	I10	146.9T08	SOSE	312	Stake Tree	N/A	1.0	16.00
02/10/91	I10	146.8T01	PIBR	312	Stake Tree	N/A	9.0	127.00
							464.0	7373.00

B. Query of Activity: Staking Trees From Mile 146.0 to 146.9

DATE	ROUTE	IDCODE	ID	ACT_NO	ACTIVITY	DESCRIP	QUAN	CST_TRAN
11/18/90	I10	146.4T18	WAFI	312	Stake Tree	N/A	5.0	79.00
02/15/91	I10	146.8T04	WAFI	313	Fert Trees	Liquid	3.0	6.00
09/03/90	I10	146.0T02	WAFI	311	Trim Trees	N/A	14.0	216.00
10/11/91	I10	146.0T02	WAFI	363	Weed Ctl	Manual	0.5	20.00
02/27/91	I10	146.9T12	WAFI	313	Fert Trees	Liquid	6.0	13.00
03/02/91	I10	146.0T13	WAFI	313	Fert Trees	Liquid	6.0	20.00
09/07/91	I10	146.0T13	WAFI	311	Trim Trees	N/A	6.0	87.00
11/29/90	I10	146.5T02	WAFI	312	Stake Tree	N/A	5.0	77.00
09/09/91	I10	146.5T14	WAFI	314	Replace Tr	1 gal	4.0	65.00
09/01/90	I10	146.0T02	WAFI	315	Remove Tr	Water	5.0	50.00
03/17/91	I10	146.0T27	WAFI	313	Fert Trees	Stake	7.0	25.00
04/05/91	I10	146.0T02	WAFI	313	Fert Trees	Stakes	14.0	52.00
09/01/90	I10	146.0T02	WAFI	314	Replace Tr	5 gal	5.0	167.00
09/04/90	I10	146.5T14	WAFI	315	Remove Tr	Disease	4.0	43.00
12/30/90	I10	146.5T14	WAFI	312	Stake Tree	N/A	4.0	65.00
05/05/91	I10	146.3T09	WAFI	313	Fert Trees	Liquid	5.0	15.00
05/20/91	I10	146.4T07	WAFI	313	Fert Trees	Stake	4.0	13.00
05/20/91	I10	146.4T05	WAFI	313	Fert Trees	Liquid	8.0	19.00
05/26/91	I10	146.4T16	WAFI	313	Fert Trees	Liquid	9.0	22.00
06/04/91	I10	146.5T02	WAFI	313	Fert Trees	Stake	5.0	17.00
06/07/91	I10	146.4T18	WAFI	313	Fert Trees	Liquid	5.0	16.00
06/12/91	I10	146.5T14	WAFI	313	Fert Trees	Stakes	4.0	13.00
09/18/91	I10	146.0T27	WAFI	311	Trim Trees	N/A	7.0	96.00
09/18/90	I10	146.0T32	WAFI	311	Trim Trees	N/A	4.0	63.00
10/16/90	I10	146.0T32	WAFI	314	Replace Tr	1 gal	4.0	72.00
07/25/91	I10	146.8T04	WAFI	313	Fert Trees	Stake	3.0	15.00
08/12/91	I10	146.8T15	WAFI	313	Fert Trees	Liquid	3.0	11.00
08/15/91	I10	146.9T06	WAFI	313	Fert Trees	Stakes	8.0	30.00
08/21/91	I10	146.9T12	WAFI	313	Fert Trees	Liquid	6.0	24.00
02/03/91	I10	146.8T15	WAFI	312	Stake Tree	N/A	3.0	54.00
12/10/90	I10	146.4T16	WAFI	315	Remove Tr	Freeze	2.0	22.00
10/13/90	I10	146.3T09	WAFI	311	Trim Trees	N/A	5.0	82.00
09/05/91	I10	146.4T18	WAFI	313	Fert Trees	Stake	5.0	19.00
09/11/91	I10	146.4T16	WAFI	313	Fert Trees	Liquid	5.0	19.00
10/22/90	I10	146.4T07	WAFI	311	Trim Trees	N/A	4.0	73.00
02/07/91	I10	146.9T06	WAFI	312	Stake Tree	N/A	8.0	165.00
12/13/90	I10	146.4T16	WAFI	314	Replace Tr	5 gal	2.0	64.00
10/25/90	I10	146.4T05	WAFI	311	Trim Trees	N/A	8.0	113.00
10/25/90	I10	146.4T16	WAFI	311	Trim Trees	N/A	9.0	124.00
10/15/90	I10	146.0T32	WAFI	315	Remove Tr	Water	4.0	42.00
07/26/91	I10	146.4T05	WAFI	369	Other Main	Mowing	1.0	10.00
09/29/91	I10	146.8T15	WAFI	313	Fert Trees	Stake	3.0	12.00
09/30/91	I10	146.9T12	WAFI	313	Fert Trees	Liquid	6.0	22.00
09/30/91	I10	146.9T06	WAFI	313	Fert Trees	Stakes	8.0	33.00
							236.5	2265.00

C. Query of Activities Performed on <u>Washingtonia</u> <u>Filifera</u> from mile 146.0 to 146.9

DATE	ROUTE	IDCODE	ID	ACT_NO	ACTIVITY	DESCRIP	QUAN	CST_TRAN
09/02/91	I10	147.1T03	PRAL	311	Trim Trees	N/A	18.0	300.00
09/03/91	I10	146.3S20	MYPA	322	Fert Shrub	Granular	204.0	400.00
09/04/91	I10	149.0S20	VEPE	321	Trim Shrub	N/A	143.0	145.00
09/04/91	I10	145.7T14	EULER	311	Trim Trees	N/A	32.0	501.00
09/04/91	I10	147.1T13	CEFL	311	Trim Trees	N/A	16.0	275.00
09/05/91	I10	148.0T08	CEFL	311	Trim Trees	N/A	13.0	185.00
09/06/91	I10	149.0S19	VEPE	322	Fert Shrub	Granular	112.0	125.00
09/06/91	I10	148.0T24	EUMI	311	Trim Trees	N/A	8.0	125.00
09/07/91	I10	145.6S03	NEOLP	321	Trim Shrub	N/A	102.0	110.00
09/07/91	I10	144.7S20	NEOLP	322	Fert Shrub	Stake	59.0	120.00
09/07/91	I10	149.0S26	ACRE	322	Fert Shrub	Stake	56.0	115.00
09/07/91	I10	144.7T23	PRAL	311	Trim Trees	N/A	17.0	280.00
09/07/91	I10	147.2T05	EUMI	311	Trim Trees	N/A	10.0	156.00
09/09/91	I10	144.8T07	EUTO	311	Trim Trees	N/A	7.0	110.00
09/10/91	I10	147.1S05	NEOLS	321	Trim Shrub	N/A	122.0	125.00
09/10/91	I10	147.1S02	VEPE	322	Fert Shrub	Granular	96.0	200.00
09/11/91	I10	146.4T14	EULE	311	Trim Trees	N/A	16.0	258.00
09/11/91	I10	147.2S03	SAGR	322	Fert Shrub	Stake	79.0	160.00
09/11/91	I10	148.1T03	EUMI	311	Trim Trees	N/A	12.0	180.00
09/12/91	I10	144.6T38	EUPA	311	Trim Trees	N/A	8.0	125.00
09/14/91	I10	147.3T22	CEFL	311	Trim Trees	N/A	10.0	155.00
09/15/91	I10	146.4S15	MYPA	322	Fert Shrub	Stake	89.0	180.00
09/15/91	I10	145.7S09	BACE	321	Trim Shrub	N/A	106.0	110.00
09/16/91	I10	146.6S02	MYPA	321	Trim Shrub	N/A	99.0	110.00
09/16/91	I10	148.1S21	LELA	322	Fert Shrub	Granular	81.0	160.00
09/17/91	I10	144.8S23	ENFA	322	Fert Shrub	Granular	80.0	160.00
09/17/91	I10	144.8T21	SOSE	311	Trim Trees	N/A	8.0	125.00
09/18/91	I10	147.4T16	EUMI	311	Trim Trees	N/A	8.0	125.00
09/18/91	I10	145.9T07	WAFI	311	Trim Trees	N/A	7.0	110.00
09/19/91	I10	146.2T08	EULE	311	Trim Trees	N/A	16.0	272.00
09/19/91	I10	146.5S15	CAME	321	Trim Shrub	N/A	138.0	150.00
09/20/91	I10	146.3T06	SOSE	311	Trim Trees	N/A	14.0	206.00
09/20/91	I10	146.4G01	GM	361	LitterPkup	N/A	11.0	110.00
09/20/91	I10	148.1S34	SAGR	322	Fert Shrub	Stake	188.0	375.00
09/21/91	I10	146.3T02	EULE	311	Trim Trees	N/A	12.0	180.00
09/21/91	I10	147.2S26	VEPE	322	Fert Shrub	Stake	189.0	370.00
09/21/91	I10	149.0S62	ACNO	322	Fert Shrub	Granular	193.0	385.00
09/22/91	I10	146.9G04	GM	342	Grn Ctl Mi	Granite	4.5	225.00
09/22/91	I10	145.8S07	LECA	321	Trim Shrub	N/A	134.0	140.00
09/22/91	I10	148.2S11	SAGR	322	Fert Shrub	Stake	73.0	150.00
09/23/91	I10	149.1S02	ENFA	321	Trim Shrub	N/A	239.0	240.00
09/24/91	I10	146.3T13	SOSE	311	Trim Trees	N/A	27.0	410.00
09/24/91	I10	146.8S06	BASAC	321	Trim Shrub	N/A	334.0	350.00
09/24/91	I10	148.2T10	EUMI	311	Trim Trees	N/A	7.0	118.00
09/24/91	I10	145.9T15	WAFI	311	Trim Trees	N/A	7.0	111.00
09/25/91	I10	146.5S13	MYPA	322	Fert Shrub	Stake	68.0	140.00
09/25/91	I10	146.6T08	SOSE	313	Fert Trees	Liquid	58.0	172.00
09/25/91	I10	146.5T30	PIBR	313	Fert Trees	Stake	30.0	110.00
09/25/91	I10	146.0IA09	PRR	333	Irr Rep Ap	Replace	1.0	180.00
09/25/91	I10	145.6S03	NEOLP	322	Fert Shrub	Stake	102.0	200.00
09/25/91	I10	147.4T33	PRAL	311	Trim Trees	N/A	8.0	126.00
09/26/91	I10	146.2T12	SOSE	311	Trim Trees	N/A	28.0	403.00
09/27/91	I10	146.3IA03	PRR	333	Irr Rep Ap	Replace	1.0	170.00
09/27/91	I10	147.4T45	EUMI	311	Trim Trees	N/A	7.0	118.00
09/28/91	I10	146.4IA15	PRR	333	Irr Rep Ap	Replace	1.0	180.00
09/28/91	I10	148.2S31	MYPA	322	Fert Shrub	Granular	56.0	115.00
09/28/91	I10	148.8T17	EUMI	311	Trim Trees	N/A	7.0	110.00
09/29/91	I10	146.4S04	MYPA	322	Fert Shrub	Stake	126.0	300.00
09/29/91	I10	147.4T58	WAFI	311	Trim Trees	N/A	7.0	116.00

DATE	ROUTE	IDCODE	ID	ACT_NO	ACTIVITY	DESCRIP	QUAN	CST_TRAN
09/29/91	I10	144.8T27	EULER	311	Trim Trees	N/A	9.0	140.00
09/29/91	I10	148.8T18	ACSM	311	Trim Trees	N/A	10.0	155.00
09/30/91	I10	146.3S20	MYPA	322	Fert Shrub	Stake	204.0	400.00
09/30/91	I10	146.9IA07	PRR	333	Irr Rep Ap	Replace	1.0	180.00
09/30/91	I10	145.7S15	MYPA	322	Fert Shrub	Stake	215.0	430.00
09/30/91	I10	145.9T21	PHDA	311	Trim Trees	N/A	8.0	125.00
10/01/91	I10	145.9S04	MYPA	321	Trim Shrub	N/A	257.0	260.00
10/02/91	I10	146.7IA06	PRR	333	Irr Rep Ap	Replace	1.0	170.00
10/02/91	I10	146.1IA19	PRR	333	Irr Rep Ap	Replace	1.0	180.00
10/02/91	I10	147.3S12	LAMO	322	Fert Shrub	Granular	237.0	460.00
10/02/91	I10	149.1S19	ENFA	322	Fert Shrub	Stake	126.0	250.00
10/02/91	I10	148.3T41	ACSM	311	Trim Trees	N/A	16.0	225.00
10/03/91	I10	145.9S05	LAMO	321	Trim Shrub	N/A	294.0	300.00
10/04/91	I10	147.3S15	BAMU	321	Trim Shrub	N/A	111.0	115.00
10/05/91	I10	147.3S20	LAMO	322	Fert Shrub	Stake	320.0	640.00
10/07/91	I10	145.9S05	LAMO	322	Fert Shrub	Granular	294.0	600.00
10/07/91	I10	148.3S37	LELA	322	Fert Shrub	Granular	70.0	140.00
10/08/91	I10	149.1S32	ENFA	322	Fert Shrub	Stake	52.0	105.00
10/09/91	I10	149.1S31	ENFA	321	Trim Shrub	N/A	274.0	275.00
10/09/91	I10	145.9S16	LEFRG	322	Fert Shrub	Granular	78.0	160.00
10/10/91	I10	147.4S17	CAER	322	Fert Shrub	Stake	78.0	160.00
10/11/91	I10	148.4S09	SAGR	322	Fert Shrub	Stake	85.0	170.00
10/11/91	I10	148.5T10	ACSM	311	Trim Trees	N/A	8.0	125.00
10/11/91	I10	149.1T40	ACSM	311	Trim Trees	N/A	8.0	125.00
10/12/91	I10	147.4S28	NEOLP	322	Fert Shrub	Granular	58.0	120.00
10/12/91	I10	147.4S41	ENFA	322	Fert Shrub	Granular	145.0	290.00
10/12/91	I10	147.5T46	EUMI	311	Trim Trees	N/A	16.0	275.00
10/12/91	I10	146.3T08	VIAN	311	Trim Trees	N/A	8.0	125.00
10/13/91	I10	148.5T31	ACSM	311	Trim Trees	N/A	9.0	140.00
10/14/91	I10	147.4S11	CAPH	321	Trim Shrub	N/A	120.0	120.00
10/16/91	I10	147.4S44	LELA	321	Trim Shrub	N/A	113.0	120.00
10/16/91	I10	147.5T72	CEFL	311	Trim Trees	N/A	10.0	155.00
10/17/91	I10	148.5S07	VEPE	321	Trim Shrub	N/A	160.0	160.00
10/19/91	I10	148.4S26	VEPE	322	Fert Shrub	Granular	60.0	120.00
10/19/91	I10	148.6T20	CEFL	311	Trim Trees	N/A	10.0	160.00
10/21/91	I10	148.5S15	VEPE	322	Fert Shrub	Granular	111.0	220.00
10/23/91	I10	148.5S20	MYPA	322	Fert Shrub	Stake	90.0	180.00
10/23/91	I10	144.6S23	NEOLR	322	Fert Shrub	Stake	530.0	1060.00
10/26/91	I10	148.6T24	EUMI	311	Trim Trees	N/A	7.0	118.00
10/27/91	I10	147.5S12	CAPH	321	Trim Shrub	N/A	117.0	120.00
10/28/91	I10	148.5S40	SAGR	322	Fert Shrub	Granular	91.0	180.00
10/28/91	I10	147.7T06	CEFL	311	Trim Trees	N/A	11.0	168.00
10/29/91	I10	144.6S27	MYPA	322	Fert Shrub	Granular	62.0	120.00
10/29/91	I10	148.7T09	CEFL	311	Trim Trees	N/A	8.0	125.00
10/30/91	I10	147.7T31	PRAL	311	Trim Trees	N/A	14.0	200.00
10/31/91	I10	148.6S11	NEOLS	321	Trim Shrub	N/A	186.0	190.00
10/31/91	I10	148.6S10	ACRE	322	Fert Shrub	Stake	54.0	110.00
10/31/91	I10	144.6S32	MYPA	322	Fert Shrub	Granular	123.0	250.00
10/31/91	I10	147.8T07	CEFL	311	Trim Trees	N/A	7.0	118.00
10/31/91	I10	148.8T07	ACSM	311	Trim Trees	N/A	9.0	140.00
11/01/91	I10	148.1S37	SAGR	322	Fert Shrub	Stake	93.0	185.00
11/01/91	I10	147.8T08	EUMI	311	Trim Trees	N/A	18.0	300.00
11/02/91	I10	147.5S36	NEOLP	321	Trim Shrub	N/A	111.0	115.00
							8812.5	23036.00

D. Query of Activities Costing Greater Than $100.00 Performed After 09/01/91

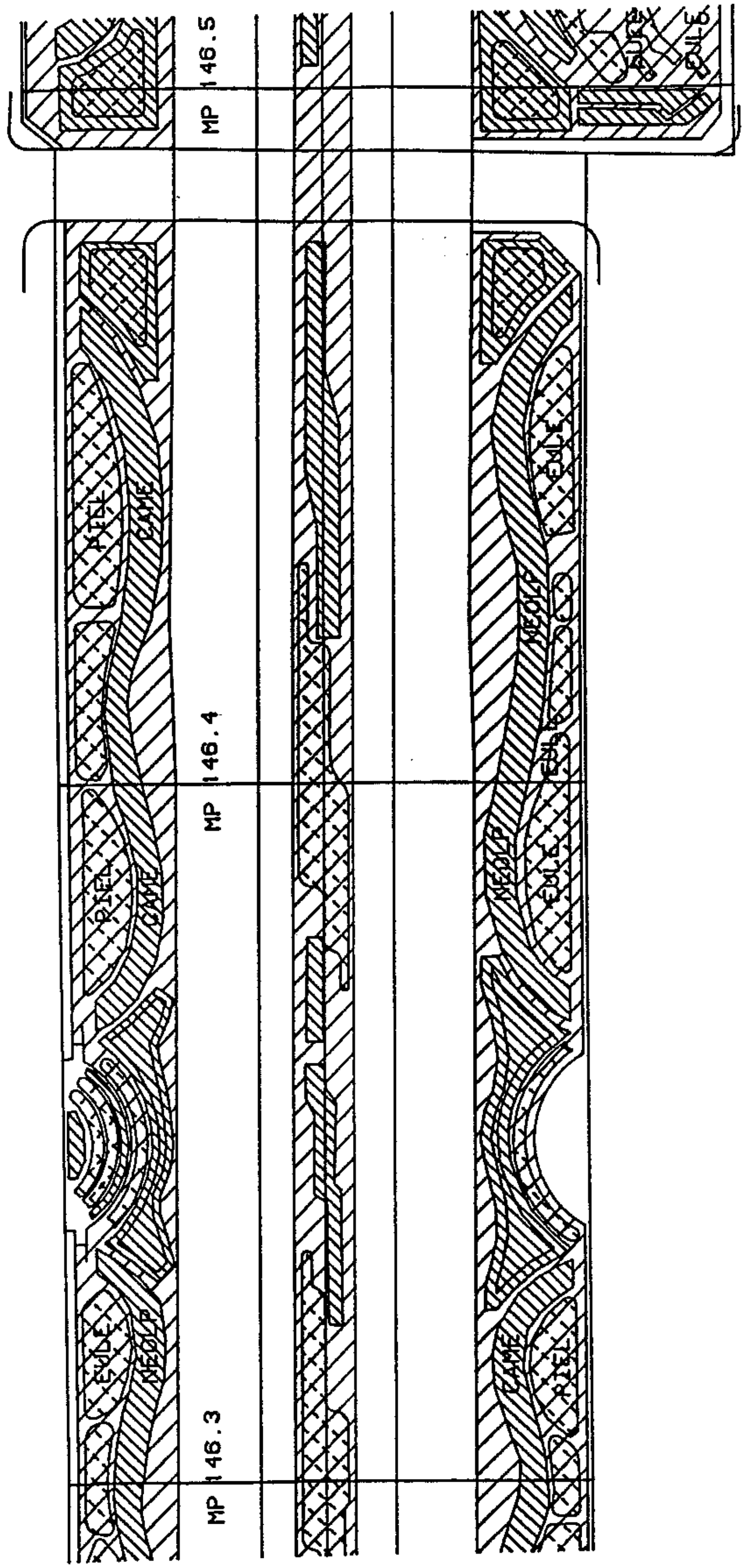
Press Esc When Done

Arizona Department of Transportation
SCHEDULED DAILY WORK REPORT

PROGRAM 100 ACT NO. 311 SUFFIX V JOB_NO 100 DATE: / /
ACTIVITY DESCRIPTION TRIM TREES
ORG 4170 ROUTE I-10 BEG MP 146.0 END MP 146.1 DIR NORTH RD_TYPE R

LABOR							EQUIPMENT			
EMP_NO.	RT	OT	CT	TRF	TRV	TRN	EQP_NO	HRS	START	END
BRUGEM	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0
	0.0	0.0	0.0	0.0	0.0	0.0		0.0	0.0	0.0

E. Screen for Reviewing the Scheduling of Daily Work Reports



A. Arc/3.4D Map-Simple Query of Graphics Database