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ALBANIA SERIES

August 1998

GPS Methodology for Cadastral Surveying and Mapping in Albania

Grenville Barnes, Bruce Chaplin, D. David Moyer



Land Tenure Center

AN INSTITUTE FOR
RESEARCH AND EDUCATION
ON SOCIAL STRUCTURE,
RURAL INSTITUTIONS,
RESOURCE USE,
AND DEVELOPMENT

UNIVERSITY OF WISCONSIN —
MADISON

GPS METHODOLOGY FOR CADASTRAL SURVEYING AND MAPPING IN ALBANIA

by

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with

Eric DesRoche, Mark Eckl, Michael Sartori

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GPS METHODOLOGY FOR CADASTRAL SURVEYING AND MAPPING IN ALBANIA

by

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1. ASSESSMENT OF EXISTING SURVEYING AND MAPPING POTENTIAL FOR GPS METHODOLOGY

The Immovable Property Registration System (IPRS) Project is part of the Albanian Land Market Action Plan (LMAP). The goal of the LMAP is to assist the Government of Albania in developing the technical and institutional support necessary to operate a property title registration system. The title registry system is a critical component for the Government of Albania as the country moves from a planned, centrally controlled economy to an open, market-based economy.

This paper is a compilation of three reports written over the 1993–96 period in the development and testing of a cadastral surveying and mapping methodology to support land registration. Section 1 covers initial fieldwork by an international team (Grenville Barnes and David Moyer) contracted by the LMAP during a two-and-a-half-week period in July 1993 to evaluate options for cadastral surveying and mapping in Albania. Section 2 contains the results from a second team (Barnes, Moyer, Michael Sartori, Ramesh Shrestha, Bruce Chaplin, and Eric DesRoche) that worked, in June 1994, on defining and testing a methodology utilizing Global Positioning System (GPS) technology and on evaluating the costs and benefits of various surveying and mapping options. Finally, Section 3 reports on further testing, in 1995, by Barnes and Mark Eckl, of the newly developed GPS methodology.

1.1 BACKGROUND

Any current or future property registration system for Albania must be viewed within the larger context of land rights and should be designed to support the massive transfer of land from state to

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private ownership. This transfer defines the most immediate needs in terms of parcel demarcation, delineation, and registration.

It is estimated that over 2 million parcels will need to be surveyed and registered. In the state cooperatives alone, land privatization involves some 531,000 hectares and approximately 375,000 families (Stanfield et al. 1992). In addition to this, rights to urban, state farm, pasture, and forest land will also be transferred. The transfer of agricultural land is already under way, and it is crucial that a reliable IPRS be put in place to both protect these rights and allow for an orderly land market. The need for a quick response is regarded as paramount in the design and implementation of an IPRS for Albania.

There is newly available technology in the West that could support much of the surveying, mapping, and general land information system (LIS) work that needs to be done. However, we believe that the enthusiasm for adoption and use of this technology must be tempered by the realities that exist in Albania at the present (1993) time (e.g., high unemployment, little support available for technology, relative isolation in terms of obtaining off-site support, as yet undeveloped institutional framework to support and manage a complex, multi-faceted project). Therefore, the general approach on which this proposal is based is to take advantage of the strengths that exist in Albania while, at the same time, not overextending the resources and capabilities that do exist.

Based on discussions with project personnel and our review of project materials written earlier, we suggest the following general guidelines in moving the IPRS project forward:

1. The IPRS needs to be put in place as soon as possible, since land has already been distributed and is being farmed by many new owners.
2. As part of the IPRS, it would be useful to prepare a plan that would help guide the development and integration of all land information needed to maximize the efficiency of the Albanian economy (i.e., a long-range plan for a multipurpose land information system, MPLIS).
3. An incremental approach is needed, for example:
 - a. first, a manual IPRS, which may be computerized later; and
 - b. afterward, implementation of an MPLIS, which can serve the needs of a wide variety of land information users.
4. Maximum attention should be given to the current situation (use available skills and resources as well as maximize the benefits from donor-provided resources).
5. Given the spotty success rate of property registration systems in many lesser developed countries (LDCs), the system in Albania should be kept as simple as possible.
6. The modernization of surveying and mapping technology in Albania should begin with adequate training and education and the cost-efficiency of specific technologies (e.g., GPS, GIS) tested before adoption.

1.2 EXPERIENCE IN OTHER LESSER DEVELOPED COUNTRIES

The implementation and modernization of land titling and registration systems have been key components in a number of economic development projects in many parts of the world. In spite

of the provision of significant amounts of technical assistance and other resources to these projects, results have been spotty at best. This section reviews what happens when land registration and titling projects fail, suggests several reasons why the use of such systems is often lower than expected, and discusses lessons that can be learned from these earlier efforts.

1.2.1 WHAT HAPPENS WHEN SYSTEMS FAIL?

Land titling projects in LDCs have been financed by several different funding agencies including United States Agency for International Development (USAID), World Bank (WB), and other major development banks. In spite of the significant resource commitment by the funding agencies, the current property-registration situation in many LDCs is characterized as follows:

- ◆ the majority of land parcels are not registered in the public registry office,
- ◆ the titling process is subject to lengthy delays (often 5 years or more),
- ◆ most of the governments involved still have little knowledge of the extent and location of state lands in their country, and
- ◆ maps that describe the current land tenure status for an entire area (such as a district) are non-existent, making it impossible to integrate tenure and other related geographic information (such as natural resources).

The failure of these projects to produce better results raises two fundamental questions:

- ◆ How can these failures be explained?
- ◆ Why have titling projects not developed into longer-term programs that provide continuity and benefits that extend beyond the initial titling effort?

A first step in answering these questions is to examine several reasons that suggest why these earlier efforts have been less than successful.

1.2.2 WHY TITLING PROJECTS FAILED TO PRODUCE EXPECTED RESULTS

One critical factor is that institutional support for the land titling system is not developed by the country itself. This means that once the project ends, the host country finds it impossible to sustain the rate of processing of titles that was generated during the titling project. With no institutional framework to maintain and expand the information, the system tends to collapse. For example, as new titles are created and previously titled parcels transferred, the system becomes more and more out-of-date and therefore less useful.

The failure to register transfers and new titles in turn suggests that the owners do not believe that it is worth their effort to record their titles. It seems likely and logical that the reason for this failure to register is a belief that the costs of doing so (in terms of time, money, and dealing with the bureaucracy) are not worth the benefits (such as increased value, greater liquidity of land, or ability to borrow money for improvements). This belief about relative benefits and costs of titling may be due to actual conditions which owners have experienced or to perceptions about what the owners believe the situation to be.

If the success of cadastral and property-registration systems is to be improved, there are a number of questions that need to be answered and a number of issues that need to be addressed.

1.2.3 LESSONS LEARNED

The experience gained in previous projects can be used to suggest ways to improve the success rate of future cadastral and titling projects. As the above discussion suggests, there is no single, guaranteed approach that will assure the success of property registration projects. However, earlier projects suggest several principles which are useful as guidelines to help maximize the likelihood of success.

1.2.3.1 Rapid registration

The speed of operation is important both for initial registration and for registering all subsequent transfers and other transactions that affect the rights of the property owner. Long delays tend to reinforce negative perceptions that owners may have about the importance of land-title registration.

1.2.3.2 Simplicity and economy

A simple, inexpensive property registration system is important if property owners in LDCs are to support and use the system as intended. Simplicity in itself will help keep costs down, as well as make the system easy for landowners to use and understand.

1.2.3.3 Clear, simple cadastral maps

A clear, simple graphic of the parcel is a good way to help assure the owner that the map is a correct reflection of the situation on the ground and to indicate that the property registration system is indeed working properly.

1.2.3.4 Clearly demarcated parcel boundaries

Clear marking of parcel boundaries helps assure that owners and their neighbors have common understanding of the location of each land parcel. If visible from above, parcel boundaries will be discernable on air photos (e.g., that are part of a photogrammetric program), thereby suggesting a photogrammetric approach (see subsection 1.4 on surveying and mapping options).

1.2.3.5 Education programs on the benefits of Property Registration Systems

Owners need to be made clearly aware of the benefits of the property registration system. Many approaches may be used for such a program, including written brochures or booklets, radio, television, or personal contacts by personnel from the registry, university, or other public agencies.

1.2.3.6 Timely delivery of other promised benefits

Acceptance and use of the property registration system will be accelerated if related programs that have been used to justify and support the registration program are made available in the timeframe and in the quantity promised. For example, availability of credit to finance improvements to the property is important. Unfulfilled promises of improved credit availability can be a serious deterrent to the implementation and use of the property registration system.

1.3 SURVEYING AND MAPPING ENVIRONMENT IN ALBANIA

Although Albania is attempting to become an integral part of the European community, it is unlikely that it will be able to emulate the sophisticated property registration systems of Western Europe. For this reason alternative systems, which will be consistent with the severe time and cost constraints under which the IPRS must be implemented, are being explored. In the process, the design of the system should not prevent Albania from moving toward a more sophisticated solution at a later date. Before outlining the various options available to Albania, the general environment in which these activities will take place is considered in terms of its advantages and disadvantages.

1.3.1 ADVANTAGES

Unlike many other LDCs, Albania has a dense network of geodetic control points (approximately 4-km density) which in many instances are clearly demarcated by means of tall tripod signals. Provisional tests using GPS (see MSI 1992) confirm that this network has been surveyed to a high degree of accuracy. Although this study dealt with a small sample, other evidence (such as surveying standards, academic qualifications) suggests that the geodetic network should be adequate for cadastral surveying purposes. Nevertheless, it would be advisable in the long term to reobserve part of the network and use this for a complete readjustment. If GPS proves to be cost-efficient in Albania, this will place more demands on the geodetic network than the current graphic approaches. Other geodetic requirements, such as gravity observations, are dealt with in MSI (1992). However, it is important to retain a higher priority for IPRS needs and not to cause delays by committing current resources to satisfy lower priority, longer-term needs.

Albania is fortunate to have a relatively high number (estimated at around 300) of well-educated surveyors who have graduated from the five-year surveying program at the Polytechnic University of Tirana. The curriculum includes a strong mathematical and measurement science foundation in the first three years (see Appendix A for curriculum details). The latter two years are more general than most surveying programs and deal with such diverse topics as ecology, urban planning, mining technology, and hydrotechnic construction. The surveying program graduates approximately twenty students per year and has apparently maintained this level for the past twenty years.

There are also several survey technicians who have specialized in surveying at the secondary school level (called middle school in Albania). The number of people with these qualifications is estimated at 500. The pool of expertise (many of whom are currently unemployed) in the area of surveying and mapping appears to be adequate to support the IPRS project. However, given the dramatic changes in land law and the introduction of a legal cadastre to support the new IPRS, additional training and education will be required to update the skills and expertise of both the university- and secondary-school-trained surveyors. Recommendations for curriculum reform are included in subsection 1.6 of this report.

The substantial set of maps that currently exist in Albania, especially at larger scales (1:500–1:10,000), provides a valuable base of land information on which to build an effective cadastre. Details of the distribution of these maps and the agencies in which they are held are given in Annex 5 of the Land Market Action Plan (LMAP), prepared by the Land Tenure Center, dated

15 May 1993. In addition to this map information, the Land Research Institute (Instituti i Studimit te Tokave) has a well-organized and referenced archive of survey records, one set dealing with control densification (triangulation) and the other with tacheometric surveys. The densification records span the period 1947–1989 and the tacheometric records are kept for a ten-year period after which they are destroyed (the most recent records are dated 1991). Unfortunately, many of the triangulation points were not permanently demarcated in the field and are therefore of little use as a tertiary network for controlling local parcel surveys. We strongly recommend that in future these points be permanently demarcated and location sketches drawn so that they can be reused in subsequent surveys.

Albania is one of the smallest countries in the Balkans (approximately the size of Massachusetts), which means that the physical scale of a national IPRS project will be smaller than in many other countries where similar projects have been implemented. However, this is offset to some extent by the rugged terrain in much of the country as well as the small, fragmented nature of landholdings (see next section).

The fact that Albania recently moved to a private property system offers opportunities that are rarely available even in Eastern Europe: the IPRS can be designed from the ground up. Provided firm foundations are laid over the next few years, there is no reason why Albania cannot become a model for other countries contemplating property registration reform.

1.3.2 DISADVANTAGES

While the recent move to a market economy and private property has advantages from a design perspective, the novelty of the IPRS also brings many implementation challenges. Government agencies have little or no experience with private property concepts and new institutional structures will have to be developed to support the IPRS. Property relations and activities that are taken for granted in the west (mortgage, liens, valuation, etc.) have no institutional support at present and are poorly understood by the landholding populace (see Sjoberg 1991). This will require a significant effort in terms of institutional development and educating landholders as to their rights vis-à-vis the government.

The government agencies that hold the primary responsibility for land administration (Land Research Institute, LRI; Geology and Geodesy Enterprise, GGE; and Military Topographic Institute, ITU) currently operate in an isolated manner. Although accuracy standards exist for the surveying and mapping work carried out by these agencies (see Appendix B), they were generated at a time when the military dominated the administration of land and most other resources. It is essential that inter-institutional working groups be formed so that all these agencies contribute to the generation of standards, data exchange protocols, and other areas of mutual concern. Albania must attempt to capitalize on the synergism that can result from cooperative effort. This will not be easy given the recent history of Albania where information on land and other economic resources was overprotected and used for political interests.

Although large areas of land are being subdivided and allocated to individual families, we were not convinced that serious surveying work was in fact taking place. This was borne out by our inability to find an area where such work was being undertaken as well as by the dates of the records in the LRI. The stagnation in the land administration institutions is due mainly to the lack

of finances to mobilize field teams and, to some extent, to the current transitory nature of land administration.

Albania has suffered to some degree from an inability to retain qualified personnel. While salary levels remain at their current (1993) level (\$35–\$50 per month for a qualified engineer), it will be difficult to retain staff who receive advanced training in the newer technologies and systems. However, if these people are allowed to enter the private sector and provide further momentum for privatization of surveying and mapping services, the drain on human resources could be averted. Training and education requisites must be addressed regardless of the above-mentioned retention problems.

The physical facilities for housing the personnel and information that will flow from the large IPRS project are presently totally inadequate. The improvement of these physical facilities must be considered within the project budget.

Perhaps the most challenging aspect of the Albanian situation is the size and fragmentation of landholdings. In our interviews we found villagers who had been allocated between one and four parcels of land (up to seven parcels are allowed by law). These individual parcels may be several kilometers apart and involve agricultural land as well as pasture and land with olive or fruit trees (defined in terms of the number of trees). From a surveying and mapping perspective this presents a challenging environment in which to identify cost-effective solutions for the creation of an IPRS.

1.4 CADASTRAL SURVEYING AND MAPPING OPTIONS IN ALBANIA

1.4.1 CURRENT TECHNIQUES

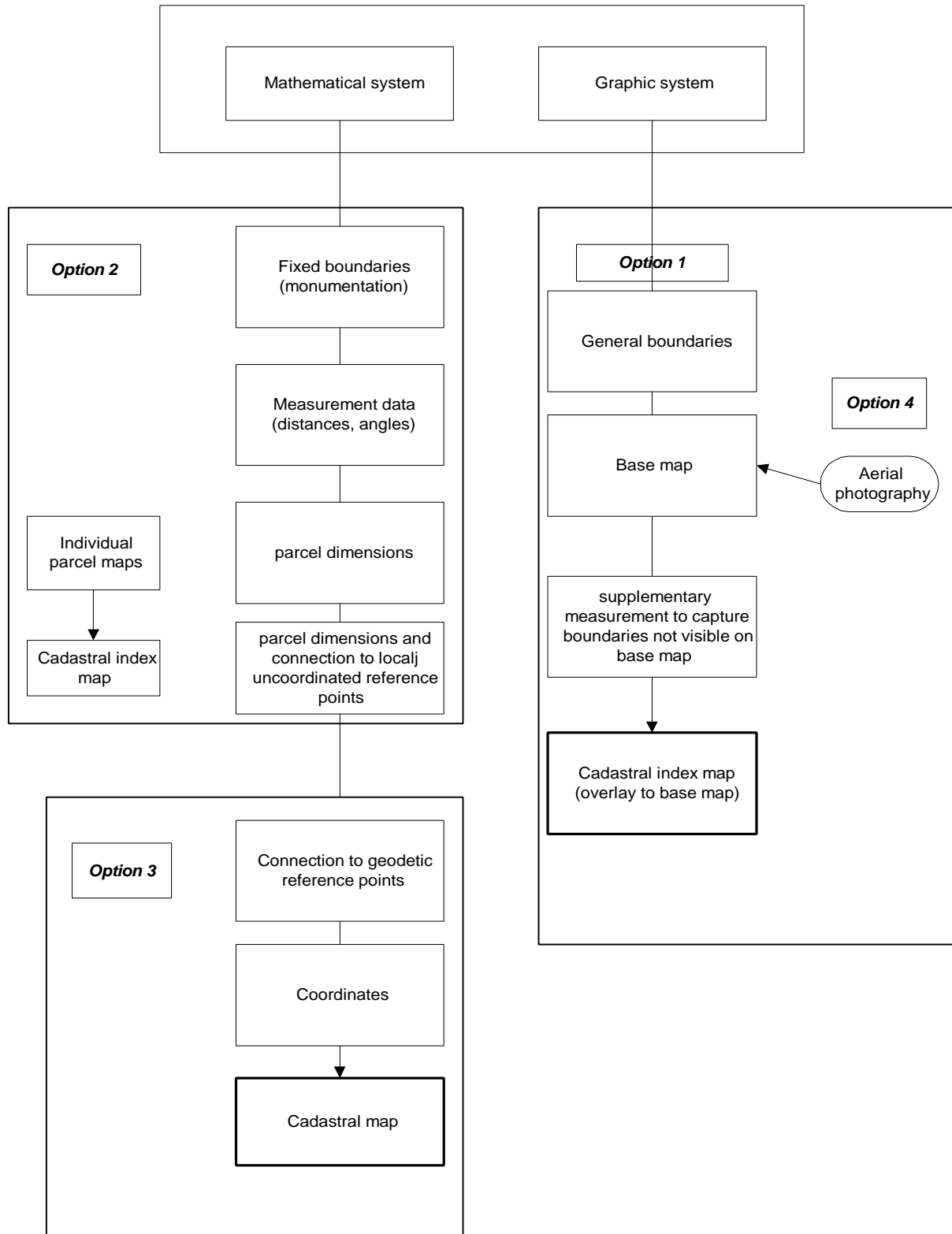
The only cadastral records that have been maintained historically in Albania relate to agriculture and land use. In rural areas, the 1:5,000 map series has provided the basic spatial information on land-use units (supplemented by village-based sector maps). The detail shown on these maps has been surveyed by means of tacheometric techniques. In some instances, these tacheometric surveys have been connected to the geodetic network by means of a mixture of triangulation (mainly resection) and tacheometric traverses. The resulting maps provide an excellent source of graphic control, particularly in areas that are crisscrossed with irrigation canals.

In other instances, “schematic” or “sketch” maps are produced from isolated tacheometric surveys. These sketch maps contain several isolated surveys on the same sheet, which means that the relative positions of features on the map are not true.

1.4.2 OPTIONS FOR THE FUTURE

There are various options that could be considered for surveying and mapping cadastral parcels in Albania. Such factors as accuracy needed, labor and skills available, and tradition followed should be considered. Among the many possibilities, we suggest four that are good candidates for further consideration and study as to their applicability to Albania. (See Figure 1.1 for a taxonomy that indicates the relationship among these options.)

FIGURE 1.1 Four options of property boundary delineation



1.4.2.1 Enlarged 1:2,500 scale maps (option 1)

As discussed above (see subsection 1.3.1), Albania is fortunate to have a relatively accurate, large-scale (1:5,000) map series for most of the agricultural areas in the western part of the country. The LRI has the equipment and has demonstrated the capacity to enlarge these available maps to 1:2,500 for use in mapping cadastral parcels. These enlarged maps are then taken to the individual villages where the parcels recently distributed by the Government of Albania are surveyed by means of tape or tacheometric techniques.

1.4.2.2 Sketch maps tied to local survey control with a permanent monument (option 2)

This option is applicable in areas covered by sketch maps where no 1:5,000 maps exist. In this approach the sketch maps are tied to one or more *permanent* monuments or reference points that are placed in the ground. Cadastral parcels on the sketch map are then tied to the(se) monuments, using classical tacheometry. This approach provides at least two important advantages.

First, by tying cadastral parcels on the sketch map to a permanent survey monument, it will be possible later to return to and reuse the same monument to map new parcels or relocate existing boundaries. Perhaps more importantly, the monument will provide a link to other land information that the village, district, or Government of Albania may decide to add, if and when a decision is made to develop a land information system (LIS) or geographic information system (GIS). For example, soil type, slope, land use, land cover, roads and irrigation networks are just a few of the “layers” of data that may become part of a GIS system. This approach also allows for the subsequent survey by GPS or some other modern techniques of the reference points so that the sketch map data are connected to the geodetic control network.

1.4.2.3 GPS and total station/electronic tacheometer survey (option 3)

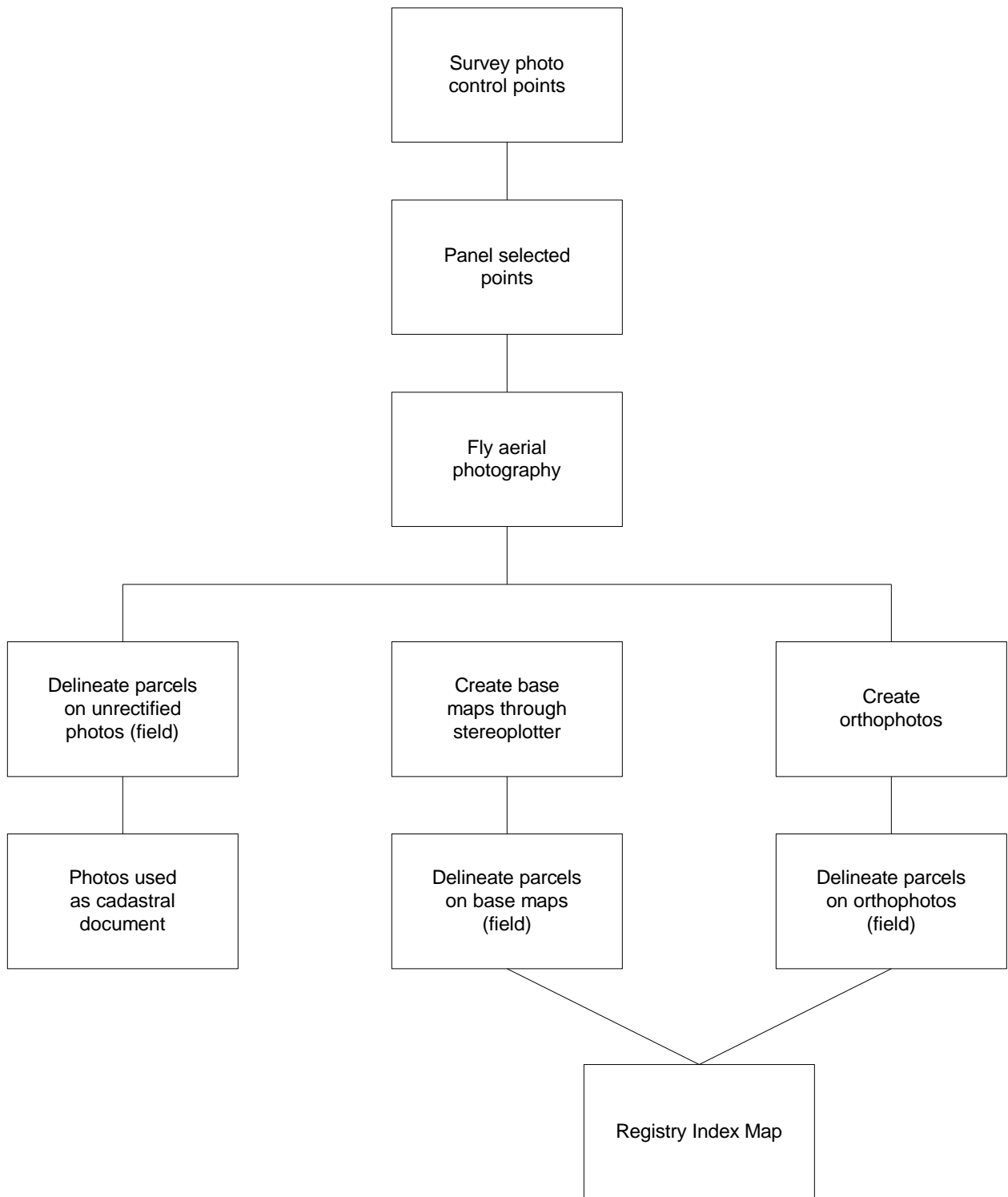
This option may be characterized as the high-tech, digital approach. GPS would be used to provide control for surveying specific parcel details that are required to be mapped. The detail survey will use GPS, total stations, or electronic tacheometers (which should prove to be more efficient than traditional tacheometry, once surveyors have overcome the learning curve). A similar approach to option 2 may be followed here where the detailed total station/tacheometer work is done first relative to certain monumented reference points which are connected later to the geodetic network via GPS.

We recommend that this option be tested as soon as possible so that relevant training can be provided should this option prove the most cost-efficient. A proposal to investigate this option is included in Appendix C.

1.4.2.4 Photogrammetric options

When considering any photogrammetric approach in Albania, one factor that must be of serious concern is the total control that the military has over any flying of aerial photography. Experience in other countries has shown that conforming with a military agenda can lead to serious delays in the implementation of IPRS projects. Any photogrammetric option will also entail a significant training component as the current skills are based on outdated technology [see Annex 5 of LMAP (1993) for more details].

Figure 1.2 describes three different photogrammetric approaches that can be used for parcel mapping.

FIGURE 1.2 Photogrammetric approaches toward cadastral mapping

Unrectified photographs

In this method all parcel data is delineated directly on the aerial photos, or on a transparent overlay to the photo. The unrectified photo then becomes the graphic record for defining the parcel boundaries. While this option has many cost-efficiency advantages where boundary fences or other physical boundary features are clearly visible on the photography, it has two serious disadvantages. First, the aerial photo is unrectified and therefore contains a distorted image (scale varies across the image) which cannot be regarded as a true map. Given the mountainous nature of much of the terrain in Albania, this scale distortion could be quite significant. Second, this approach will provide a set of distinct photo records that cannot easily be integrated to provide a consistent record across the whole district. This option is not recommended for Albania.

a) Base map derived from photogrammetry (option 4)

The second photogrammetric method is one that follows a traditional photogrammetric approach toward mapping. Control points are surveyed to control the position of the aerial photographs. Using a conventional stereoplotter (or one fitted with digital encoders), a map of the parcel boundaries is produced together with any other required details (e.g., buildings, fences, roads, rivers). No attempt should be made to plot contours unless they are urgently needed for some other purpose. The base map produced in this manner will then become the Registry Index Map. This method should be tested in Albania, particularly in large areas where no reliable large-scale mapping is available and where physical boundaries (visible in the photography) are predominant.

b) Orthophotos

The third photogrammetric method is to produce orthophoto maps from the aerial photography. The technology required for this does not exist in Albania at the present time. Further disadvantages include the lack of control over the amount and type of detail that appears on the map (since this is an image map) and the difficulties associated with updating the orthophoto map. This method is not recommended for Albania.

1.5 EVALUATION OF CADASTRAL SURVEYING AND MAPPING OPTIONS

Surveying and mapping of cadastral parcels is a critical component of the IPRS project for at least two reasons. First, reliable surveying and mapping of the ownership parcels is important to the effective operation of cadastral systems in general. Second, given the limited resources available in the Albanian economy, it is important that cadastral surveying and mapping be done in the most cost-effective manner possible. Therefore, it is important that the most cost-effective technology be applied to the surveying and mapping task.

The cost-effectiveness approach suggested here is based on a number of considerations we believe are important.

1. Avoid mistakes that have been made in the past in other countries.
2. Take advantage of the unique situation in Albania, where the IPRS is being put in place as part of the move from a controlled to a free market economy.
3. Provide the survey and mapping component of the IPRS at the least cost possible.

4. Provide a framework for measuring the effectiveness of the surveying and mapping system that will be useful not only in Albania, but also in Eastern Europe and possibly other parts of the developing world as well.

As noted, one critical criterion for measuring the cost-effectiveness of the surveying and mapping system is the least costly method. Other criteria that are important include:

- ◆ How effective are the resulting surveying and mapping products in avoiding conflicts among property owners?
- ◆ How effective are the products in resolving those conflicts that do occur?

The latter criteria suggests the importance of re-examining the effectiveness of the Albanian surveying and mapping system periodically to determine how effective it has been in both avoiding conflicts and solving those that do arise. For instance, such an evaluation would be extremely useful in the context of any problems that occur at the time of inter-generational transfer of land within the family.

We should also note that the surveying and mapping system put in place for the IPRS will have important implications for the Albanian economy far beyond the property registration itself. In particular, the system adopted will likely serve as the foundation for a variety LIS and GIS efforts that are needed to support the continued development of the Albanian economy. We have also considered the needs for LIS and GIS in our efforts to develop an evaluation plan for the cost-effectiveness of the surveying and mapping component of the IPRS.

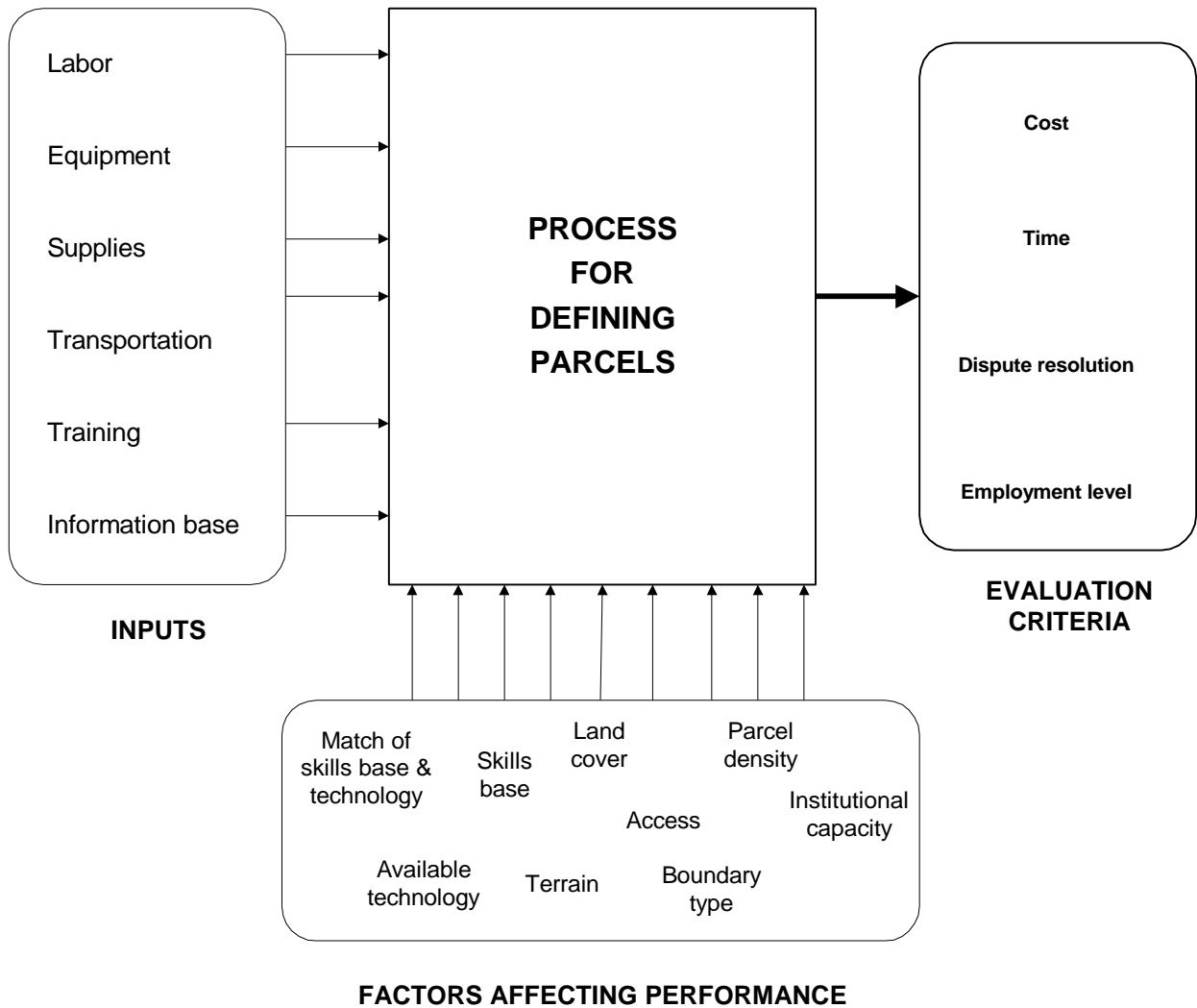
In the following sections we consider the factors that impact the cost-effectiveness of cadastral surveying and mapping programs, the parameters that will affect the cost of each option, and the criteria by which we propose that cost-effectiveness of the options be judged. This approach is summarized in Figure 1.3.

1.5.1 INPUTS AND COSTS OF SURVEYING AND MAPPING

The inputs required to undertake the surveying and mapping process comprise the typical needs of any field surveying exercise. Most importantly, appropriate personnel must be identified. In most cases (except when traditional methods are used) additional training will be required to familiarize project personnel with the requirements of the project and to make them proficient in the surveying and mapping technique to be used (e.g., GPS or photo interpretation). In the case of Albania, surveying and mapping personnel will be able to bring a significant skill base to the project, given their university education and field experience.

The kind of equipment required for surveying and mapping will depend on the specific technique, but in almost all options at least some equipment will be required (whether it be tacheometric rods or GPS receivers). Transportation to allow personnel to get around the field is also fundamental to getting the work done in an efficient manner. In Albania it is particularly difficult to purchase reliable 4-wheel drive vehicles, making this input especially important to project planning. The final input that is identified in the surveying and mapping process is existing information. This may include maps, geodetic control data, or historical land tenure records. One of the major reasons why the graphic approach (option 1) is so attractive in Albania is that the existing map information base offers a reliable record of landscape features (canals, roads, rivers, etc). However, before any existing information base is used as input, it should be evaluated with respect to accuracy and currency.

FIGURE 1.3 Schema for evaluating cost-effectiveness of different cadastral surveying and mapping options



During our review and analysis of the current status and operation of cadastral surveying and mapping in Albania, we talked with several agencies regarding their approaches to monitoring and estimating costs. The Land Research Institute (LRI) and the Geology and Geodetic Enterprise (GGE) were particularly patient and helpful in explaining their procedures and answering our questions. Our conclusion is that given the current status of the IPRS project, the best approach is to have field crews complete an additional form while surveying in pilot areas over the initial part of the project. These data can then be used in the measurement of the most cost-effective approach for surveying and mapping. Since it can be expected that technology, labor costs, and other factors will change over time, we believe that the approach suggested here will be helpful as the project evolves over time, to assist in the selection of the most cost-effective approach, at any time, for any set of circumstances.

Appendix D contains a proposed data collection form for the collection of relevant data by the field survey crews. The following items are included in the data collection form.

1.5.1.1 Labor

The most expensive part of most surveying and mapping projects, including those for cadastral purposes, is personnel. Various options require various mixes of skills for various amounts of time. Documentation of labor costs for the various pilot areas of the IPRS project should provide a good sample of labor costs under a variety of conditions. We suggest the collection of personnel data based on educational level of each category of persons on the survey team. This approach will provide flexibility for various techniques used, as well as providing management with information that will continue to be useful over time.

1.5.1.2 Equipment

Equipment includes all items that last beyond the life of a particular survey job. The costs to be included here are mainly a depreciation or amortization cost for each item. That is, the life of each item should be estimated in terms of years, or jobs, or number of hectares or parcels surveyed and mapped. Then, a depreciation charge can be made for each surveying job. This approach will provide the funds needed for equipment replacement as items wear out or as technology changes.

1.5.1.3 Supplies

Material that is used on each job such as pegs, concrete, field books, and computation paper should be included in this category.

1.5.1.4 Transportation

This item refers to the costs incurred for transporting the surveying and mapping crews to the job location. The simplest way is to charge a standard charge per kilometer for each vehicle used for the job. (It is assumed that drivers will be provided for each vehicle, and that their wages will be included in the labor category discussed above.)

1.5.1.5 Per diem

Per diem refers to the costs of lodging and meals when survey and mapping crews travel to sites outside of Tirana and stay overnight. The method of charging either a flat rate by location or a percentage of wages would seem to be an appropriate approach for charging per diem to each job.

1.5.1.6 Preparation time

While we did not include this item on the data collection form itself, we believe that managers and administrators may find it useful to include costs that are incurred in preparing materials for each job before the team goes to the field. This item could be added to the form or tallied on a form or book in the central office.

The data collection form in Appendix D should be considered a draft form that is tested during the upcoming working in the three pilot areas. After use for a period of time, the form and the data collected should be analyzed to be sure that: (1) the data collected are serving the needs of managers and administrators, and (2) the forms are as simple as possible, so as not to unduly burden the field teams who are completing them.

1.5.2 FACTORS AFFECTING THE COSTS OF SURVEYING AND MAPPING OPTIONS

The effectiveness of any surveying and mapping technique is influenced to a large extent by the conditions in the field and the capacity of existing institutions to deal with the vast amount of information that typically flows from cadastral and registration projects. Field conditions will vary according to the terrain, land cover, and type of boundary used. When boundaries are defined by easily identifiable physical features (e.g., roads, hedges, canals), they are easier to locate for surveying and mapping purposes than boundaries defined by corner markers. In the former case, a general boundaries approach using maps graphically to define the parcels will generally be more cost-effective. In a fixed boundary system, a numeric approach (e.g., using GPS or tape/theodolite to measure parcels) is often preferred.

Access can have a significant effect on the speed with which parcels can be surveyed and mapped. In extreme cases, where roads are scarce and it is necessary to resort to more basic modes of transport (e.g., mule, foot), the time required to get to a parcel may actually exceed the time needed for measurement. When it is necessary to obtain information from individual landholders, as is generally the case in any IPRS project, access to these persons may also present problems. This is particularly true where absentee ownership is common (typically, not the case in Albania).

Parcel size and density can influence the surveying and mapping process in several ways. Small parcels that are close together offer advantages since equipment and people do not have to be moved very far from one parcel to the next. However, this high parcel density increases the amount of work as well as the cost per unit area. For this reason it is a good idea to evaluate output in terms of both number of parcels and area covered.

In countries like Albania, where land tenure institutions are either nonexistent or extremely weak, lack of institutional capacity can severely constrain the ability to move from data capture (survey) to mapping and ultimately to the delivery of information to the registry. It is for this reason that “technical” projects often include an institutional strengthening component or regard this as a major objective.

1.5.2.1 Terrain

The degree of slope and the general terrain affect costs of surveying. While distances (e.g., between property corners) are relatively short, the severity of elevation changes impacts on costs. For example, severe slopes may require drop taping, which increases costs. The difficulty of

assessing the impact of terrain change is difficult since this generally dictates which surveying techniques are used (e.g., in hilly areas it may be extremely costly to use traversing, but relatively inexpensive if triangulation techniques are employed).

1.5.2.2 Parcel size and density

Parcel size and density affect cadastral surveying and mapping costs in a number of ways. Small parcels that are close together can lower costs since equipment and people do not have to be moved far in going from one parcel corner to the next. However, if costs are being compared on the basis of land area, smaller parcels have a higher cost per unit of area (e.g., a higher cost per hectare).

1.5.2.3 Type of boundary being surveyed

One significant advantage of a general (versus fixed) boundary system is that a physical boundary (hedge, fence, canal, etc.) is usually easier to locate than a boundary marker (fixed) planted at the parcel corners. This means that field searching times (even with the assistance of owners) for boundary points are usually shorter with a general boundaries approach. A general boundaries approach may also offer cost-effective photogrammetric options for mapping parcel boundaries. In our field visits we identified both types of boundaries (general and fixed) and, given the provision for both systems in the Land Registration Act, we recommend that this flexibility be maintained.

1.5.2.4 Land cover (vegetation)

The type of land cover in the general area of the cadastral surveying work may have a significant impact on costs. Costs are much less for flat, agricultural fields than for dense stands of forest timber. This increase in cost is related both to the difficulty in moving and setting up equipment, as well as to the increased number of setups that are typically required in forested areas.

1.5.2.5 Road network access

Easy access by road to the area for which cadastral surveys are being prepared can significantly lower the costs. Movement of people and equipment to the site by vehicle reduces pack time and allows crews to complete more parcels or hectares in a given unit of time. In some cases there may also be a correlation between road access and other cost reducing factors (such as vegetative cover and terrain).

1.5.2.6 Skill base of the surveying community

In addition to the physical factors, there are also a number of institutional and organizational factors related to cadastral surveying and mapping cost-effectiveness. One of these non-physical factors is the skill base of the personnel who are available to work on surveying and mapping projects.

Three aspects of skill base need to be considered. First, surveyors and cartographers need the training and skills necessary to carry out the required tasks. Therefore, educational facilities available, educational levels attained, and relevant experience all affect the quality of the available labor pool. Second, sufficient numbers of these trained personnel need to be available to do the required cadastral surveying and mapping and complete the task in the time specified for the project. (Our cursory review of both of these aspects in Albania indicate that neither will be a constraint on the surveying and mapping aspects of the IPRS.) Third, there may be a

significant cost element associated with the learning curve if new skills have to be taught to surveyors.

1.5.2.7 Technology available

A second institutional/organizational factor is the availability of technology (i.e., equipment and supplies) to support the surveying and mapping effort. Since several options are usually available and considered (as is true in this effort to evaluate the cadastral surveying and mapping options for the IPRS project), the availability of each feasible technology is an important consideration. In many developing countries, there is a wide variation in the supply of equipment needed for cadastral surveying and mapping, depending on the technology selected. Our discussions with knowledgeable personnel in Albania suggest that this is the situation in Albania as well. For example, as would be expected, there are currently no GPS or total stations available for use by the public sector in Albania. Therefore, if one of these technologies is selected, immediate purchase or lease of such equipment would be necessary. However, equipment shortages in Albania are not restricted only to high technology surveying options. There is even a severe shortage of quality 30-meter tapes.

1.5.2.8 Match of skill base and technology

People are necessary to operate the equipment and carry out the techniques, regardless of what surveying and cadastral option is used. It is important that the consideration be given to how compatible personnel skills match up with technology used. In considering the possible options for Albania, it appears there is a wide variation in how compatible these two items are.

For instance, the skills necessary for classical tacheometry appear to be readily available, and, with the addition of relatively inexpensive items such as survey tapes, this option could move forward. Therefore, there are few constraints as to the match of personnel and technology for this option.

In Albania, there are currently much more substantial constraints as to other options such as total stations and GPS which require substantial amounts of relatively expensive equipment. Also, training, ranging from moderate to substantial in terms of time, would be required. The time needed to move to the productive portion of the learning curve could also vary substantially.

1.5.2.9 Institutional and organizational capacity

Two kinds of institutional capacity are relevant. The first is the capacity of individual agencies to provide the organizational support (both technically and intellectually) necessary for their portion of the surveying and mapping effort. The second kind of capacity is the overall and coordinated institutional and organizational support of all relevant agencies in the Government of Albania. This second capacity is more difficult to attain and more important if cadastral surveying and mapping is to move forward in the most cost-effective manner. Our review of the situation in Albania is that the first capacity is in place, but that the institutional integration is yet to be achieved.

1.5.3 CRITERIA FOR EVALUATING COST-EFFECTIVENESS

Criteria for evaluating different surveying and mapping techniques should be solidly based on the needs of the project and not on the biases of individual professionals. Given rapid

privatization and the pressing need to create the IPRS before a land market develops, the most important criterion in Albania must be speed. In the short term, continuing with traditional tacheometric techniques (option 1) will often be more efficient since it does not require any lead-time for equipment acquisition and training. However, once project personnel learn techniques and equipment is purchased, this advantage will be reduced. Ultimately, it may be more beneficial to adopt a more modern approach (e.g., GPS), which will almost certainly be more efficient over the long term.

Cost is an important criterion in any situation, but this is especially true in poorer countries like Albania. Labor-saving, capital-intensive solutions should be avoided in situations where capital is minimal and labor is cheap and plentiful. Surveying and mapping options should be evaluated on the basis of cost per unit area as well as per parcel.

In countries (such as Albania) where unemployment is exceptionally high, it would be inappropriate policy to pursue an approach that is labor saving. Therefore, the extent to which the surveying and mapping process brings people into employment will reflect the effectiveness of the process within a more general economic context. It will generally be more effective in this regard when the surveying and mapping technique matches the existing skill base. Skill-base match is therefore included as an evaluation criterion, though it is recognized that these skills may change over time as new educational and training programs take effect.

Land surveyors have often been faulted (rightly so) for their concern with accuracy. While this is clearly a factor that must be considered in this evaluation, it is certainly secondary to such criteria as speed and cost. The GPS approach, for example, is an attractive alternative mainly because it appears to offer significant gains in terms of cost and time. Depending on the technique and the type of receiver used, it may also provide more accurate results. However, this should be seen as an additional as opposed to the primary advantage.

The final criterion in the evaluation model is dispute resolution. Theoretically, the surveying and mapping option that provides the least ambiguity and provides certainty will achieve the highest rating in this category. Sometimes, greater accuracy and precision will promote this, but this is not always the case. For example, a general boundary (e.g., stone wall) defined graphically on a map can offer greater clarity and certainty than a very accurately surveyed fixed boundary. The underlying goal of the surveying and mapping process is to resolve existing boundary disputes and minimize the possibility of future argument. However, this must be pursued through a strategy that considers not only this criterion but all of the above-mentioned guidelines.

1.5.3.1 Cost per unit

Cost per unit (such as hectare or parcel) is the most frequently used and most easily understood of the evaluation criteria that can be used. Many of the preliminary estimates of resource requirements for the IPRS project have been based on needs per hectare.

1.5.3.2 Time

Because of the importance of having the IPRS in operation as soon as possible, time to complete the surveying and mapping task could be deemed more important than the total cost (or any other criterion).

1.5.3.3 Avoiding and solving disputes

Another criterion regarding the effectiveness of surveying and mapping programs is how well they support two critical tasks: preventing conflicts and resolving conflicts that do occur. These criteria may be deemed more important than cost or time, particularly if political considerations are a major factor.

1.5.3.4 Employment levels

A fourth evaluation criterion is the amount of labor (including all personnel from engineers to laborers) employed in the surveying and mapping effort. The importance of this criteria will depend on such factors as general employment levels in the economy, employment levels in the surveying and mapping sector, and excess (or deficient) capacity of people with surveying and mapping capabilities (education and training).

1.5.3.5 Efficiency

An increase in efficiency can be defined as doing more work (i.e., producing more output) with the same amount of resources (with the same inputs) or as producing the same output with less resources. For the IPRS project, efficiency can be used to measure changes over time (e.g., as surveying teams become more proficient). Efficiency can also be used to compare two or more options (e.g., with a given amount of labor or time or money) as to which approach can produce the most output. The latter is a measure of cost-effectiveness.

1.6 THE FUTURE

This report has focused generally on the IPRS and more specifically on options for evaluating the cost-effectiveness of options for carrying out the cadastral surveying and mapping portions of the IPRS project. During the course of our field work in Albania, we have had the opportunity to visit with a wide variety of government officials, university personnel, owners of newly formed private businesses, and owners of recently distributed private agricultural lands. In this section we discuss the cadastre, possible future directions as to development of a multipurpose land information system (or multipurpose cadastre) for Albania, the educational needs that face Albania in regard to newly attained private ownership of land and the development of a market economy, and the role for private sector surveying as the new Albania continues to unfold and develop.

1.6.1 CADASTRE

A cadastre is “a record of interests in land, encompassing both the nature and extent of these interests” (McLaughlin 1975, p. 60). Since cadastral information is about property ownership, the usual object on which the cadastre is based is the ownership parcel. The cadastre, therefore, is an information system, based on parcels, containing information about the ownership, use, and value of these parcels.

In some systems, cadastre information is divided into three subsystems: juridical (ownership), fiscal (value), and environmental (use and management).

1.6.2 MULTIPURPOSE LAND INFORMATION SYSTEMS

Ownership of land has been a concern of many societies for hundreds or even thousands of years. As time has passed, populations have increased in size, societies have become more complex, and the value of land and the need to manage it wisely have increased. These changes have increased the need for information about land, and consequently the value of land information.

During the last 20 to 30 years, there has also been an explosion in technology that can serve as the basis for meeting the increased need for land information. These technology changes have included computers (ranging from personal computers (to large mainframe machines), digital mapping, orthophotography, and high quality, automated cartographic product production processes.

These two trends—the need for more, better, and integrated land information and the availability of technology to meet this need—have set the stage for the development of Multipurpose Land Information Systems (MPLIS). An MPLIS, by definition, is a system that serves multiple purposes (Hendrix, Moyer, and Strohlic 1992). The MPLIS contains many kinds of land data, ranging from ownership (cadastral) to soils, land use, geology, planned uses, use restrictions, and other related information.

Information in the MPLIS includes both graphic (map) information and textual (or attribute) information. Thus, the cadastral map being produced in the IPRS project would be part of the graphic material of an MPLIS and the property register information (such as registry books, *tapi*, and Form 6) would be included as part of the attribute record in text form.

MPLIS information is generally stored by layers (see Brown and Moyer 1990, Appendix D, Figure 7-5). The ownership parcel provides the basic unit for data in many layers (for instance zoning and ownership), while resource polygons provide the second major spatial units for other data (e.g., soil type, wetlands, floodplains, geology, and land cover).

An MPLIS is only as good as the data in the system. Quality of data relies on at least two major steps: putting good quality data in the system initially, and then assuring that data are updated on a regular basis. Each data layer is generally the responsibility of one specific agency. This agency is responsible for building the layer of data initially, and then being sure that all changes are made to keep the MPLIS current. Thus, each agency is the custodian for specific layers of data in the MPLIS. This custodian approach is also the least disruptive to government in general, since no major changes in data responsibility occur—each agency continues with its normal responsibility, just being sure that all changes in their data are made available in the MPLIS quickly and accurately.

Updates to the MPLIS layers are usually based on the occurrence of transactions that affect data in the MPLIS. For example, a land sale reported in the registry office would generate a change in the ownership layer of the MPLIS. A permit to build a new house or business might generate changes in the land use layer or land cover layer. Changes in data by other agencies would result in similar updates.

The above discussion suggests that an MPLIS is a relatively complex system, but one that covers many needs of both government and the private sector. We recognize the current need to focus on the IPRS as part of the Land Market Action Plan. However, we also believe that the

Government of Albania should begin planning for the future when the needs for an MPLIS will continue to increase and the market economy will make such a system economically feasible. Therefore, we suggest several steps that will help lay the foundation for the future development of an MPLIS for Albania.

1.6.2.1 Research

Research should soon begin on the scope and detail of data that might be included in the Albania MPLIS. Such research could be funded by one or more grants from the Land Market Project (LMP), with the faculty of the Polytechnic University of Tirana playing a major role. Other researchers and advisors (e.g., from U.S. universities or government agencies) could be included in certain parts of this research activity.

1.6.2.2 Educational efforts

The research should involve several government ministries that rely on and are concerned with various kinds of land information. These agencies, or designated working groups representing them, should help design the scope of any MPLIS research effort. These discussions would provide education for all involved, as to the potential benefits, likely costs, and other considerations of implementing an MPLIS.

We suggest that faculty of the Polytechnic University of Tirana take the lead in developing one or more research proposals to address the MPLIS issue. This will provide opportunities to increase the knowledge base of the faculty. Efforts should also be made to involve students in the research efforts as much as possible, since this group of students are the ones who will carry out actual development and implementation in the years ahead.

The needs for MPLIS and GIS capabilities already exist and will continue to grow. It appears quite likely that the Albanian economy will soon have the capacity to develop and implement such systems, particularly if their funding partners continue to support land information system modernization efforts.

1.6.3 EDUCATIONAL NEEDS IN SURVEYING AND MAPPING

Earlier in the report we discussed briefly the surveying curriculum at the Polytechnic University of Tirana and its apparent strength in surveying fundamentals. The entire land administration framework in Albania has been altered dramatically from the system that existed under the centralized regime just a few years ago. It is highly likely that the District Registry Offices will be managed and staffed by qualified surveyors. In the first instance the university will have to educate surveyors who are familiar with and understand the implications of this new decentralized, market-oriented institutional structure.

In the second instance, the university will also be responsible for providing education and training in modern technologies associated with surveying, computations, mapping and information management. The university should be educating surveyors who will be familiar with technologies like GPS, total stations, and GIS so that these can be assimilated into the routine land administration functions in the future.

While we have favored a low technology approach for the initial survey cadastral and registration work, there is no doubt that this will change as the technology becomes available in

Albania and, most importantly, as Albanians are trained to use this technology. Education and training therefore play a key role in triggering and enabling the move to a higher level of technology and ultimately to its acceptance within the land information management community. We strongly recommend that Albanians be given the opportunity to gain such education and training through graduate study and short courses in the United States and that study tours to other European countries be encouraged.

The change from a land-use cadastre to a legal cadastre that supports property registration has several implications to the current surveying curriculum (see Appendix A for details). It is essential that future surveyors be familiar with the general legal framework (such as courts and code) as well as the specifics of land law in Albania. This can be done as part of a cadastre course, but should preferably be treated as a separate course.

A component (three or four courses) of the future surveying curriculum should focus on the cadastre and property registration system. Surveyors will no longer be confined to dealing with the definition of different land uses, but rather with the demarcation, delineation, and mapping of legal rights to land. It is also anticipated that surveyors will play a major role in running the district registry offices. Topics that need to be covered in the cadastre and property registration component of the curriculum include:

- ◆ land as immovable property;
- ◆ public and private rights to land;
- ◆ history of land tenure in Albania;
- ◆ evolution of the cadastre concept in Europe;
- ◆ functions of a cadastre (fiscal, legal, multipurpose);
- ◆ cadastral surveying techniques (in Albania and elsewhere);
- ◆ functions of a property registration system;
- ◆ registration of deeds versus registration of titles (and hybrid systems);
- ◆ integration of cadastre and property information;
- ◆ computerized, parcel-based, land information systems (LIS);
- ◆ multipurpose LIS and geographic information systems (GIS);
- ◆ property valuation and assessment;
- ◆ land taxation systems;
- ◆ land reform; and
- ◆ land use regulation (e.g., zoning).

Modern surveying programs are striving to strike a balance between the measurement science component (the dominant part of the current Albanian curriculum) and the broader aspects associated with land administration and land information management (see Barnes and Palmer 1993 for a comparison of three surveying curricula). It is the latter component that needs to be developed in Albania.

From our discussions with the surveying faculty at the Polytechnic University of Tirana, it became clear that very few of them have the background necessary to implement this expanded vision of surveying. This problem can be addressed in several ways: through the creation of visiting faculty positions to allow qualified individuals to offer courses to Albanians; through the use of video-based instruction (lectures are videotaped abroad and sent to Albania); and by gaining practical experience through involvement in the development of the cadastre and property registry system in Albania.

1.6.4 PRIVATIZATION OF SURVEYING AND MAPPING SERVICES

In many western countries the bulk of the cadastral surveying work is carried out by private surveying companies. The same trend can be observed in the field of large-scale mapping. In these situations the government surveying and mapping agencies provide the basic spatial infrastructure—geodetic control, national small-scale mapping, geoid definition, coordinate system definition—and coordinate the collection of this information by the private sector.

Albania needs to develop a dynamic private surveying and mapping sector which would be consistent with their move to a market-oriented economy. With the large number of qualified surveyors (mostly unemployed) in Albania, there is no doubt in our minds that, given the right opportunities, this could occur rapidly.

When all surveying and mapping services are in the public sector, the issue of standards (of surveys) and qualifications (of surveyors) is relatively simple to control. However, these issues become more complicated when privatization occurs. In most other countries, this problem is resolved by creating a professional organization which is neither public nor private, but represents the interests of the surveying profession as a whole. This organization then defines qualifications necessary for entry into the profession and develops relevant surveying standards. Although a surveying “association” was formed some years ago in Albania, it was limited to surveyors working within the military.

Given the dominant role that the public sector has played in surveying, mapping and other activities in Albania, we believe it essential that this be countered by an equally strong surveying organization which emanates from the private sector and represents the interests of all surveying professionals. Although organizations like American Congress on Surveying and Mapping (ACSM), National Society of Professional Surveyors (NSPS), and state societies of land surveyors may have some relevance to the Albanian situation, it would be useful to examine the models that have emerged in other European countries.

1.6.5 SURVEY ACT AND REGULATIONS

A Survey Act provides the legal framework within which surveyors perform their duties. The regulations framed under this Act describe more specifically the activities called for in the Act and the standards to which this work must be done.

There are two pieces of existing legislation that will have a direct influence on the future Survey Act and Regulations. The first is the Land Registration Act which defines such terms as “survey plan” and “registry index map” (Section 2), as well as dealing with maps, parcels and boundaries with respect to property registration (Part IV). Although the Land Registration Act is broad, covering many surveying requirements, a Survey Act is required to provide additional guidance to surveyors, particularly in the following areas:

- ◆ minimal qualifications required to be designated as a land surveyor (or licensed/registered surveyor);
- ◆ powers and duties of public officers (e.g., registrar) with respect to the examination and archiving of cadastral survey information;

- ◆ powers and duties of professional bodies regulating the practice of surveying, licensing requirements, including the creation of boards for controlling survey regulations and educational standards;
- ◆ relationship of Regulations with regard to the Survey Act;
- ◆ duties, responsibilities, and liabilities of private land surveyors;
- ◆ quasi-judicial powers of land surveyors with respect to boundary disputes and disagreements;
- ◆ resurveys and the standing of new information vis-à-vis the existing cadastral record,
- ◆ survey requirements for subdivision, consolidation (merging of parcels), and boundary disputes;
- ◆ the legal standing of survey data from initial allotment with respect to the registry index map and survey data collected when boundaries are fixed;
- ◆ setting of reference marks and connection to geodetic control network;
- ◆ rights of entry to undertake survey work on private land and reasonable notice to landowners;
- ◆ penalties for destroying or moving property monuments; and
- ◆ nature and format of survey plans and other information collected to support the cadastre.

The Survey Act should promote standards and procedures that will lead to the unambiguous definition of land parcels. In this way it will support the development of a reliable land registration system and provide the basis for the broader integration of geographic data into a multipurpose land information system.

The Survey Regulations should be designed to achieve three objectives, namely: (a) to enable the ordinary landowner to identify his/her boundaries and the surveyor to define them, (b) to standardize the presentation of boundary evidence so that it can be used in subsequent resurveys, and (c) to control the reliability of boundary evidence (Simpson and Sweeney 1973, p. 101). These regulations essentially deal with the rules that apply to field measurement, monumentation, and the precise format and content of the information (plans, computations, records, etc.) that must be submitted to the cadastral office.

Albania already has a detailed set of measurement regulations contained in Legislative Act 110 of 1984 (see Appendix B). This Act lays down the standards for all first and second order geodetic control surveys as well as standards for all mapping at scales 1:500 to 1:50,000. It also defines in great detail the standards for the vertical control network and the survey of detail (map features) for mapping purposes. We were informed that all government agencies involved with surveying and mapping had conformed with these standards. Since they are de facto standards and appear to be adequate for control and mapping purposes, any future Survey Regulations should take these standards into account. This Act does not, however, deal with the requirements of cadastral surveys nor does it provide for modern surveying techniques.

Time constraints prevented a more detailed investigation of this component, but it is vital that a Survey Act and Regulations be framed to guide and control the practice of cadastral surveying. This is particularly important in a country that has an abundance of surveyors but very few lawyers.

2. DESIGN AND EVALUATION OF GPS METHODOLOGY

This section provides a follow-up on the 1993 fieldwork described in Section 1 and documents activities carried out in the summer of 1994. The major thrust in 1994 was to define and test a methodology utilizing GPS technology and to begin implementation of the proposed study on costs and benefits of various surveying and mapping options. There were four components of the work plan:

- (a) Design and test a cadastral surveying and mapping methodology using GPS.
- (b) Provide advice to the Project Management Unit (PMU) in three major areas:
 - ◆ predicting future changes and how to plan for the impact of these changes,
 - ◆ suggesting directions the PMU should take regarding surveying and mapping of cadastral parcels in the pilot districts, and
 - ◆ recommending training requirements to support the proposed surveying and mapping methodologies.
- (c) Evaluate the costs and efficiencies of current surveying and mapping activities being carried out by the PMU through the District Cadastral Offices and compare with costs to similar work using GPS equipment.
- (d) Outline an action plan for surveying and mapping activities to be completed in the next year (that is, by 30 June 1995).

2.1 METHODOLOGY FOR GPS TESTING IN ALBANIA

The following three procedures were used to carry out the components described above for testing GPS methodology in the Albanian setting..

2.1.1 DEFINE AND TEST GPS METHODOLOGY

GPS began as a system to support military activities, but in the past ten years it has been adopted widely in the private sector for a broad array of applications. Today GPS is regarded by many as the “next utility,” which in due course will make geographic positions as easily available as time.

In the area of cadastral or property surveying, GPS has been used primarily as a means of densifying geodetic control networks, or establishing such networks in areas where they had not previously existed. The focus in surveying has therefore been at the high-precision (centimeter) level responding to geodetic requirements. As GPS technology has evolved it has become more affordable and portable and has made observing times shorter, so the appeal for using GPS directly to survey property corners has increased. Why not use existing control, skip the densification step, and use GPS for the complete cadastral survey?

While GPS appears to be an attractive alternative for surveying at the parcel level, there are few studies that test the cost-efficiency of a GPS methodology and compare it with traditional approaches. This study was designed to fill this void by developing and testing a GPS methodology that would be most appropriate for the cadastral needs of Albania.

The first step in this process was to identify existing GPS techniques that were likely to be appropriate for Albania. This was achieved by forming a team comprising GPS and cadastral specialists who were familiar with conditions in Albania. The team consisted of individuals from the University of Florida and from MSI, a private GPS company in Denver, Colorado. The team met in a workshop forum over a period of three days to identify candidate GPS techniques and integrate the ideas of individual members of the group.

The second step was to test the candidate techniques under controlled conditions and begin to develop field and office procedures. For this reason a test site was established on the University of Florida campus. A number of monuments were set as parcel corners so that the resulting parcels approximated the parcel sizes in Albania. These points were accurately surveyed and the coordinates used as a basis for testing GPS techniques under different conditions. From these tests, a single GPS methodology was designed for further testing in Albania.

The third step included testing the methodology under Albanian conditions and further refinement of the required procedures. This also involved an assessment of the training needed in Albania in order to institute the GPS approach for cadastral surveying.

2.1.2 COMPARISON OF TRADITIONAL AND GPS TECHNIQUES

The analysis to compare the currently used surveying and mapping techniques involved two components:

- (a) collecting and/or compiling of information on resources required for current (traditional) surveying and mapping activities, and
- (b) collecting of information while testing GPS technology in the field.

These data for the two surveying and mapping options were then analyzed in order to provide suggestions to the PMU as to the most cost-effective approach they might wish to follow. Cost effectiveness as used here includes personnel time, equipment, training requirements, use of available resources, and similar relevant prerequisites.

Two major activities accounted for the bulk of the activity carried out in the summer of 1994. First, information was acquired on procedures being used for the surveying and mapping activities that were being supervised by the PMU, housed in the Land Research Institute (LRI). This included interviews with Spiro Lamani, Ahmet Jazoj, Mehmet Grepsa, and Lert Lira. Also, trips were made to several field locations in IPRS pilot areas for the purpose of interviewing cadastral office and village land commission personnel. In the village of Zhurje this included Wilson Cami from the Tirana Cadastral Office and a village elder.

In addition, a visit was made to the Military Topographic Institute (ITU) where the option of using photogrammetry techniques was explored. This visit included a tour of the various laboratories and work areas of ITU where Edmond Leka, director of ITU, explained the relevant processes.

2.1.3 ANALYSIS OF PRELIMINARY RESULTS

Our work in 1993 had identified four potential surveying and mapping options (see Section 1). These included the use of: (a) enlarged 1:2,500 scale maps updated by means of tape

measurements to include individual parcels; (b) sketch maps tied to local survey control with a permanent monument (in areas where no 1:5,000 maps exist); (c) Global Positioning System (GPS); and (d) photogrammetry (Barnes, Moyer, and Gjata 1994). The work described in this report focuses on the evaluation of the first (enlarged map and tape) and third (GPS) options since these were viewed as the most viable.

2.2 TRADITIONAL SURVEYING AND MAPPING METHODOLOGY

2.2.1 PROCEDURES

Regardless of the surveying and mapping option used, certain steps must previously have been carried out. These steps include:

- ◆ distribution of the land by Village Land Commission,
- ◆ completion of Form 6,²
- ◆ preparation of *tapi* (Certificate of Allotment),
- ◆ signing of *tapi* by owners,
- ◆ preparation of 1:5,000 maps for use in the field, and
- ◆ identification of parcel boundaries in the field and resolution of any disagreement between adjoining landowners (this determination is made by the owners and the village elder, with Cadastral Office personnel documenting the result).

In addition to the above, the following steps are also necessary to complete the fieldwork for the taping option.

2.2.1.1 Base map enlargement

This step entails the enlargement of 1:5,000 maps to 1:2,500 (on which officials in the Cadastral Office later sketch parcels). In itself this is an involved process and includes considerable hand drafting. A 1:2,500 enlargement is made from the 1:5,000 map using a photo enlargement process. The resulting 1:2,500 output is a film positive that is then re-drafted onto a paper copy. This latter step is necessary because the line width produced by the enlargement process is too thick for use in the field.

2.2.1.2 Boundary adjudication and measurement

One cadastral survey official and two technicians measure the dimensions of the parcel. The length of time required is determined primarily by the number of problems encountered in getting agreement as to the location of parcel boundaries. In Zhurje, the cadastral surveyor indicated that there were very few boundary disputes; therefore the work proceeded relatively rapidly.

² Form 6 is filled out for each household receiving land and signed by the District Land Commissions, indicating approval of the land distribution done by the Village Land Commission. This form includes information on the land distributed to a household, the name of the household head, and names of the neighboring owners for each parcel in the holding. Form 6 is also signed by the household head, indicating agreement with the land allotment. The information on Form 6 is then transferred to the *tapi*.

In addition to the actual taping of the parcel, the Cadastral Office field crew also prepares field sketches. In Zhurje, these notes were made on loose sheets, usually one sheet of paper per parcel.

2.2.1.3 Office checks and cadastral map

After returning to the Cadastral Office (either the same day or soon thereafter), the cadastral surveyor completes a “land area balance” calculation to be certain that the measurements are in conformance with information contained in the *tapi*. If there is a problem, measurements apparently are calibrated.

Next, the cadastral surveyor uses his field sketch, field notes, and measurements to prepare a draft parcel layout on the 1:2,500 parcel map that had been prepared earlier by employees in the LRI offices. The draft 1:2,500 map is then delivered to the LRI, where the staff reviews the map and transfers the information, by hand, to a mylar copy of the 1:2,500 map. This is the final version of the parcel map. When all work is completed, a copy of the final product is returned to the District Cadastral Office.

2.2.2 RESULTS

During the course of field visits to three district offices, several villages, and the PMU in Tirana, the following information was obtained on the cost of the taping approach for parcel mapping. These data are included to document the 1994 field data-collection results. It should be noted that there are several inconsistencies and discrepancies, which will require additional data and further analysis. One of the primary objectives of the Data Collection Forms (see Appendix D) designed in 1993 (and not yet utilized in June 1994) was to eliminate these inconsistencies and provide a more systematic base for the analysis.

By June 1994, thirty-seven crews had begun work in the three pilot districts (Kavaje = 10, Lushnja = 10, and Tirana = 17). In addition, thirty-three crews had started working in a number of other districts in an effort to demonstrate that activity is under way throughout the country (i.e., is not limited to a few selected pilot districts).

Survey crews from the District Cadastral Office (DCO) can complete about 7.5 hectares per day. This includes compiling data on maps and finalizing field notes in the office. In cases where boundary problems arise, usually a dispute between adjoining owners as to the location of the boundary, the time per hectare doubles (i.e., production drops to 3.75 hectares per day per crew). The crews also indicated that determining the location of parcel boundaries is the most time-consuming part of their job, often accounting for as much as two-thirds of the total field time (the remaining one-third is required for taping to determine parcel dimensions).

The typical DCO survey crew for the taping operation consists of three persons, one topographer and two assistants. Crews for the tacheometry approach apparently (we did not see any of these teams) require four persons, two topographic specialists and two assistants.

The completion rate by crew varies both by district and by type of terrain. In the village of Zhurje (Tirana District), the DCO crew apparently measures 5–6 parcels per day, which is lower than average. The number of parcels surveyed varies widely in the district, but 10–12 parcels (approximately 0.5 hectare each) per day is the average. The average parcel size is 0.25 hectare

(2,500 square meters). These numbers are inconsistent, since an average of 10 parcels per day and 5 hectares would equate an average parcel size of 0.5 hectare per parcel.

Skender Sheme, the DCO officer in charge of Lumthi (in Lushnja District), indicated that he is using two-person crews instead of the typical three-person crew, and that these smaller crews can still complete 8–12 hectares per day.

2.2.3 COSTS

Current (1994) salaries for topographic specialists on the DCO field crews are US\$70 per month. This compares to a 1993 salary of US\$30 and an expected 1995 salary of US\$100. Therefore, inflation of wages is a major factor and will require periodic reevaluation in order to keep abreast of the most cost-effective way to complete the surveying and mapping work.

Assistants currently earn US\$45 per month, which is expected to rise to US\$50 per month within the next year. Assistants' salaries are also supposed to cover equipment and travel costs. Current meal costs are US\$2 per day. Since most crews return home at night, little cost for hotel rooms is incurred. Vehicles dedicated to the surveying and mapping project are not available, so private cars are often hired. For example, topographic specialists were paying 100 lek (about US\$1.10) for a round trip from Tirana to Zhurje, a distance of about 50 kilometers.

2.3 GPS SURVEYING AND MAPPING METHODOLOGY

2.3.1 DESCRIPTION OF RECOMMENDED GPS METHODOLOGY

The GPS methodology tested and implemented in Albania utilized the technique known as "Differential Pseudo-Range Positioning." A minimum of two GPS receivers is required for this technique. The first receiver, known as the "reference" or "base" receiver, occupies a known geodetic control monument. The second receiver, known as the "remote" or "rover" receiver, occupies points that require positioning, for example, parcel corners. The data collected at the reference receiver are used to compute actual corrections to the pseudo-range measurements. These differential corrections are then applied directly to the remote receiver, either in real-time via a communication link or in a post-processing mode. Provided that the distance between the reference receiver and remote unit is not too great, the magnitude of these corrections is common to both units. The technique is capable of yielding positions with submeter accuracy at the remote station when utilizing the appropriate hardware, software, and observational procedures.

The technique has the following advantages:

- ◆ implementation is relatively simple;
- ◆ observational technique is robust, therefore requiring minimal training;
- ◆ only one base station is required to support multiple rover units (productivity can then be significantly increased at a relatively low cost); and
- ◆ no coordination is required between rover units (field crews can therefore operate independently of each other).

A description of the methodology is outlined below. This description serves to document the procedures involved in the process rather than provide a detailed operations manual. The

methodology may be divided into the following three categories: office planning and preparation, field procedures, and post-processing operations.

2.3.1.1 Office planning and preparation

a) Satellite coverage

Comprehensive planning and organization make up an essential part of the GPS methodology. Therefore, prior to the survey, the satellite coverage must be evaluated in the area of interest for the given time period.³ Recent ephemeris data, which describe the most up-to-date computed orbital parameters of the satellite constellation, should be acquired. The ephemeris data are obtained by utilizing a GPS receiver to collect data from at least one satellite for approximately 15 minutes. This ensures that the full navigation message is obtained.

The collected data are downloaded (transferred) to a personal computer (PC). Quick Plan, the mission planning software supplied by TRIMBLE, is used to generate a number of satellite visibility plots and reports. Graphs include the number of satellites, PDOP (Position Dilution of Precision), elevation, azimuth, satellite availability, and a skyplot. PDOP is an indication of the geometric strength of the satellite configuration. It accounts for the relative location of each satellite in the constellation to predict the accuracy of positions obtained utilizing that constellation. Lower PDOP values indicate good satellite geometry. The graphs depicting “Number of Satellites” and “PDOP” offer a convenient means of quickly assessing whether or not sufficient satellite coverage is available. The assessment of satellite coverage is based upon the following criteria:

- ◆ a minimum of 4 satellites is required to determine a 3-D position, and
- ◆ low PDOP values are required for reliable point positioning.

b) Creation of a data dictionary

A data dictionary is created using the PFINDER software. This is a catalog of information about the definition, structure, and usage of the data. The use of a data dictionary is recommended since it structures and guides the data collection process and provides additional meaning to the resulting data files. Each dictionary consists of:

- ◆ a list of features,
- ◆ a list of attributes for each feature, and
- ◆ a list of values for each attribute.

Each data dictionary created must be tailored to the type of data being collected; for example, for parcel mapping a single feature, “Parcel Corner,” was deemed adequate in the tests. Attributes such as “Parcel ID,” “Date,” and “Time” were also included. The test areas in urban Tirana required a more detailed dictionary, including features such as “Power Pole,” “Building Corner,” “CL of Road,” “Concrete Bunker,” “Fence Corner,” and so on.

Each data dictionary is uploaded to the TDC1 datalogger for subsequent use in the field.

³ With the full constellation of satellites available since 1996, there is adequate coverage in most areas of the world.

c) Base receiver configuration

Achieving submeter accuracy with the Pathfinder Pro XL is possible only under specific operational conditions. These conditions relate to the circumstances under which data are collected. The reference and rover receivers should be configured to ensure compliance with certain requirements. The following parameters were set for the reference receiver:

logging interval:	5 secs
elevation mask:	10 degs
PDOP mask:	8
SNR mask:	4

The logging interval specifies the regularity with which positions are stored within the receiver. This is dictated mostly by the amount of internal memory stored in the receiver. An interval of 5 seconds should be selected, since this provides a balance between the volume of data generated and the occupation time required by the rover at each point. The elevation mask should be set at 10 to ensure that satellites too close to the horizon are excluded, since atmospheric effects may result in signal degradation. The PDOP mask is set to a value of 8 to ensure that data are collected only when a favorable satellite constellation exists. The SNR ratio provides a measure of the strength of the signal being received; low signal strength, for example, would have an adverse effect on positional accuracy.

d) Rover receiver configuration

The rover receiver should be configured in a similar way. However, values for the parameters set may in some cases differ from those of the base receiver. The following values should be specified:

logging interval:	5 sec
elevation mask:	15 deg
PDOP mask:	6
SNR mask:	6

In order to achieve submeter accuracy with the given hardware configuration, the logging interval at the base and rover receivers should be identical. This obviates the need for interpolation of pseudo-range corrections at the base station. In addition, a requirement of the differential correction process is that the rover collect a subset of the satellites being tracked at the base station. The remaining parameter values are thus slightly more stringent than for the base receiver; for example, elevation mask is higher, therefore satellites would be excluded at the rover prior to the base station. In addition, the following parameters were set at the rover receiver:

antenna height:	2.00 m
minimum no. of positions:	6
datum:	WGS 84

Although the Pathfinder Pro XL yields submeter accuracy on a second-by-second basis, it is recommended that more positions be collected. These positions may then be averaged after differential correction to yield a more reliable position. The minimum number of positions should be 6, therefore requiring each point to be occupied for 30 seconds.

2.3.1.2 Field procedures

a) Reconnaissance

A thorough reconnaissance is an essential part of the fieldwork if efficiency and productivity are to be maximized. This applies to all surveying techniques but is especially true for GPS surveying. The productivity that can be realized using GPS technology is largely dependent on comprehensive planning of the fieldwork. A thorough reconnaissance is required primarily to identify suitable existing geodetic control points in the vicinity. The selected control point should be accessible, preferably by vehicle, and should have an open horizon.

Furthermore, the area to be mapped must be identified. Sketches of the fields should be drawn to facilitate parcel-level sketches drawn during the measurement process. These procedures enable the measurement process to be optimized and organized in a logical fashion.

b) Base receiver set-up

The base receiver is set up at the recovered control point and the configuration is checked once more. The receiver must be centered over the mark using a precise optical plummet. It must then be powered up and set to begin collecting data. The height of the antenna must be measured and recorded in a field book, together with the station name, the date and time, and other pertinent information. Care should be taken to ensure that the base station is collecting data prior to any rover receivers, since only simultaneous data between base and rover receivers may subsequently be differentially corrected.

The issue of security should also be addressed during all phases of data collection. It may be necessary to recruit a local person to “guard” the receiver throughout the day. This could be avoided if access to the control point is restricted, for example, on the rooftops of certain buildings. If this is not possible, alternative arrangements should be made during the planning phase of the survey.

c) Data collection with rover receiver

The rover receiver (Pathfinder Pro XL) is enclosed in a backpack, which affords a convenient means of conducting the data collection. The antenna is mounted on a range pole, and the data collector is held by the operator. This configuration is well suited to the mobility required for the fieldwork.

Once the receiver is powered up, the configuration should be checked once more. Before data can be collected, it is necessary to specify the name of the file in which the data will be stored. The default filename should be selected that reflects the date and time of file creation. The measurement process then involves the identification of each parcel corner by the village community leader/elder, the collection of GPS data at each point, and the annotation of a field sketch. It should be noted that the identification of each parcel corner as well as any conflict resolution by members of the community can be a time-consuming process. However, it is fundamental to the creation of a sound cadastre and should not be taken lightly. Furthermore, the time required for this process is independent of the measurement technique utilized.

d) Field sketches

Field sketches are an essential part of the data-collection procedure. Since GPS measures point positions, it is necessary in the post-processing stage to connect these points in order to depict the boundary lines to be shown on the cadastral map. It is therefore imperative that adequate notes be maintained in the field to allow the reliable generation of the cadastral map, preferably by a party not involved in the data-collection process. The sketch should therefore depict as clearly as possible the point name, the boundary lines as determined in the field, any parcel identification numbers, and other relevant field features.

2.3.1.3 Post-processing operations

a) Downloading and archiving

At the end of each day's work, the data should be downloaded to the PC and archived on removable media prior to any processing. This ensures that a back-up copy of all raw data is maintained for security reasons.

b) Processing

All data collected and stored in the receiver relate to the World Geodetic System of 1984 (WGS 84) reference ellipsoid. It is recommended that the data be processed on WGS 84 and converted to the local datum once processing has been completed. However, these transformations require some knowledge of the relationship between the two systems. The differential correction process may be conceptually divided into the following steps:

- ◆ specify and prepare the base data file(s),
- ◆ enter the reference position of the base station,
- ◆ specify and prepare the rover data file(s),
- ◆ differentially correct the data,
- ◆ output the results, and
- ◆ transform the results to local datum.

These are executed as functions within the PFINDER software and are discussed in more detail as follows.

- i) The base data file should contain all data collected for the observing session. If a power failure occurred during data collection, more than one base data file may exist. These files may be concatenated into one file, so that the differential correction procedures need be run only once.
- ii) The reference position of the base station entered should relate to the WGS 84 ellipsoid. It may therefore be necessary to transform the position from the local datum to WGS 84. However, as mentioned previously, this requires some knowledge of the relationship between the two systems. Furthermore, extreme care should be exercised in the transformation and subsequent entering of this position, since any error in the base reference position will be reflected in similar magnitude in the differentially corrected positions.
- iii) If multiple files exist for the rover receiver, these files may also be concatenated to avoid duplication of processing effort.

- iv) When the differential correction procedures are executed, two files are created. The first is a difference file, which contains the actual correction values for the satellite measurements on an epoch-by-epoch basis. This file may be used to differentially correct other rover files collected during the same time period. The second file is the correction file, which contains the differentially corrected rover positions.
- v) The differentially corrected rover positions should be exported from the PFINDER software in a usable format. Note that the software automatically averages all positions collected for each feature, for example, parcel corner. An ASCII output format containing point name, latitude, longitude, and ellipsoidal height was deemed adequate for the tests conducted. This file then serves as input into the transformation software.
- vi) The final results should be transformed to the local datum for the production of the cadastral map. The transformation package Geographic Calculator (version 3.0) was used for this purpose during the tests.

c) Map production

The data collected and processed as described above are of little value to the property and land registration system unless they are presented in graphical format. This formatting represents the final step, and one of the most critical, in the proposed GPS methodology, since it ensures that the GPS data are compatible with the traditional measurement process currently utilized for parcel mapping in Albania. The computer-aided drawing software (AutoCAD version 11 386) was used during tests conducted in Albania for the production of the final “cadastral map.” All of the GPS-based maps included in this report were generated by this method. It should be noted that the production of a reliable representation of the data is highly dependent upon the compilation of comprehensive sketches during the data-collection process.

2.3.1.4 Geodetic considerations in Albania

The use of GPS techniques within Albania raises some important geodetic issues. All GPS data are related by definition to the WGS 84. This system is an earth-centered, earth-fixed (ECEF), 3-dimensional coordinate system, with an ellipsoid that best approximates the surface of the earth as a whole. The local geodetic datum presently in use in Albania is based upon the Krassowsky ellipsoid. The established triangulation network was based upon seven baselines (initial sides), at the ends of which astronomical (Laplace) azimuths were performed. Furthermore, an initial point was selected at Kamza, and the astronomical coordinates determined by astronomical observations. Astronomical azimuths were also determined at this point, and at one other (Tapiza). These observations form the basis of the present geodetic datum in Albania. However, since no gravimetric observations have been performed, the geodetic coordinates of the point of origin at Kamza could not be accurately determined from the astronomic coordinates. For this reason, geodetic coordinates for the origin point at Kamza were based upon existing triangulation performed in 1955 and are therefore based upon the Pulkovo 1942 datum (Isufi 1993).

The Albanian datum is therefore based upon a locally best-fitting ellipsoid. The relationship between the local ellipsoid and the global geocentric reference systems, such as WGS 84, is therefore not easily determinable, making accurate transformations between these systems difficult to achieve. Since all GPS data relate to WGS 84, it is recommended that all processing and analysis of the data be conducted on this system. Final corrected positions may then be

transformed onto the local datum in Albania using the appropriate transformation routines. This approach also requires that the reference station coordinates be known in the WGS 84 system.

As mentioned above, the parameters for transformation between these data are unknown. These parameters may be approximated in a number of ways. First, ties may be made to global reference stations that are known in the WGS 84 system, such as stations comprising the Cooperative International Geodetic Network (CIGNET). These continuously operating stations track GPS satellites and store the data, which are then available through a number of agencies, for example, through the Internet. Such stations exist within relatively close proximity to Albania, for example, Matera in Italy, and Ankara in Turkey. Baselines may be processed to known stations within Albania and used to compute mean **DX**, **DY**, and **DZ** translations between the systems. These translations may be applied with appropriate signs to transform between the WGS 84 and the local system, using the following simple three-step process:

$$(j,l,h)LOCAL \Rightarrow (X,Y,Z)LOCAL \Rightarrow (X,Y,Z)WGS\ 84 \Rightarrow (j,l,h)WGS\ 84$$

An alternative means of determining the required transformation parameters utilizes the methods of satellite geodesy, which has the capability of providing high-accuracy geocentric coordinates. The determination of at least three points in both coordinate systems enables the solution of a 7-parameter transformation, that is, three translations, three rotations, and a scale change. However, regional parameter variations may exist due to network inhomogeneity. It is therefore advisable to get as many well-distributed common points as possible to obtain increased redundancy and more reliable determination of the parameters for the complete region of interest.

The U.S. Defense Mapping Agency (DMA) is currently undertaking a countrywide GPS campaign in Albania. The results of such a campaign will enable the computation of "accurate" transformation parameters. Discussions with DMA representatives indicate that transformation parameters may be available as of October or November 1994.

2.3.2 SELECTION OF CANDIDATE GPS TECHNIQUES

A three-day workshop, entitled "Digital Cadastral Surveying Using GPS," was held at the University of Florida in Gainesville on 1–3 June 1994. The objective of this workshop was to define and develop a methodology for surveying land parcels using GPS so that cost-efficiency would be maximized under conditions typically found in Albania. It was designed to integrate the knowledge and experience of the participants in the two areas of GPS and cadastral surveying. Details of the workshop are included in Appendix E.

2.3.3 CONTROLLED TESTING AT UF TEST SITE

These tests involved the two most promising GPS methodologies identified in the workshop (options 1 and 3 in Appendix E). The primary focus was on the effect of baseline distance (i.e., distance between reference base station and rover receiver) on the accuracy of the GPS positions and the establishment of efficient field procedures. Tests were carried out on a test site created specifically for this project on the University of Florida campus.

Details of the test results are given in Appendix F. The significance of these results is that no densification in geodetic control is required to support the recommended GPS methodology. As can be seen on the map of Albania in Figure 2.1, a single base station in Tirana (e.g., on the roof of the LRI building) can serve almost the entire country, since the required accuracy is attainable up to a baseline distance of 135 kilometers. This implies a significant saving in resources and time and allows greater control over the base station.

2.3.4 FIELD TESTS IN ALBANIA

Tests were carried out in various environments where there is perceived to be a high demand for surveying and mapping. Although the earlier focus of the Immovable Property Registration System (IPRS) project was on rural areas, it has become apparent that the highest frequency of land transactions is likely to be in the urban fringe around the larger cities, particularly Tirana. If this project is to support the land market that will evolve in Albania, then it is essential that the emphasis shift more toward the peri-urban areas. As a result of these changing needs, we conducted tests in both rural and urban areas.

2.3.4.1 Rural sites

a) Zhurje

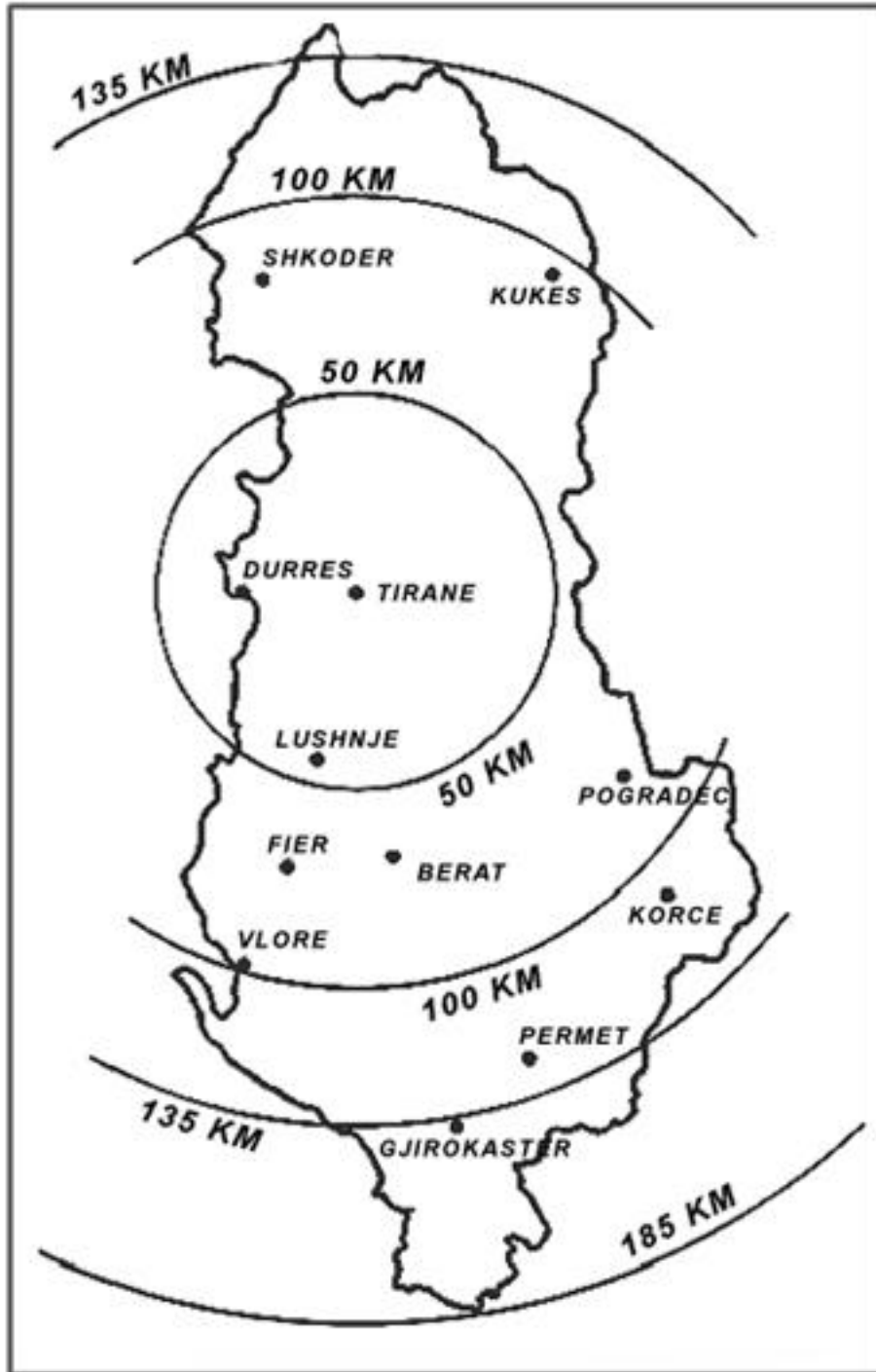
The village of Zhurje is located approximately 20 kilometers west of Tirana; it is part of the ex-cooperative of Ndroq. This village was selected because it was currently in the process of being surveyed by traditional methods and a direct comparison of the GPS and traditional approaches could therefore be made. Approximately three-quarters of the 100 hectares of the village had already been surveyed. Zhurje is a typical example of nonmountainous farmland and has the further advantage of being easily accessible from Tirana. The average parcel size in the village is approximately 0.25 hectare (2,500 square meters).

An existing control point at the top of the LRI building was used as one reference point for the GPS survey and an additional point was located in the vicinity of Zhurje. All of the geodetic control points are shown on the 1:50,000 map sheets and the coordinates of these points were obtained from the LRI. Many of the observation signals that were typically erected over these geodetic control points are missing (they were taken by local inhabitants for bed frames) and so it is not always easy to locate them in the field. GPS proved to be useful for navigating and locating the general area (within 50–100 meters) of these points.

Once the two reference or base station receivers (both geodetic receivers) had been set up, the survey of the parcel corners was begun. This was done by means of a TRIMBLE Pathfinder Pro XL receiver, which is extremely light and designed to be carried in a backpack. The antenna is attached to a range pole and attribute data (e.g., point type and name) are entered through a hand-held data collector.

It is essential in the process of cadastral surveying in Albania to include a village representative in the survey team in order to identify the location of the parcel corners. Parcel corners are generally not monumented, but are identified by the edge of a field of crops or a small irrigation furrow. In Zhurje, we were fortunate to have the services of both a village elder who had been involved with the original allocation of individual parcels and the surveyor who was undertaking the survey of the village.

FIGURE 2.1 Base station coverage in Albania



A total of 29 parcels was surveyed over a period of 4 hours and 35 minutes (excluding 40 minutes to set up the base station) using GPS. Besides individual parcel corners, GPS positions were also determined for the boundaries of the residential area (“economic zone”), a village parcel (Ndroq), and two buildings. The results of this survey are shown in Figure 2.2.

b) Lumthi

The second rural test area was located in the village of Lumthi (Lushnja District), about 15 kilometers south of the city of Lushnja. It is flat, well-irrigated farmland that is crisscrossed by numerous irrigation canals and furrows. The village contains 208 hectares of land distributed to 131 different families (average of 1.6 ha/family). Each family has been allocated between two and four parcels, with the large majority (90%) having three parcels.

We were accompanied into the field by the head of the Lushnja Cadastral Office and one of the surveyors from this office. Once again we enlisted the help of a village leader who had been involved in the original allocation of individual parcels. We were able to recover a nearby geodetic control point, which was used as the base station for the GPS observations.

A total of 17 parcels was surveyed in 1 hour and 40 minutes (excluding 35 minutes to recover and set up the base station). Some problems were experienced with the field identification of the parcel corners because Lumthi was one of the first villages to be subdivided and allocated to individual families. This meant that almost 3 years had passed since the work had been completed and the village elder had problems identifying several boundary lines. This indicates the need for the surveying and mapping process to follow closely behind the allocation process, especially where no physical markers are used to demarcate corners (typically the case in this area). The results of this survey are portrayed in Figure 2.3.

2.3.4.2 Urban sites

a) Selita

Selita is located on the urban fringe of Tirana just outside the “yellow line,” which designates the urban boundary of Tirana. It consists of a mix of old buildings (mainly around the periphery), recently completed buildings, and houses in the process of construction (from foundations to almost completed structures). The buildings are substantial and solidly built from brick, a testament to the building skills developed during the communist era when apartment blocks were built using communal labor.

The only boundaries that could be construed as property boundaries were the walls built around several of the houses. There does not seem to be any preconceived subdivision plan and building is occurring in a random fashion. The corners of 30 buildings in different stages of development were surveyed using GPS as well as road centerlines and power poles. The control point on the LRI building was used as a base station to differentially correct all GPS observations.

The Pro XL receiver performed very well and only on a small number of occasions were we unable to obtain sufficient satellites for a position fix. These problems were experienced primarily where buildings of two or more stories were situated close together. A tape was used to establish the position of the corners that could not be measured by GPS. A total of 124 points was measured over a period of 3 hours (excluding the time for base station set-up). The results of this survey are illustrated in Figure 2.4.

FIGURE 2.2 Parcel plot in Zhurje

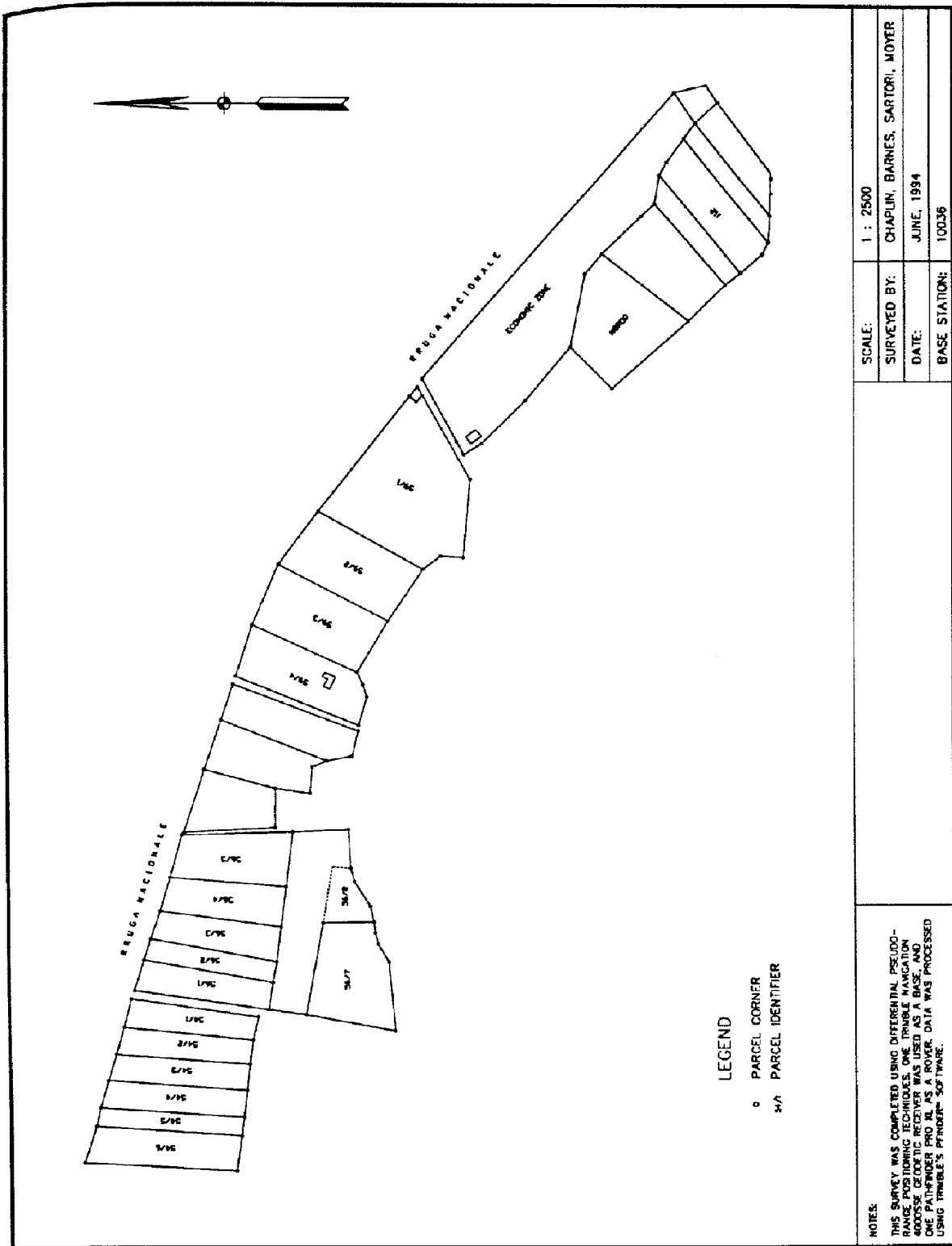


FIGURE 2.3 Parcel plot in Lumthi

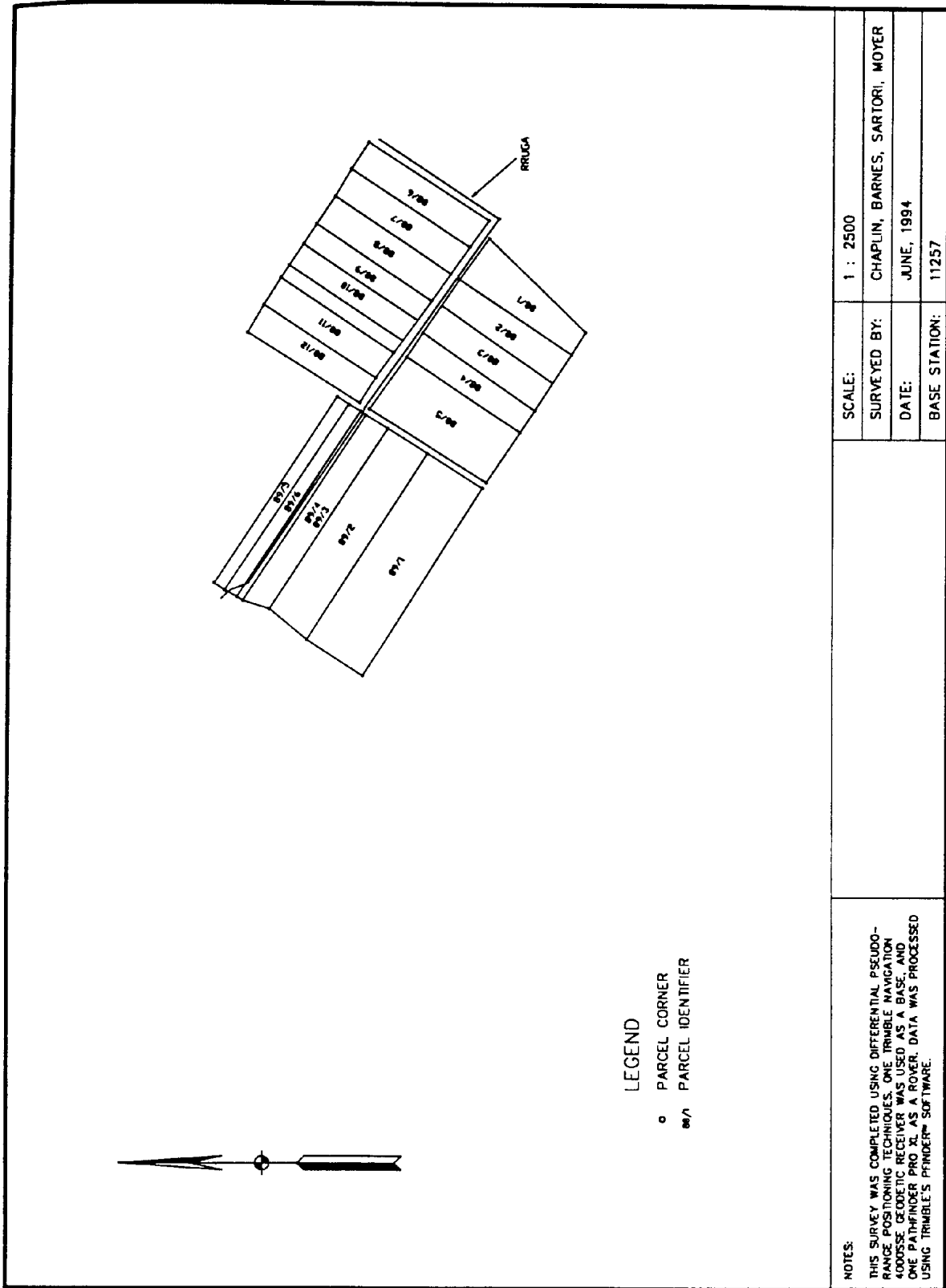
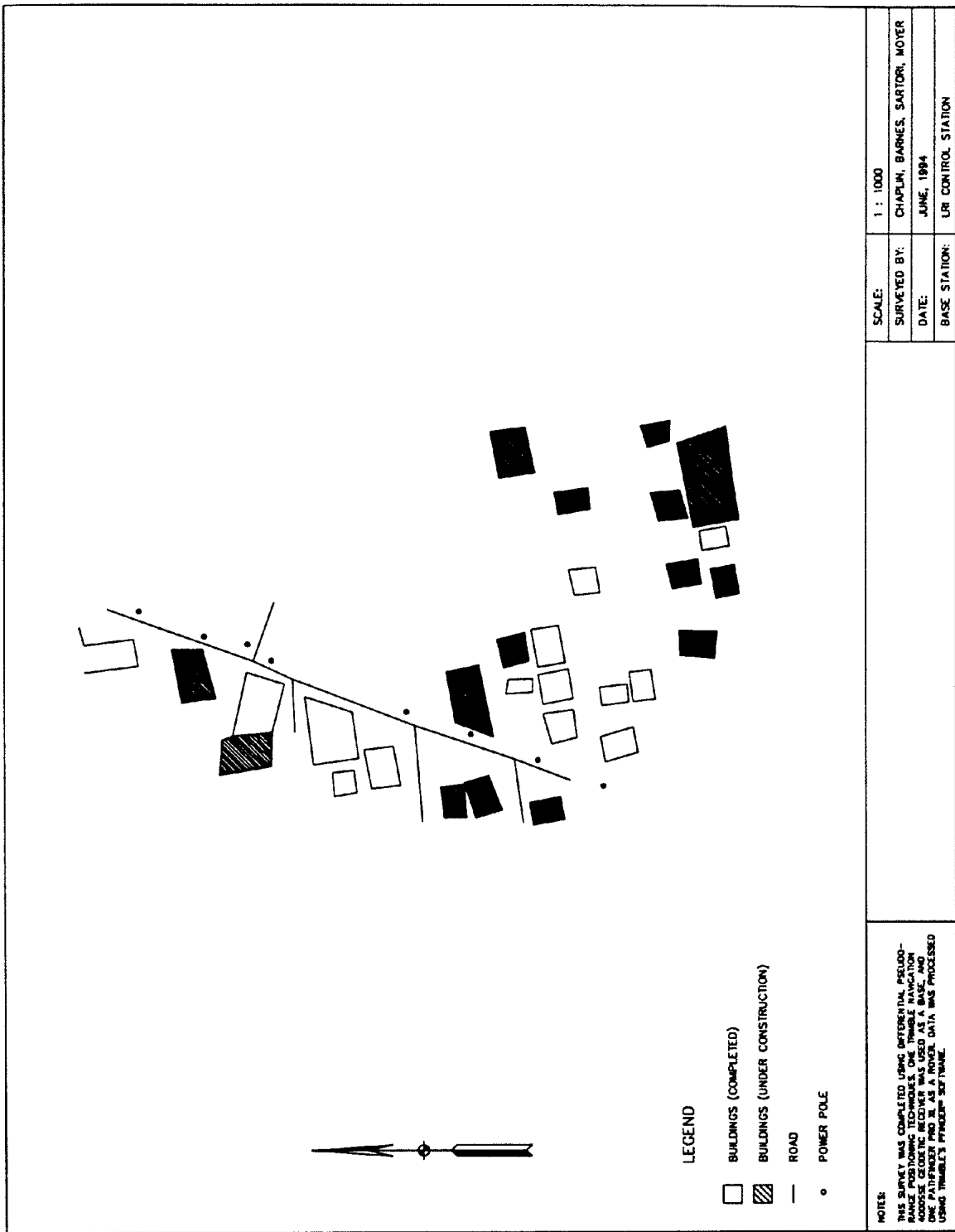


FIGURE 2.4 Urban plot of Selita



b) Priest Hill

This is a 12.2-hectare area on the east side of Tirana. A former vineyard and olive grove, the site is undergoing rapid transformation into a densely populated suburban neighborhood. Approximately 85 residences exist on the site; they are in various stages of completion, ranging from occupied dwellings complete with fenced gardens to bare foundations with no apparent boundaries save the groundwork itself.

The site was surveyed by the Pathfinder Pro XL in five hours. Again the existing control point at the top of the LRI building was used as the base station for differential correction of the rover data. All roads, irrigation channels, power lines, and bunkers were located, as well as an irregular boundary line on the west side that consisted of the existing school wall and factory buildings (see Figure 2.5). A total of 100 points was surveyed. No attempt was made at this stage to locate individual parcels or foundations, the intent being to produce a working map of the area which could later be completed with the Pathfinder Pro XL or updated by means of taping and sketching. The Pathfinder Pro XL performed well in this setting since there are no dense, multistory buildings to interfere with satellite signal reception. The production of this map required an additional three hours of office time.

c) Kamza

Site of a former state cooperative, Kamza is an 88-hectare area west of Tirana on the highway to Kruja. This site is also undergoing rapid transformation from agriculture to suburbs.

The entire 88-hectare parcel was outlined and divided into subsections in one-half day of fieldwork with a three-man crew using the Pathfinder Pro XL, with an additional 4 hours required to produce a working map of the area (see Figure 2.6). Again the point on the roof of the LRI building served as the base station for differential corrections. Field location was done on all periphery roads as well as well established interior roads, major drainages, bunkers, and powerlines. The location of these features to submeter positional accuracy will enable a follow-up survey to locate individual parcels and structures more easily and efficiently.

In this environment the Pathfinder Pro XL is an effective and efficient tool for rapid and accurate data collection and map production.

2.3.4.3 Road mapping using vehicle-mounted GPS

A small test was done to ascertain whether the Pathfinder Pro XL could be used for rapid surveying of roads and other features. The antennae of the Pro XL were mounted on the roof of a vehicle by means of a magnetic attachment. We then drove from Tirana to Kruje, about a 1-hour drive. Along the way we entered specific features of interest, such as bridges, the Agricultural University, and road intersections.

On our return to Tirana we processed the data and produced a map of the route with the selected features. This map is shown in Figure 2.7. The accuracy of the results is in the region of 50 to 100 meters, but this can very easily be improved to the meter level by using a differential approach (i.e., by setting up a base station receiver at a reference station).

FIGURE 2.5 Infraestructure plot of Priest Hill

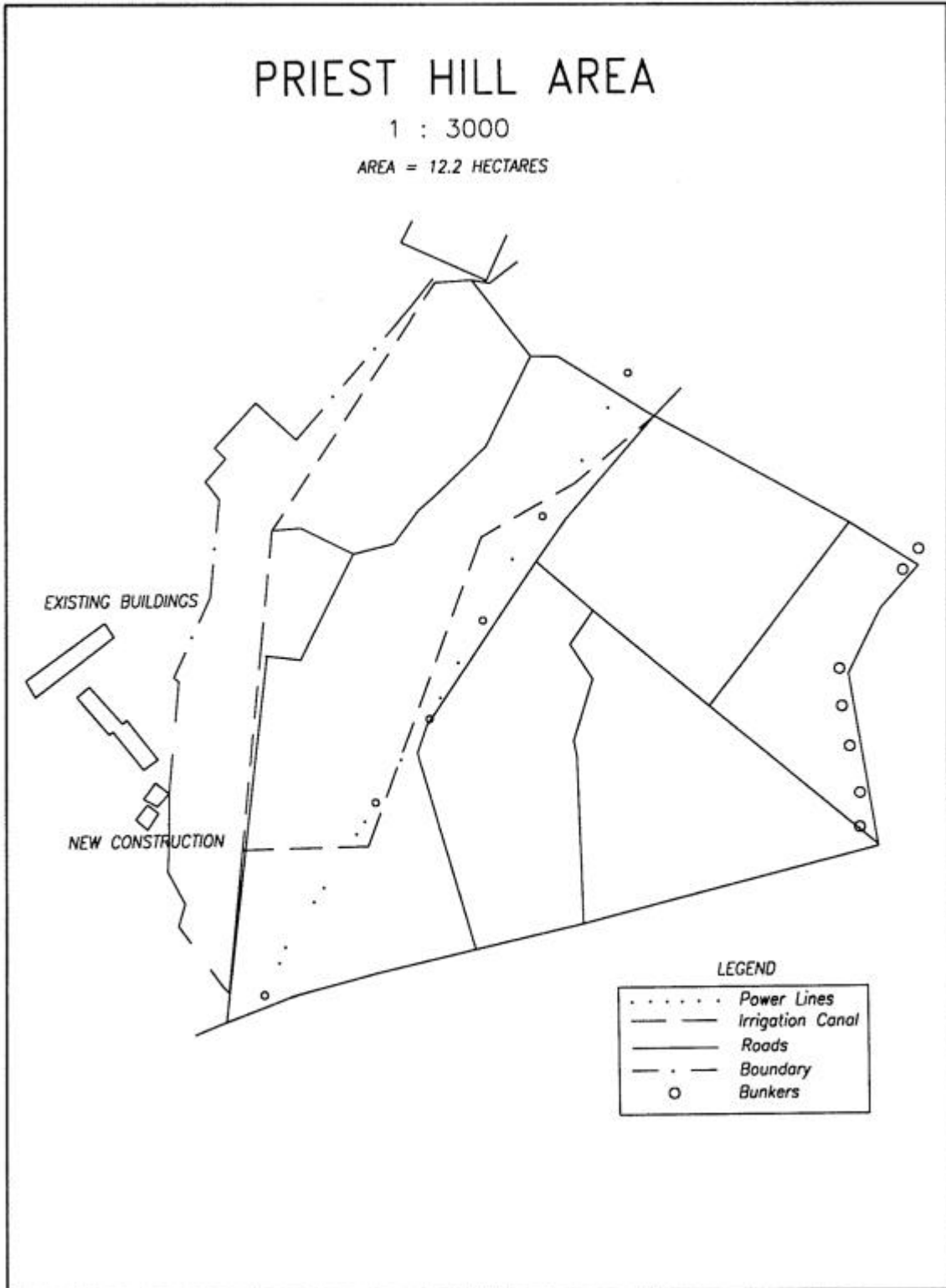


FIGURE 2.6 Infrastructure plot of Kamza

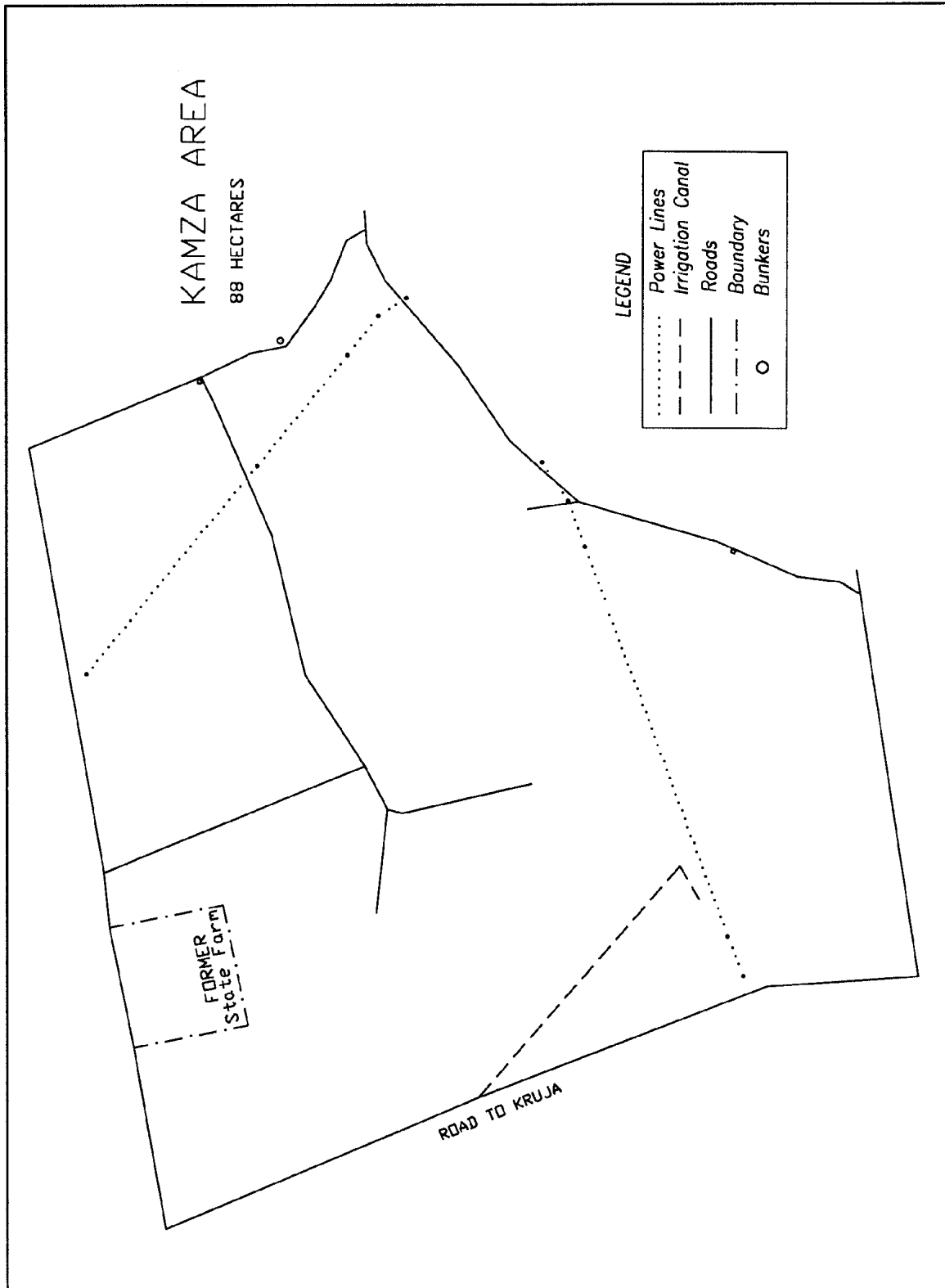
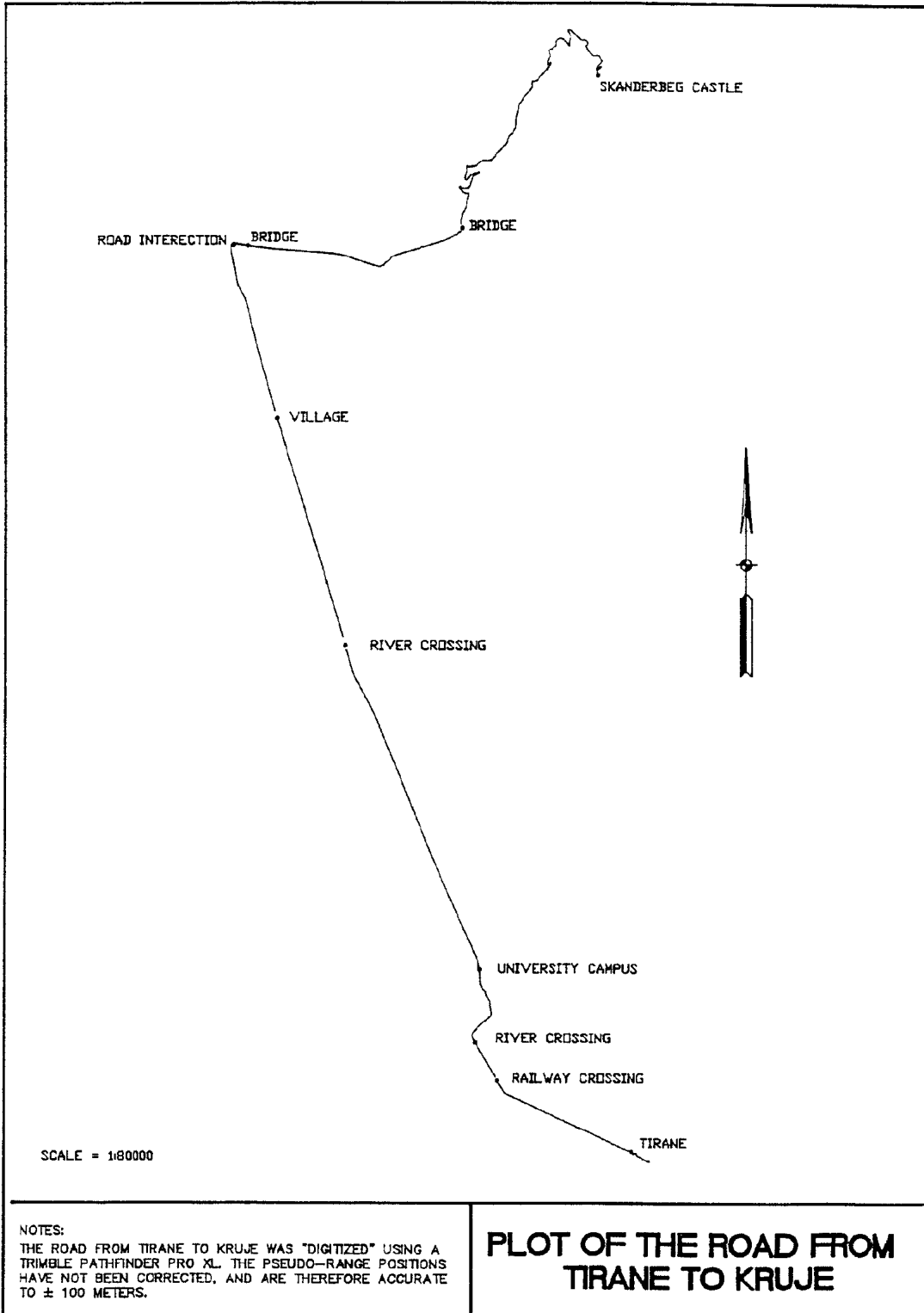


FIGURE 2.7 Plot of Tirana-Kruje road



2.4 EVALUATION OF EXISTING METHODOLOGY IN ALBANIA

Surveying and mapping of cadastral parcels is often the most time-consuming and costly component of a cadastral or land registration project. However, it is also the cornerstone of modern property registration systems since it defines the spatial unit—the parcel—to which most other cadastral data are referenced. An appraisal model has been developed to evaluate the various surveying and mapping options in Albania. This model is composed of four distinct components, namely:

- ◆ the surveying and mapping process under evaluation,
- ◆ inputs required by the process (see subsection 1.5.1),
- ◆ factors affecting the performance of the process (“degree of difficulty”) (see subsection 1.5.2), and
- ◆ criteria used to evaluate the process (see subsection 1.5.3).

The different processes of surveying and mapping consist of the various techniques described in the previous section. Theoretically, each of the techniques would be subjected to a separate evaluation. In a practical sense, those techniques that are not viewed as being viable in Albania will not be evaluated.

2.4.1 INPUTS

The inputs required for the existing surveying and mapping method include an adequate supply of personnel trained in the surveying and mapping techniques. Because of the high quality of surveying education available at the university level in Albania, available personnel have the required skills. As reported in Section 1, the supply of such persons a year ago (1993) appeared to be adequate to complete the surveying and mapping of all cadastral parcels in Albania using current methods. However, in the year since we first reviewed the matter, considerable inflation has occurred in Albania and the number of opportunities for employment has increased. Scattered reports of difficulty in finding adequate numbers to fill the field crews have been received. Therefore, we are less confident as to the adequate supply of trained surveying personnel than we were a year ago.

2.4.1.1 Equipment

The equipment for the existing method (i.e., taping and/or tacheometry) is available and inexpensive. The major items needed for the current surveying and mapping method are 30-meter tapes. While not initially available last year, an adequate supply of steel and fiberglass tapes has been obtained for the project. In certain parts of the country, tacheometry equipment is needed; this also appears to be available in adequate quantities.

2.4.1.2 Information base

The current base of information on which to build the surveying and mapping system for parcels is inadequate. This is due not to a lack of information but rather to an inability to gain access to information that exists in a variety of ministries and offices. The net result is that while progress is being made, the output would be greater and the quality higher if a government policy of open sharing of available data were in place.

We note that similar problems with data access, such as the existing geodetic network, exist in other Eastern European countries as well. For instance, the Parliament in Romania only recently approved the release of the coordinate location information for seven geodetic control stations spread across the country. Open access to such information is needed for both parcel surveying and mapping and for related geographic information system (GIS) activity. Further, in addition to in-country benefits, open access to geodetic network information facilitates ties to the European Reference Network.

Finally, it is critical to note that the traditional method is based on existing maps: if such maps do not exist, this method breaks down and, at the same time, alternative approaches become more effective as to both cost and quality of output.

2.4.1.3 Training

As noted under staffing inputs, the university system in Albania has trained, and continues to train, an adequate number of surveying and mapping personnel. The key unknown, given the major shifts that are occurring in the Albanian economy, is whether these personnel can be attracted to these surveying and mapping jobs. Given the scarcity of resources for both equipment and training, a major advantage of the traditional surveying and mapping method is that little additional training is required. Therefore, if the salaries are adequate to attract the required personnel, traditional surveying and mapping can proceed full-speed ahead, with little constraint due to either training or new equipment costs.

2.4.2 OUTPUTS

One output from the current surveying and mapping method is a map for each ownership parcel in Albania. The maps are produced by hand at a scale of 1:2,500 and contain a graphic depiction of each parcel. A second output is a variety of tabular data concerning dimensions and area of each parcel, owner name, and parcel identification number.

The quantity of output in tests in the three pilot districts was discussed earlier in subsection 2.2.2. Spiro Lamani of the Land Resources Institute (LRI) has indicated that plans are to complete surveying and mapping of 188,000 hectares in the next six months (i.e., by 31 December 1994). Mr. Lamani is confident that the crews will meet this goal and pick up the leftover work from the previous six months as well. To meet the 188,000-hectare goal requires that each crew complete an average of 10 hectares per day or 200 hectares per month. The DCO requires that these rates be maintained in order for the crews to be paid, a substantial incentive.

We estimate that 156 crews will be necessary to reach the target production goal. Mr. Lamani reported that the PMU plan calls for 168 crews, so if a full complement of personnel can be hired, the surveying and mapping system has the employee capacity to reach the PMU goal. Office personnel at LRI will need to complete a final map for 600 parcels per month in order to keep pace with the 188,000-hectare goal.

Edmond Leka of the Military Topographic Institute (ITU) also provided output estimates for a second parcel surveying and mapping option: photogrammetry. Mr. Leka said his estimate of cost per parcel for surveying and mapping in the flat areas of the country using the current method being pursued by the LRI is \$10 per hectare. This cost is based on densities that range from 3 to 20 parcels per hectare. Mr. Leka estimates that by using photogrammetry in the

mountainous areas, the cost could be held to \$4 per hectare. This is based on the assumption that parcel density is less in the mountains, (i.e., about 10 parcels per hectare). It is not certain if this estimated cost includes field identification of the parcels.

It must be emphasized that much of the data on costs and output rates is based on hearsay and anecdotal evidence; hard numbers are needed. Therefore, to facilitate the collection of such information, we urge the PMU to begin using the Data Collection Forms which were designed in 1993 as soon as possible. In addition to making more accurate cost and production estimates possible, these data will help program managers make decisions concerning changing technologies as the economy of Albania continues to expand and develop.

2.4.3 PERFORMANCE

The goal for the six-month period (July–December 1994) is 188,000 hectares, or 10 hectares per crew per day. Spiro Lamani is tracking progress by monitoring a number of indicators, including number of field teams and workers, hectares surveyed, field costs, number of office drafting personnel, months worked, and costs. We emphasize our belief that these data could be improved and made more useful if the Data Collection Forms we suggested last year were put into use.

We have used the information provided by Mr. Lamani to make some estimates of the costs of the existing methodology. The current salaries for crew members are \$70 per month for the topographic specialist and \$45 per month for each of the two assistants, for a total wage cost of \$160 per crew per month. In addition, each crew member receives \$2 per day for meals and about \$1 per day for transportation, for an additional cost of \$180 per crew per month. Therefore, the total costs per month for one field crew are estimated to be \$340, or \$1.70 for each of the 200 hectares surveyed and mapped each month.

Costs are also incurred for additional work that takes place in the office by the office mapping personnel in the LRI. While estimates of these costs were not available, total costs for the 188,000 hectares were obtained from Mr. Lamani. These costs are summarized in Table 2.1.

TABLE 2.1. Estimated costs of existing methodology

ITEM	LEK	DOLLARS
Updating of maps	40,879,068	\$441,992
Enlargement	2,800,000	\$30,720
Total	43,679,068	\$472,212

Therefore, total cost per hectare for the surveying and mapping program is \$2.51 (\$472,684 divided by 188,400 hectares). Subtracting the estimated field cost of \$1.70 per hectare leaves an estimated office cost of \$0.81 per hectare. This method of computation is somewhat inflated since some tacheometry costs are included in the total. These estimates appear reasonable, since the production rate for office personnel is three times the production rate of field crews (i.e., 600 hectares per month in the office versus 200 hectares per crew per month in the field).

In an attempt to define and identify costs more precisely for surveying and mapping, we sought to reconcile available information on number of parcels, households, and persons per household. We believe that such data would be very useful in tracking the overall progress of the surveying and mapping program as well as the performance within each district and even within individual field and office crews. However, we were unable to reconcile these data because of incompleteness and inconsistencies in information

The difficulties we encountered are due to various factors such as topography and size of villages, inconsistencies in the data available to us, and the relatively few direct observations we were able to make. As an example, land distribution data available nationwide suggest:

- ◆ 0.22 hectares per person,
- ◆ 1.39 hectares per household,
- ◆ 6.33 parcels per hectare, and
- ◆ 5.37 persons per household.

Other data suggest a household size of 4.5–5.0 people. The net result is that we were unable to verify the number of parcels per household or the average size of household. However, in two villages where we conducted GPS tests, the average number of parcels per family was substantially less than the national estimate (i.e., about 3 parcels per household in Zhurje and Lumthi).

Our primary concern for raising the issue of these data—and the inconsistencies that we believe exist—is to emphasize the need for a consistent database on which IPRS program managers can make decisions.

2.5 EVALUATION OF GPS METHODOLOGY

2.5.1 INPUTS

Certain inputs such as transport are common to all surveying methodologies and can therefore be disregarded in comparative analyses. The inputs discussed in this section are those that are most important to implementing the GPS methodology described earlier in this report. One of the primary questions in this context is what inputs are required before GPS can be adopted so that Albania will be in a position to maximize the potential benefits of this technology. The inputs discussed below include training, equipment, and base information.

2.5.1.1 Training

Training is undoubtedly the most important input required in this approach, which makes use of a technology that has not previously been used in Albania. While there are Albanians who possess many of the skills necessary for implementing the GPS methodology, these skills are fragmented across different groups with different professional backgrounds. This means that there are almost no individuals who currently possess the range of skills required.

There is a small group of computer scientists who are extremely computer literate, but who have no background in geodesy or mapping. Similarly, there are almost no geodesists or cartographers who have the necessary computer skills. Although there are a few AutoCAD specialists (AutoCAD is the software used to create maps from GPS coordinate data), most of

their experience has been in the areas of architecture and engineering drawing. They have little or no experience with mapping or dealing with data imported from GPS or other sources.

One of the questions that arises when facing this fragmented skill base is which group should take the lead in implementing the GPS. Our feeling is that those with a geodesy and cartography background, such as graduates from the surveying program in Tirana Polytechnic, can more easily be taught the required computer skills than computer specialists taught geodesy and cartography. However, in the short term it would be advisable to approach training in a team environment, which involves individuals from all of these groups.

The field operation of the GPS receivers is a relatively simple process, which could be done by the surveyors who currently do field surveying by traditional methods (mainly tape). The more difficult tasks are planning the survey, solving problems, adjusting observations, and resolving issues related to post-processing. A more detailed list of areas that should be included in a training program is:

- ◆ basic DOS commands and file handling,
- ◆ directory and subdirectory structure,
- ◆ setting up a data dictionary,
- ◆ previewing satellite availability and PDOP,
- ◆ planning a GPS survey,
- ◆ geodetic considerations (datums and geoidal undulation),
- ◆ map projections,
- ◆ file naming conventions and file organization,
- ◆ configuring base and rover receivers,
- ◆ downloading data from receivers,
- ◆ applying differential corrections,
- ◆ viewing data graphically,
- ◆ running checks and quality control,
- ◆ exporting GPS data to AutoCAD or GIS,
- ◆ applying basics of AutoCAD,
- ◆ creating maps in AutoCAD,
- ◆ plotting of final maps, and
- ◆ problem shooting.

This training should be provided in the first instance by an international consultant who is familiar with conditions in Albania and has an appreciation of the cadastral needs of the country. This consultant should provide in-depth training to a selected group of Albanians who will become future GPS trainers.

2.5.1.2 Equipment

Given the complete absence of GPS hardware or software in Albania, new equipment will have to be purchased. A minimum configuration would be advisable in the initial stage of implementation. This would include one or two (preferably) geodetic receivers (with appropriate chip) to serve as base stations and at least two roving receivers. The roving receivers must be capable of measuring to an accuracy of less than 1 meter and should be portable. A code receiver (e.g., TRIMBLE Pathfinder Basic) is not adequate since it measures only to an accuracy of 2–5 meters. While this accuracy may be sufficient in certain cadastral environments, the extremely

small parcels in Albania demand a higher level of accuracy. (A detailed list of hardware, software, and accessories is contained in Appendix G.)

2.5.1.3 Information base

The GPS methodology developed in this project requires reference points for differentially correcting the GPS measurements of parcel corners. Fortunately, Albania has a relatively dense network of geodetic control points which appear to be adequate for supporting this methodology. The specific information required for this support are the coordinates of the control points (available from LRI) and 1:50,000 maps showing the location of these points relative to roads and other topographic features. Part of such a map is shown in Figure 2.2. Although local reference points would be useful as a back-up and check, we recommend that, where possible, a centralized reference station be used (e.g., at the LRI building)

Base maps, such as those at a scale of 1:5,000 (or enlargements of these), are extremely useful for aiding in the planning and execution of the fieldwork. In the absence of such maps the drawing of field sketches, which show the association of point positions and parcels, can become quite challenging.

One significant advantage of a GPS approach is that the technology can be used where no maps exist to provide generalized base maps of the area (similar to the approach used in the urban test areas). Where the information base is either nonexistent or impossible to acquire from a government agency, the traditional taping approach becomes almost unusable. On the other hand, the GPS approach offers an efficient means of acquiring general map information such as roads (this can be obtained by mounting a receiver on a vehicle), buildings, fences, bunkers, and other topographic reference data.

2.5.2 PERFORMANCE

A summary of the results obtained in the field tests together with an indication of the productivity of the GPS methodology are given in Table 2.2.

TABLE 2.2. Examples of GPS productivity

STUDY AREA	AREA (HA) SURVEYED	UNIT	NO. OF UNITS	FIELD TIME
Zhurje	16.97	parcels	29	5h 15m
Lumthi	7.58	parcels	17	1h 15m
Selita	3	houses	30	3h 20m
Priest Hill	12.2	points	100	5h
Kamza	88	points	53	4h

The work done at the University of Florida test site demonstrated that the accuracy level of the GPS methodology is under 1 meter, provided the distance from the base station to the rover remains less than 250 kilometers. This was the case for all the tests conducted in Albania. In

addition, the relative distance between certain points (e.g., corners of a building) was checked by tape and found to be accurate within 1 meter.

An accuracy of around 1 meter should be more than adequate for most rural parcels since the corners are generally not identified by any physical markers or monuments. It appears that in most cases the corners are identifiable only to within about 1–2 meters. The accuracy requirements are likely to increase in the future as land values increase and will undoubtedly be most stringent in urban areas where land values will be highest.

2.6 CONCLUSIONS

The limited data available on the performance of the current approach and the experimental nature of the performance data collected on the GPS approach make it impossible to do a detailed comparative analysis. However, we do have sufficient comparative data to obtain a general idea of the productivity of the two methodologies. These data are summarized below.

TABLE 2.3. Comparison of daily field and office productivity

METHODOLOGY	FIELD SURVEY PRODUCTIVITY			OFFICE PRODUCTIVITY
	Area	Parcels	Points	
Current	10 ha/day	6–12	-	5 ha/day
GPS (rural)	37 ha/day	76 (25) ^a	-	37 ha/day
GPS (urban)	-	-	190/day	-

a. Takes into account adjudication time.

The above figures assume that an average workday is 8 hours. One significant difference between GPS and traditional productivity rates is that the latter includes time spent on adjudicating boundaries. This can apparently account for two-thirds of the total field time, but will obviously depend on the level of boundary consensus in a community. In order to take this into consideration, an additional productivity rate has been computed (shown in parentheses in the above table), based on the assumption that measurement takes up only one-third of the field time.

Office productivity for the GPS methodology is not based on actual data collected in Albania, but on a best estimate, which assumes that an equivalent amount of time is required for field and office. The preliminary evidence, therefore, indicates that GPS is twice as productive in the field and 7–8 times more productive in the office.

2.6.1 GENERAL OBSERVATIONS

Consistent data are needed on a nationwide basis to support and evaluate progress in the cadastral parcel surveying and mapping program. For example, data are needed for each district,

and ideally for each village, on the number of hectares, families, and parcels as well as on the number of hectares for each land use (i.e., agriculture, pasture, forest, etc.).

- a) The Albanian project needs to begin now to keep detailed records on costs, time, and so forth for each village and each survey crew.
- b) Urban areas, particularly in fringe areas, should be given priority for surveying, mapping, and registration.
- c) Simple, consistent, and written procedures, supported by a quality-control review process, are needed for field crews to assure a minimal, consistent level of performance.
- d) Data should be collected, for each field crew for each day, to provide:
 - ◆ information on the progress of the surveying and mapping process compared to program targets, and
 - ◆ information on the costs for each function of the surveying and mapping program to compare with budget resources (these data will be of critical importance to the PMU Executive Committee when faced with decisions regarding review of methods for surveying and mapping, for example, when wage rates and equipment costs change).

2.6.2 BENEFITS OF GPS APPROACH

The only data available on the GPS methodology in Albania are those accumulated during the field tests. However, there is sufficient evidence that the GPS approach offers significant advantages in terms of productivity. Other advantages of this approach are discussed below.

- ◆ All data are collected on a unified system, thereby ensuring compatibility between surveys conducted by different parties.
- ◆ The methodology generates digital data, which will facilitate the transition to a Multipurpose LIS/GIS in the future.
- ◆ Even if the data collected at present were not directly utilized in this transition, the introduction of digital technology into Albania will prepare the foundation of expertise required for this transition.
- ◆ The cadastral maps are easily reproducible in the event of loss or damage of the original.
- ◆ Different cadastral map scales may be generated with minimum effort to support alternative applications.
- ◆ The steady increase in salaries in Albania points toward the need for more economical mapping solutions. The steady decrease in the cost of GPS hardware, coupled with the high productivity attainable, makes this methodology an attractive solution for the future.

The introduction of current technology, and the gradual transfer of this technology in Albania, will prepare the way for future surveying and mapping activities such as for environmental assessment studies and AM/FM (Automated Mapping/Facilities Management) applications.

3. EVALUATION OF TRIMBLE PRO XL GPS UNIT

The 1994 phase of this study included the design, definition, and testing of a medium accuracy GPS methodology for cadastral surveying in Albania. This was undertaken through a workshop held at the University of Florida (UF) to define the most feasible GPS options and to integrate cadastral needs with technological options. Controlled testing was then carried out on a “cadastral test site” established specifically for this purpose on the UF campus. Tests were carried out using baseline lengths from 2 to 235 kilometers. Field tests were then undertaken in two rural sites and three peri-urban sites in Albania. The results of these tests and recommendations are available in Section 2. This section reports the performance of different types of global positioning system (GPS) equipment using medium-accuracy methodology.¹ This testing was done in 1995.

3.1 SCOPE OF ACTIVITIES

David Stanfield of the Land Tenure Center sent letters of inquiry to the major GPS vendors (Trimble, Ashtech, Leica) requesting their cooperation by making their receivers and software available for a short period of time for testing on the University of Florida campus. Grenville Barnes followed up on this request to arrange for delivery of the GPS equipment and software. Although these companies were contacted several times by telephone and by fax, Trimble was the only company that responded. While the central offices of these companies are interested in doing international business, they rely on their local offices to provide equipment needed inside the United States. We were not successful in obtaining any equipment from these local offices, but did manage to obtain Trimble receivers from the Latin American Office of Trimble based in Miami and from MSI, a private company based in Denver. All further tests, therefore, used Trimble equipment.

3.1.1 INVESTIGATION OF POSITIONAL ACCURACY VERSUS BASELINE DISTANCE

Based on the 1994 experience, it was decided that further tests were needed into accuracies over baseline distances between 50 to 150 kilometers. Longer distances tested in Phase I did not produce accuracies acceptable for cadastral surveying in Albania. Furthermore, Albania is small enough that two base stations could provide coverage for the whole country at baseline distances of less than 150 kilometers.

¹ Two types of receivers were used for the tests of the previous phase, namely Trimble Pathfinder code receivers (Pathfinder Basic and Pro XL) and Trimble 4000 series geodetic receivers, which were used to occupy the base stations and provide differential corrections. The Pathfinder Basic was subsequently rejected for cadastral purposes as its accuracy level of 2–5 meters was deemed inadequate for Albania. Since other vendors have developed “sub-meter” receivers since the start of this research, it was proposed that additional tests to evaluate these receivers be carried out before Albania purchase their own receivers. Further testing of the Trimble GPS receivers was also proposed based on the experience gained in the previous phase of this research project.

3.1.2 INVESTIGATION OF 12-CHANNEL PRO XL AS BASE STATION

In 1994, geodetic receivers (with Maxwell chip technology) were used as base stations to differentially correct the GPS observations. These receivers are more accurate than the Pro XL rover receivers, but they are also more expensive. Subsequent to these tests, Trimble released a 12-channel Pro XL receiver which they claimed could be used as a base station for the Pro XL rover receivers (instead of the geodetic receivers) without any loss in accuracy. Since the best arrangement for Albania appears to be a mix of permanent base stations (initially only in Tirana) and movable base stations (located on control in the project area), the 12-channel Pro XL was seen as an affordable and viable solution for the movable base stations. The tests in this phase investigated the performance of this receiver when operated as a base station for differentially correcting GPS observations.

3.1.3 INVESTIGATION OF OCCUPATION TIME VERSUS POSITIONAL ACCURACY

Cadastral surveying in Albania demands a rapid field measurement approach if it is to improve on current boundary delineation techniques (taping and plotting on large-scale maps). However, occupation time must be balanced against the accuracy required. Occupation times of 30–60 seconds were found to be practical in the field tests in 1994, but additional investigation was needed to ascertain the effect on positional accuracy of occupying a point for an additional 30 seconds.

3.1.4 USE OF A SECOND BASE STATION

In the 1994 investigation of positional accuracy over varying baseline distances, an apparent systematic bias in the results was noticed. The accuracy appeared to vary significantly more along the line between the base station and the point occupied by the rover receiver than in a direction perpendicular to that line. In order to improve this as well as provide a check on the results, tests were carried out using a second base station located at approximately right angles to the baselines observed in 1994.

3.1.5 TEST OF “PHASE PROCESSOR” SOFTWARE

During the 1994 research, Trimble introduced a new software product known initially as the “decimeter processor,” claiming that it would deliver decimeter-level accuracy when used with the Pro XL. (Trimble have since withdrawn this claim and changed the name to “phase processor” to recognize this fact.) Decimeter accuracy is highly desirable in the urban areas of Albania and for surveying small rural parcels. Tests were carried out to investigate whether this product could in fact deliver the promised accuracy and to determine what additional constraints (e.g., longer occupation times) were associated with this approach.

3.2 EFFECTS OF BASELINE DISTANCE ON POSITIONAL ACCURACY

3.2.1 OBJECTIVE

The distance between the base station (known position) and the rover (unknown position) is a crucial element of differential GPS because positional accuracy decreases with increased baseline distance. However, by maximizing this baseline distance the need for control is reduced. This test was designed to determine the maximum baseline distance which could be used but which would still deliver meter-level accuracy. These tests build on previous work completed at the University of Florida during the summer of 1994.

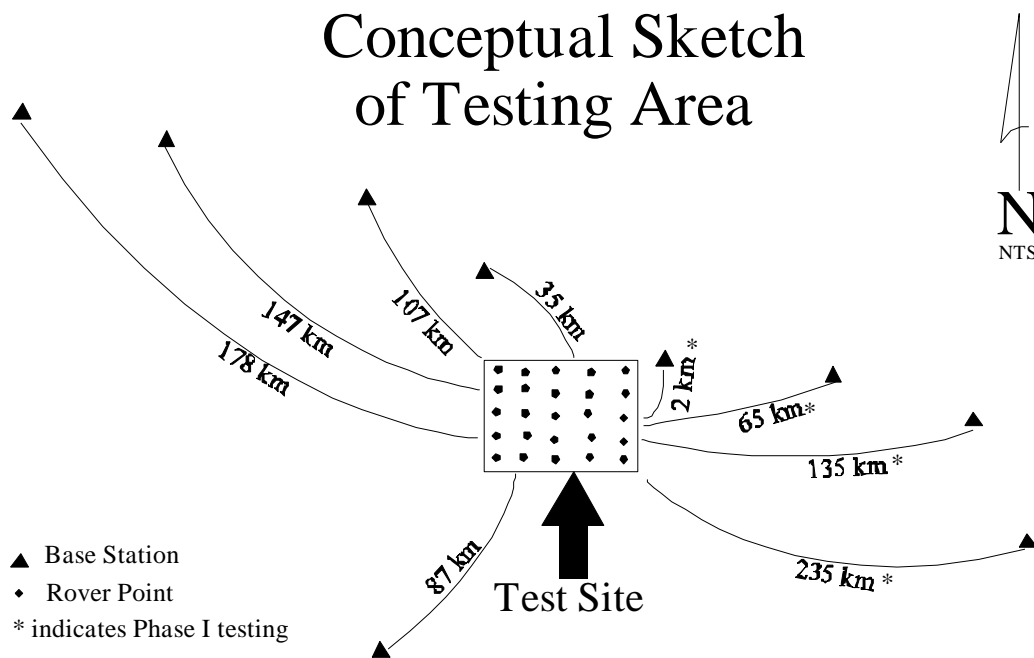
3.2.2 METHODOLOGY

During the summer of 1994, a test site was established to test GPS equipment for cadastral surveying. The site consists of 47 points located by using geodetic-accuracy GPS receivers and traditional survey methods (i.e., total station). The computed coordinates of these points are considered the “true” values for testing purposes. Four additional points, tied into the Florida High Accuracy Reference Network (HARN), were selected as base stations for the Phase I testing. These points were at distances of 2, 65, 135, and 235 kilometers from the test site. Based on the results of the Phase I tests, it was decided that additional tests should focus on distances from 50 to 150 kilometers in order to obtain a better understanding of the accuracy obtainable at these distances (see Table 3.1 and Figure 3.1). Larger baseline distances do not meet the accuracy requirements of this methodology.

TABLE 3.1. Positional accuracy by distance

SESSION	BASELINE DISTANCE	PHASE
1	2 kilometers	I
2	65 kilometers	I
3	135 kilometers	I
4	235 kilometers	I
5	35 kilometers	II
	87 kilometers	
6	107 kilometers	II
	87 kilometers	
7	147 kilometers	II
	87 kilometers	
8	178 kilometers	II
	87 kilometers	

FIGURE 3.1



The tests were performed with a Trimble 4000 SE geodetic receiver at each base station and a Trimble Pro XL roving receiver at the test site. Test site points were occupied for 1 minute each while using a logging interval of 5 seconds. This procedure was repeated at each baseline distance (except the 87-kilometer distance). At the 87-kilometer distance a 12-channel Pro XL was used as a base station. This receiver was in place and collecting for every session that the 4000 SE was in operation. Each test site position was then differentially corrected relative to the 4000 SE and the 12-channel Pro XL base stations. The 12 positions logged for each point over the 1-minute period were then averaged and compared to test site points' true value.

3.2.3 RESULTS

Figure 3.2 is a plot of the mean values showing the decrease in accuracy as distance between the rover and base receiver is increased. The additional tests conducted in Phase II show that the relationship between baseline distance and accuracy is much more linear than previous results showed. It also appears that results obtained at baseline distance of 135 kilometers were unusually good and are not indicative of the typical trend between accuracy and baseline distances.

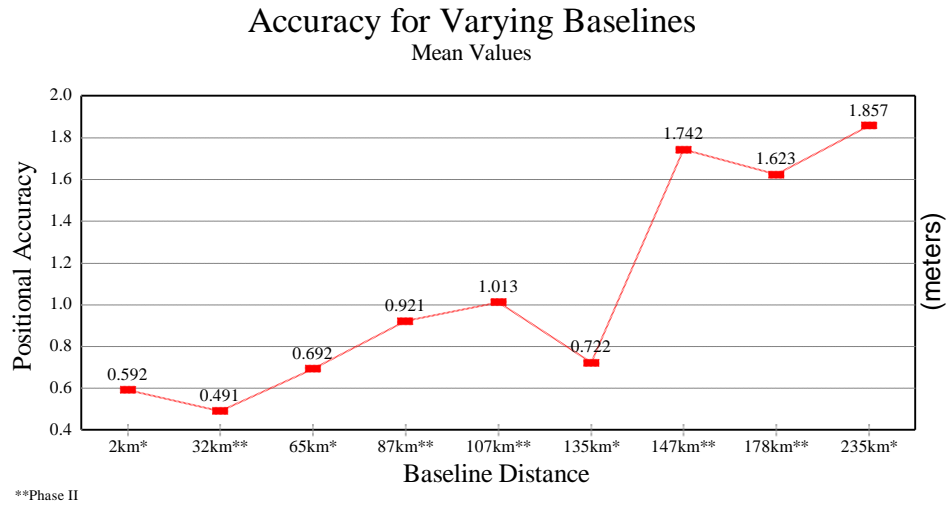
FIGURE 3.2

Table 3.2 shows the statistical breakdown of data collected for each baseline distance. These data indicate that baseline distances should be kept below 100 kilometers to ensure a mean difference of less than a meter.

TABLE 3.2. Descriptive statistics of positional accuracy over varying baseline distances

	BASELINE DISTANCE								
	2km*	32km**	65km*	87km**	107km**	135km*	147km**	178km**	235km*
Mean	0.592	0.491	0.692	0.92	1.013	0.722	1.742	1.62	1.857
Standard error	0.004	0.003	0.004	0.00	0.007	0.004	0.014	0.01	0.016
Standard deviation	0.342	0.271	0.358	0.67	0.666	0.400	1.255	1.06	1.418
Minimum	0.096	0.148	0.124	0.05	0.150	0.248	0.171	0.24	0.332
Maximum	1.924	1.106	2.011	3.03	2.318	1.911	4.676	4.15	5.685
Confidence level(0.9500)	0.063	0.125	0.066	0.13	0.326	0.151	0.465	0.41	0.525

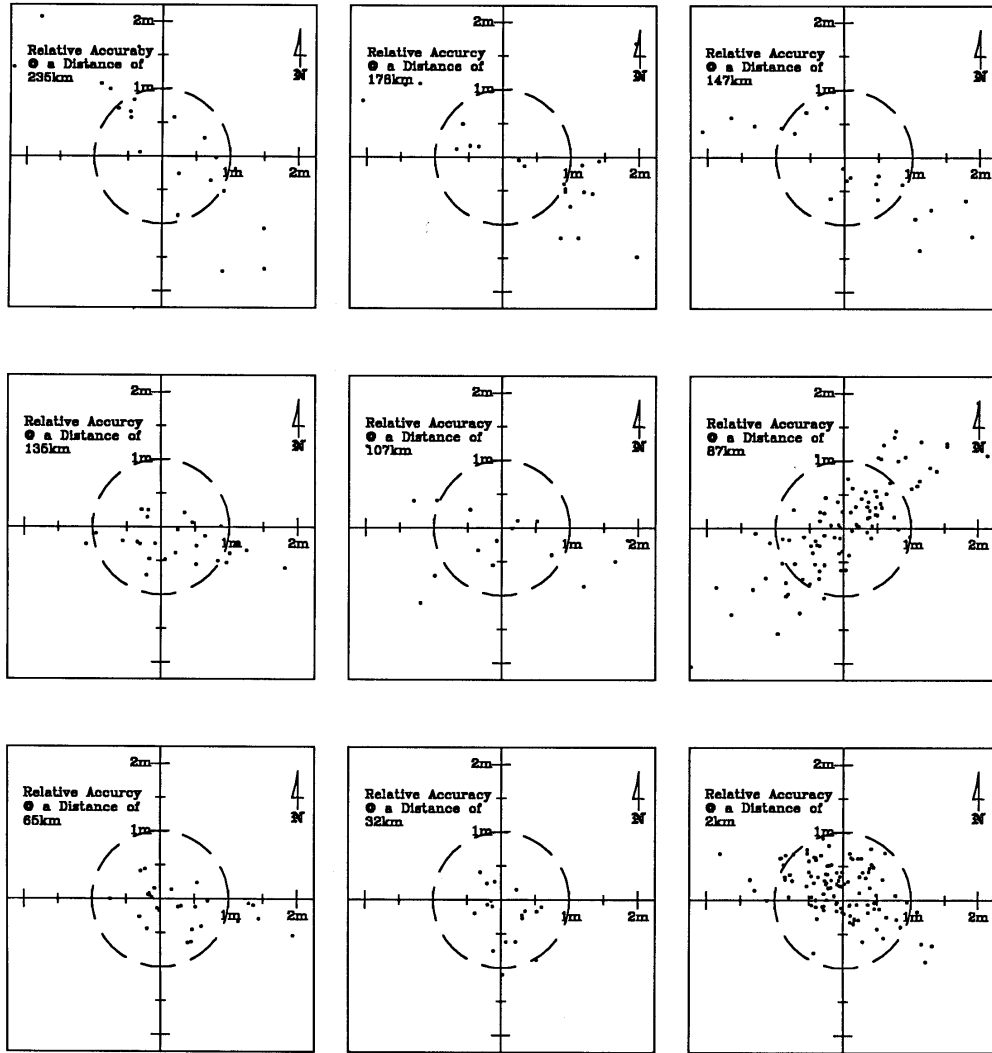
* Data are from tests completed in 1994.

** Data are from tests completed in 1995.

The 87-km baseline testing was done with a 12-channel Pro XL with 4 megs of RAM.

FIGURE 3.3

FIGURE 3.



Spread of Positional Accuracy at Different
Baseline Distances

Figure 3.3 shows how the observed coordinate values are scattered around the “true” value at different baseline distances. All dots within the 1-meter circle indicate observations that are at the sub-meter accuracy level.

3.2.4 CONCLUSIONS

Our analysis concurs with Trimble’s claims that the Pro XL will yield sub-meter accuracy on a second-by-second basis for baseline distances up to 50 kilometers. Furthermore, analysis of the results would support a claim of meter-level accuracy (averaged point position is within one meter of the true position) for baseline distances up to 100 kilometers. Although the mean value of the positional error from a baseline distance of 100 kilometers is approximately 1 meter, when the standard deviation is considered the error approaches the 1.5-meter range. Therefore, base stations beyond 50 kilometers are better suited as secondary base stations when sub-meter accuracy is vital.

3.3 TESTING OF THE 12-CHANNEL PRO XL AS A BASE STATION

3.3.1 OBJECTIVE

The objective in this test was to investigate the viability of using a 12-channel Pro XL as a base station. To differentially correct a rover receiver’s data files the base station must use a Trimble receiver with Maxwell chip technology. The Pro XL is the least expensive Trimble receiver with this type of technology. Due to its versatility, portability, and low cost, the Pro XL would be suitable for situations where a movable (nonpermanent) base station is required. The antenna was specifically designed to work in areas with obstructions so if the receiver loses a satellite signal due to a temporary obstruction, it regains lock within seconds.

3.3.2 METHODOLOGY

A Trimble 12-channel Pro XL receiver was set up as a base station over a control point 87 kilometers from the test site. During this time an 8-channel Pro XL roving receiver at the test site occupied 25 points for 1 minute while logging a position at intervals of 5 seconds. This procedure was repeated for a total of 4 sessions. Each position was then differentially corrected relative to the control point and the mean of positions for each point was computed and compared with its true value.

The base receiver we used had 4 megabytes of memory for storage (standard memory is 640 kilobytes) which is sufficient for several days of observations. After 24 hours of data collection only one-third of the available memory had been used. Four megabytes of memory is strongly recommended, especially if situations may occur where the field crew is not able to download daily.

This test was done concurrently with the Phase II testing of the “Effects of Baseline Distance on Positional Accuracy” which is outlined in subsection 3.2. Every position logged by

the rover receiver (Phase II) was processed twice, once using the 4000 SE base station data (see subsection 3.2) and again using data from the Pro XL base station.

3.3.3 RESULTS

The 87-kilometer baseline distance results are shown in Table 3.2, Figure 3.2, and Figure 3.3. The resulting accuracy of the Pro XL as base station is consistent with those of the geodetic receiver (see subsection 3.2). Even beyond 50 kilometers the mean accuracy was still around 1 meter and the standard deviation was approximately the same as that of the geodetic receiver at a comparable distance.

3.3.4 CONCLUSIONS

The 12-channel Pro XL meets the requirements for a movable base station and achieves the same level of accuracy as a geodetic receiver used in conjunction with the Pro XL rover.

3.4 EFFECTS OF OCCUPATION TIME ON POSITIONAL ACCURACY

3.4.1 OBJECTIVE

Trimble documentation (1994a, pp. 4–30) states that the Pro XL can achieve sub-meter accuracy (root mean square, RMS) on a second-by-second basis when a differential correction is applied. By collecting multiple positions on a point and averaging the results, a more reliable point position can be obtained. Trimble suggests that positions be recorded at intervals of 5 seconds for each set of positions to allow the geometry of the satellites to change. This test was to identify accuracy achievable for different occupation times and to determine the shortest possible occupation time without a significant loss in the accuracy of the results.

3.4.2 METHODOLOGY

An 8-channel Pro XL was set to record a position at 5-second intervals. Each point at the test site was then occupied for one minute. After all the points at the test site were occupied, the base station (i.e., 4000 SE) was moved to a different control point. This process was repeated until the base station occupied control points at the distances of 32, 68, 107, 148, and 178 kilometers from the test site.

Positions were then computed from 15, 30, 45 and 60-second subsets of each 1-minute data set. With each subset of data a difference was calculated between the computed value and the “true” value of the point. This difference represents the positional accuracy of each subset of data. The average of the positional accuracy and standard deviation of the positional accuracy for each subset was then compared.

FIGURE 3.4

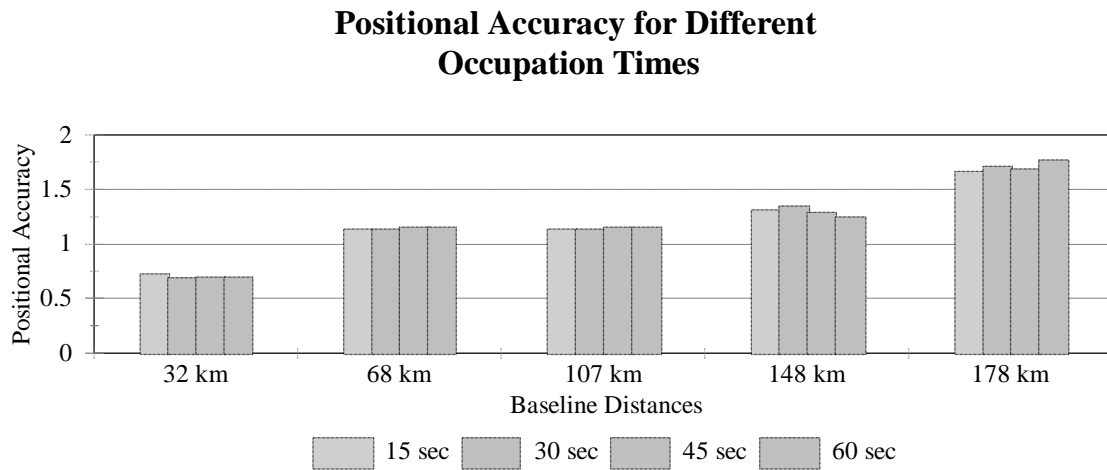
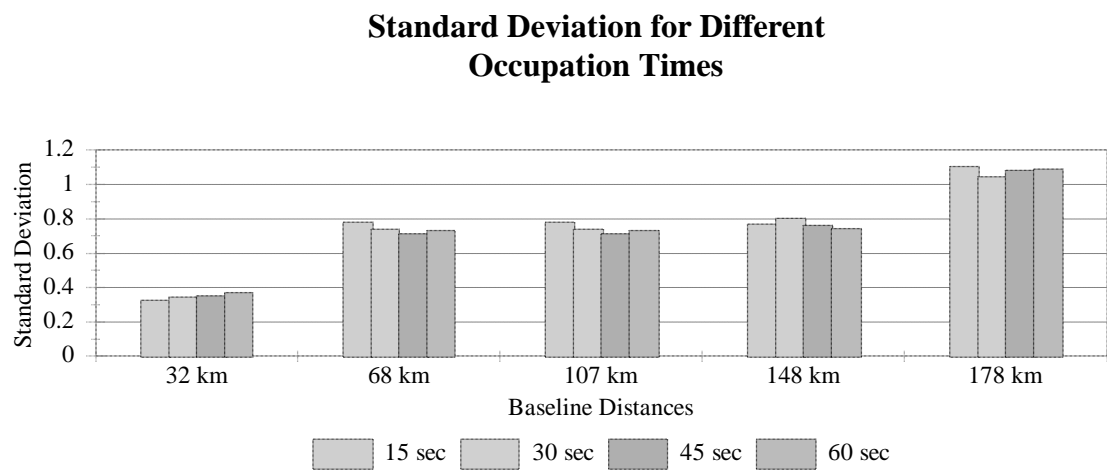


FIGURE 3.5



3.4.3 RESULTS

Figure 3.4 shows the mean positional accuracies for different occupation times while Figure 3.5 shows the corresponding standard deviations. Each graph shows data grouped by session. Each session is based on the baseline distance between the base station and the rover receivers. The data is then divided into 15, 30, 45, and 60-second occupation-time data sets.

3.4.4 CONCLUSIONS

The data show that an increase of occupation time from 15 seconds to 60 seconds does not significantly affect positional accuracy. A point's position computed from a 60-second data set consists of 12 positions (i.e., points logged every 5 seconds) that are averaged, while a 15-second data set is averaged with only 3 positions. From the authors' field experience, it has been found that it takes less than a minute to enter a point's attribute data into the data logger (i.e., TDC1), and therefore an occupation time of 30 seconds is sufficient. In addition, this provides some redundancy of measurement at each point.

3.5 UTILIZATION OF SECONDARY BASE STATION FOR DATA AUTHENTICATION

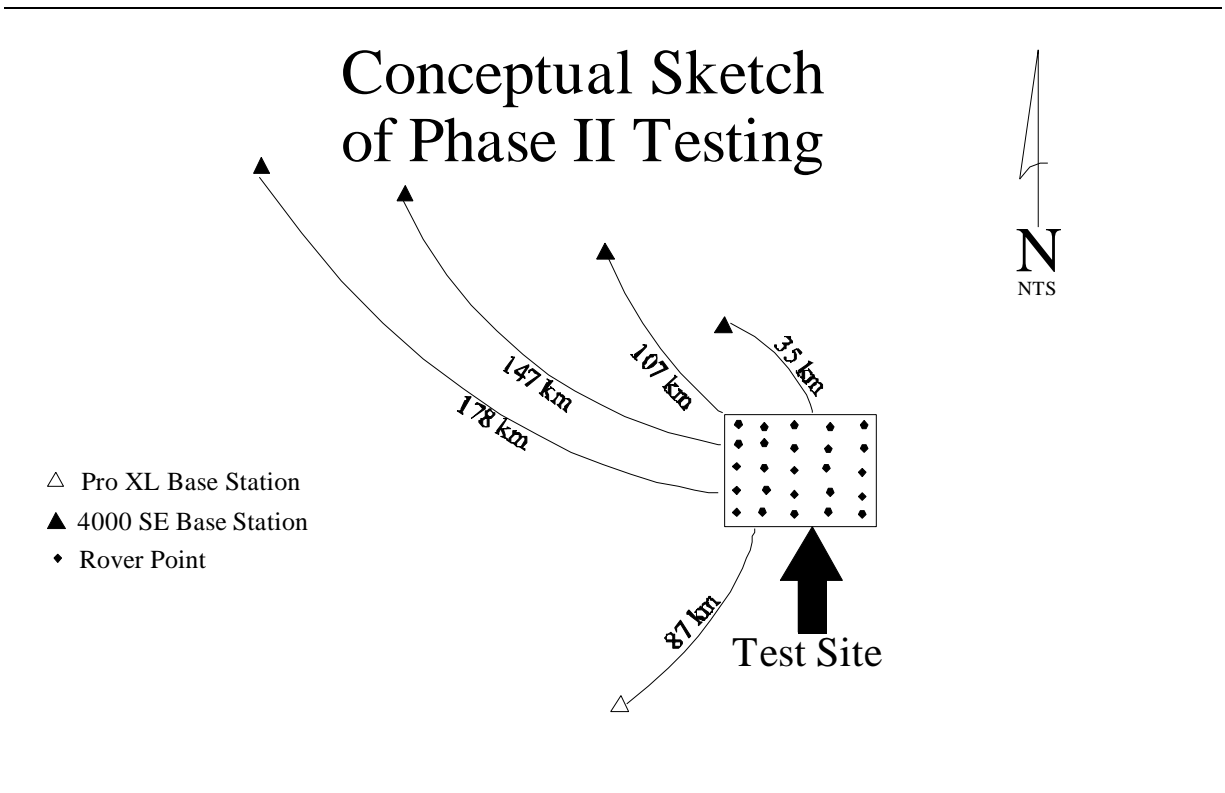
3.5.1 OBJECTIVE

The purpose of this test was to identify data authentication techniques that can be used to check the integrity of the processed Pro XL data files and possibly improve positional accuracy of their final coordinates by use of redundancy (i.e., more measurements than required to solve for the unknowns).

3.5.2 METHODOLOGY

A 12-channel Pro XL and a 4000 SE geodetic receiver were both used as base stations while an 8-channel Pro XL was used as a rover receiver at the test site. The azimuth of the baseline from the 12-channel Pro XL to the test site was approximately 90 degrees to the azimuth of the baseline from the 4000 SE to the test site. With the rover receiver set to log a position every 5 seconds, 25 test points were occupied for 60 seconds each. This test was repeated for 4 sessions. For each session the 12-channel Pro XL remained at a control point 87 kilometers from the test site, but between sessions the 4000 SE was moved to different control points at varying distances from the test site. The 4000 SE occupied base stations at distances of 32, 107, 147, and 178 kilometers from the test site (see Figure 3.6). Coordinates for every point of each session were then computed twice, once using differential corrections from the 12-channel Pro XL and again using differential corrections from the 4000 SE.

FIGURE 3.6



3.5.3 RESULTS

All point positions for each session of Phase II were computed from both the Pro XL and 4000 SE base files. The plots in Figure 3.7 show the difference between the “true” and observed values for each point’s position.

The mean positional accuracy (the distance from the “true” position of a point to the computed position of the same point) for each of the nine baseline distances (see Figure 3.1) was computed (see Table 3.3). The mean value from each session was then plotted in relation to baseline distance. A linear regression using these data points was performed to show how the positional accuracy was effected by baseline distance (see Figure 3.7 and Table 3.5).

For four of the sessions where coordinates of each point were computed from two baseline distances, a single set of weighted coordinates was calculated. The weighting was based on the inverse of the distance the point is from each base station. From these weighted coordinates a positional accuracy was computed. From these values, a mean positional accuracy could then be computed for each session (see Figure 3.6 and Table 3.4). These mean values from each of the four sessions were then plotted in relation to baseline distance. A linear regression using these four data points was performed to show how the weighted positional accuracy was affected by baseline distance (see Figure 3.7 and Table 3.5).

TABLE 3.3 MEAN POSITIONAL ACCURACY FOR DISTANCE

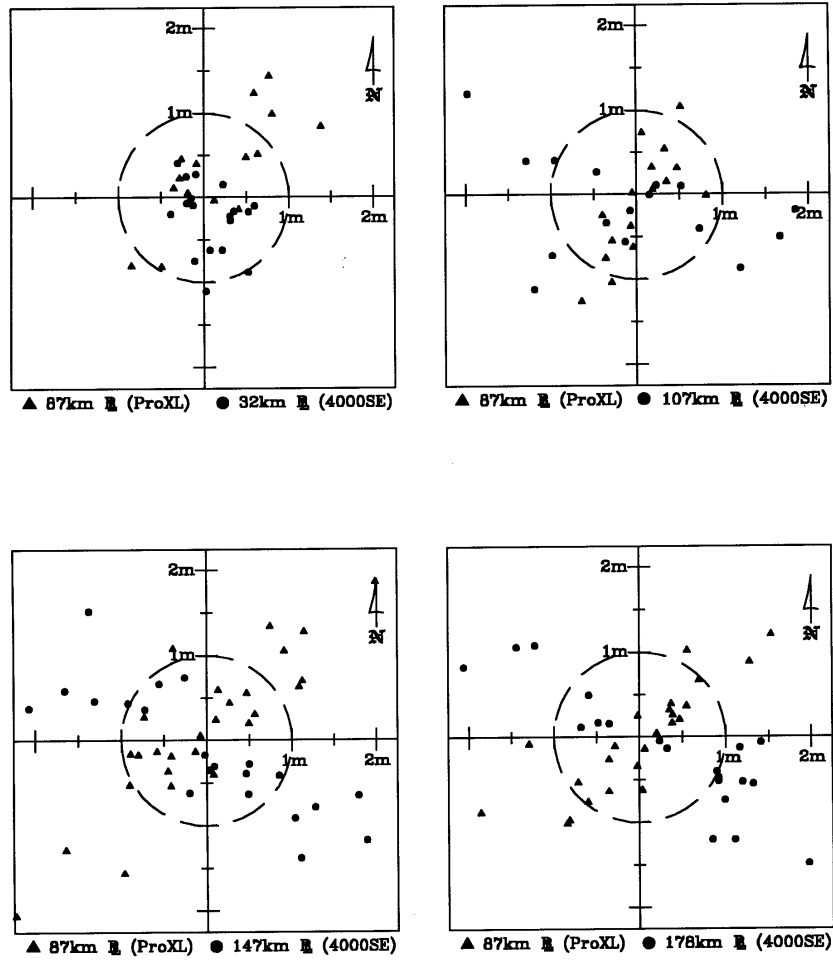
SESSION(S)	BASILINE DISTANCE	MEAN POSITIONAL ACCURACY
1	2 kilometer	0.592
5	35 kilometer	0.491
2	65 kilometer	0.692
5 6 7 8	87 kilometer	0.921
6	107 kilometer	1.013
3	135 kilometer	0.722
7	147 kilometer	1.742
8	178 kilometer	1.623
4	235 kilometer	1.857

TABLE 3.4 Weighted positional accuracy

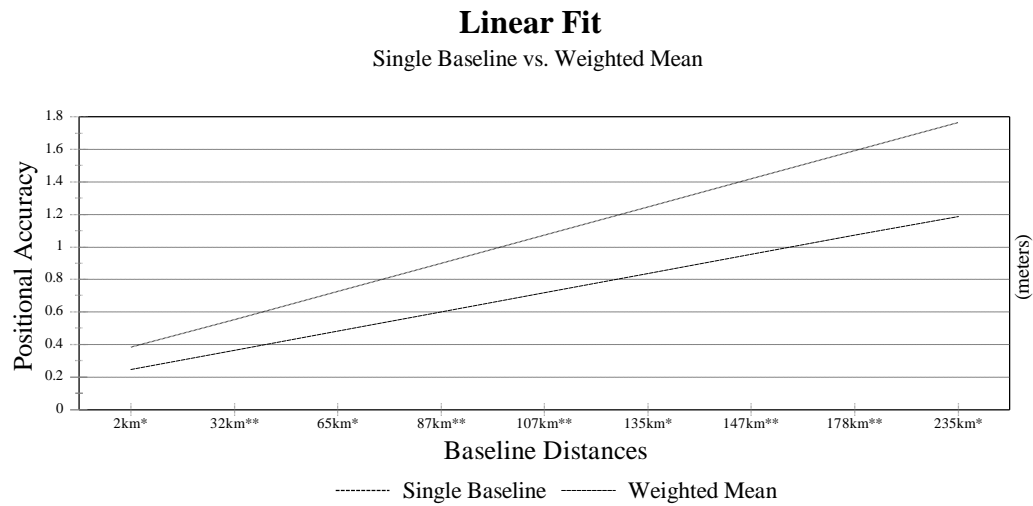
SESSION #	BASILINE PAIR	POSITIONAL ERROR OF THE WEIGHTED MEAN
5	35 kilometer	0.422
	87 kilometer	
6	107 kilometers	0.529
	87 kilometer	
7	147 kilometers	1.162
	87 kilometer	
8	178 kilometers	0.991
	87 kilometer	

FIGURE 3.7

FIGURE 6.



Spread of Positional Accuracy for
Two Simultaneously Operating Base
Stations

FIGURE 3.8**TABLE 3.5 Regression results of single baseline and weighted mean**

REGRESSION OUTPUT	SINGLE BASELINE	WEIGHTED MEAN
Constant	0.37724	0.22031
Standard error of Y estimate	0.27319	0.23121
R squared	0.76573	0.71931
No. of observations	9	4
Degrees of freedom	7	2
X Coefficient(s)	0.00633	0.00479
Standard error of coefficient	0.00132	0.00212

3.5.4 CONCLUSIONS

When collecting parcel corner data it is imperative that 100 percent of all the point positions are resolved. We have had occasions where none of the positions from the rover file could be differentially corrected because of a problem at the primary base station. We could save that day's data because we had a secondary base station as a backup. Just as any survey method, redundant information is always preferred.

To differentially correct GPS data, the true coordinates of the base station must be entered. If differential corrections are based on the wrong coordinates all the corrected points will be shifted. Without a secondary base station there is no way on knowing if this shift has occurred. By comparing coordinates computed from the primary base station to those computed from a secondary base station a major mishap can be avoided.

Redundant data from a secondary base station can be used to improve the positional accuracy. Our tests show that accuracy of the differential corrections is dependent upon the distance the rover receiver is from the base station. When using the inverse of the distances from a point to two base stations as a weight to compute a point position, positional accuracy can be improved (see Figure 3.8).

A secondary base station also gives us the opportunity to check our results. From the results of the regression analysis of the positional accuracy (see Figure 3.8 and Table 3.5) we can predict the amount of expected error for any baseline distance. By comparing the expected error to the distances between the final weighted point and the two original points (computed from each baseline), we can determine if there is problem with a point position.

3.6 TRIMBLE'S "PHASE PROCESSOR"

3.6.1 OBJECTIVE

Trimble markets a software package called the "Phase Processor" which can be used in conjunction with the Pro XL to improve positional accuracy. Trimble's documentation states that by following recommended field and post-processing procedures and then processing the data with the Phase Processor software it is possible to get positional accuracies of one decimeter. The objective of this test was to see if we could improve the positional accuracy of the Pro XL by using the phase processor without introducing other constraints (e.g., unacceptably long occupation times).

3.6.2 METHODOLOGY

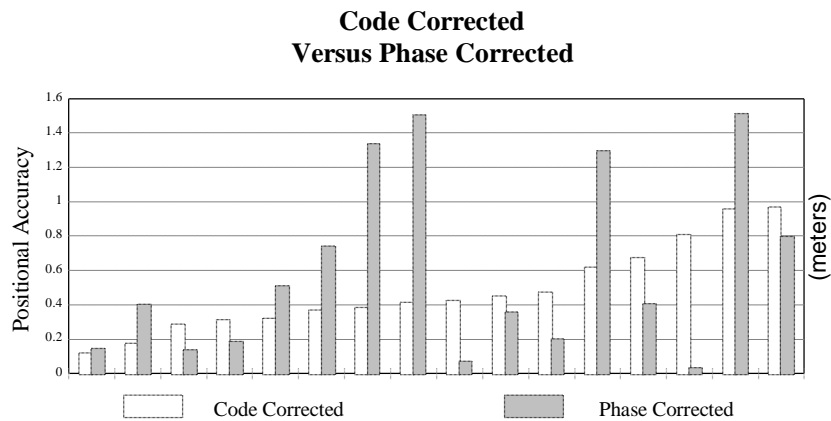
A roving 8-channel Pro XL was set to collect data in "decimeter mode" at four test points on the test site. While in decimeter mode the rover receiver collected data for 10 minutes at each of these points while the base receiver simultaneously collected base data on a control point. Between the four sessions that the rover receiver operated, the base station was moved to a different control point. This gave us baseline distances of 32, 107, 147, and 178 kilometers from the test site resulting in four points being occupied four times each (producing sixteen data

points) using the Phase Processor techniques. The logged positions were then post-processed using the standard post-processing software (i.e., Pfinder) and then processed again with the “Phase Processor” software. The resulting positions were compared with the true value of each point to find positional accuracy.

3.6.3 RESULTS

Figure 3.9 compares the positional accuracy of each point before and after processing with the Phase Processor. The graph has a pair of bars for each of the sixteen points occupied for this test. The first bar of each pair shows the positional accuracy achieved by just using the Pfinder post-processing software. The second bar of each pair shows the positional accuracy achieved after processing with the Phase Processor software.

FIGURE 3.9



3.6.4 CONCLUSIONS

The results from the Phase Processor show that there is no significant improvement in positional accuracy as compared with results processed using the standard software. Trimble now maintains that the Phase Processing kit is better suited for use with the Geo Explorer (2–5 meter receiver). This may be true, but their documentation indicates that positional accuracy should improve when using the Phase Processor with the Pro XL (see Trimble 1994a, p. 7/22, for example).

Carrier phase receivers pose greater problems than code phase receivers when using medium accuracy techniques. The first problem is that the occupation time must be increased. While in decimeter mode, each point must be occupied for at least 10 minutes. In large areas where travel times between points are relatively large, this is acceptable, but where points are easily accessible 10 minutes per point is overly restrictive. The second problem is that a GPS receiver must maintain continual lock on a satellite when it is collecting carrier phase information. This is a problem when there is a loss of lock due to thick foliage. One of the strongest attributes of the Pro XL is its ability to gather information even with moderate

overhead obstructions. This attribute is lost when collecting carrier phase information. The third problem is with the memory used when collecting carrier phase information. For Phase processing it is required that the Pro XL rover receiver log phase data every second for at least ten minutes. This produces a data file that rapidly exceeds the standard memory (i.e., 640 kilobytes) of the receiver. In our tests, using a rover with 640 kilobytes of memory, we were only able to collect data on five points before we ran out of memory. This means that a field crew would need to download data about every hour.

The results show that the Phase Processor did not consistently improve positional accuracy. Figure 3.9 shows that by processing the differentially corrected positions with the Phase Processor only eight positions improved. Conversely, positional accuracies of eight of the points were degraded. Even if positional accuracy were improved, the occupation time, memory requirements, and satellite lock problems would limit the use of this software for medium-accuracy survey methods.

3.7 CONCLUSIONS

3.7.1 PROBLEMS WITH THE PRO XL

3.7.1.1 OBSTRUCTED SATELLITES

During Phase II of this research we discovered a basic problem which affects the selection of reference stations and post-processing of GPS observations. The problem arises when there is an obstruction at the base station which blocks a satellite that is visible at the rover receiver. Theoretically at least four satellites are needed to compute a point's position. When a differential correction method is applied, both the base and the rover receivers are required to have a common set of four satellites. However, these theoretical circumstances do not apply when the Pro XL system is used.

The divergence between theory and practice is due to the data storage method employed by the rover receiver and the Pfinder post-processing software. To conserve storage space, the Pro XL rover receiver does not store all the raw observations but uses them to compute a pseudorange position which is stored instead.² All other information needed for computation of the differential corrections is stored at the base station. While processing, if a satellite is encountered in the rover files that is not found in the base files (due to an obstruction at the base station), the post-processing software (i.e., Pfinder) cannot compute the coordinates for those positions.

In one of the tests described earlier in this report, only 77 percent of the differential corrections for the rover points could be computed by using the base station files from the geodetic receiver (4000 SE). In all instances the problem could be traced to an obstruction at the base station that blocked a single satellite from the base receiver that was visible at the rover receiver.

² Chiqui Alvarez (Trimble), personal conversation, August 1995.

With proper planning this problem can be minimized. The selection of a totally unobstructed horizon around a control point is one precaution that should be taken. If any obstruction is on the horizon (i.e., radio towers, trees, buildings) the preplanning software should be used to compute observation times in which no satellites are obstructed.

A second precaution is to make sure that the elevation masks at the base and rover receivers are properly set (the elevation mask is a receiver setting that controls how far above the horizon a satellite must be before the receiver will start to track it). To reduce the possibility of observing a satellite at the rover and not at the base station, the elevation mask at the rover must be more constraining. For tests described in this report, elevation masks of 10 degrees at the base receiver and 15 degrees at the rover receiver were used. This did not, however, prevent the problem from occurring, due to obstructions.

A final consideration for alleviation of this problem is selection of the base station receiver. A GPS receiver can be categorized by number of channels (i.e., 8- or 12-channel receivers). The number of channels determines the total number of satellites a receiver can track at any time. To avoid the problem previously discussed the receiver at the base station should have the same or more channels than the rover receiver. Pro XL receivers can have either 8 or 12 channels. We recommend that a 12-channel receiver be used as a base station and less expensive 8-channel receivers as rovers.

3.7.1.2 Installation

The post-processing software Pfinder is a DOS-based program. Installation of this program can be difficult if the person installing it is not familiar with DOS memory management. The Pfinder software requires 580 kilobytes of free conventional memory and will not run with less. This forces the user to reconfigure the boot files (i.e., CONFIG.SYS and AUTOEXEC.BAT) specifically for Pfinder. There is no installation program for this process and must therefore be done manually.

3.7.1.3 Documentation

The Pro XL comes with five manuals covering the equipment and software (Trimble references). These documents can be vague and ambiguous. Tasks such as creating a Data Dictionary are difficult to follow for users who do not have a great deal of GPS experience.

3.7.1.4 Control of GIS output

The Pfinder software allows for output in many different formats. In the Phase II tests, data was output to AutoCad by using Pfinder to create files in a DXF format. This process is simple but gives little control over the attributes of the data (e.g., text size). This forces the user to go through the time consuming processing of reformatting data imported into an AutoCad drawing.

3.7.2 ADVANTAGES OF THE PRO XL

3.7.2.1 Physical suitability

When considering the purchase of any GPS system, its compactness and ease of use must be appraised. The Pro XL comes in two compact packages with about everything needed to complete a survey. Included with the software package are the mission planning and the post-

processing programs, hardware lock, and documentation. The hardware package comes in a small case that contains the receiver, datalogger, antenna, batteries, battery charger, cables, and backpack. The only additional equipment that the user needs to supply is a computer for the software and a tripod or a range rod for the antenna.

One of the most attractive aspects of the Pro XL system is its physical compactness and ease of use. Receiver, batteries, and all cables fit into a small, light-weight backpack. Initial assembly of the field equipment takes five minutes and is easily managed by one person. The receiver is carried in the backpack and is controlled with the handheld datalogger (e.g., TDC1).

The TDC1 is a DOS-based computer that comes equipped with the “Asset Surveyor” software. This software controls the receiver functions, data collection processes, and file transfer protocols. The TDC1 has a standard memory of 640 kilobytes for data storage, but can be upgraded to 4 megabytes. Although the 640 kilobytes of memory are adequate for an average day, the 4-megabyte option is recommended if the system is to be used as a base station or if the “Phase Processor” option is used (see Section 3.6).

3.7.2.2 Software

Pfinder post-processing software is relatively easy to learn. Trimble provides examples in the documentation with sample data files for common tasks that can be accomplished with the software. After working through the sample data for a particular task, users should have enough experience to apply it to their own data. When a problem does occur, users within the United States can call Trimble’s technical support (1-800-TRIMBLE). All requests for help are responded to promptly either by phone or by fax.

3.7.2.3 Position attributing

A Data Dictionary can be designed using the Pfinder software. This is then uploaded into the datalogger for use with the Asset Surveyor software. A Data Dictionary can be customized for each job. It is a hierarchical structure beginning with each feature being classified as a point, line, or area. Once it is classified, each feature is given a name (e.g., parcel corner). Each feature can then be given an attribute (e.g., iron rod) and a value (e.g., 5mm). Within the Pfinder environment these attributes can be used as filters to view, sort, or process specific data and will remain with the position when the data is brought into a GIS.

3.7.2.4 Conversion to a GIS

The Pfinder software allows for output into many different GIS formats and the format chosen can be specified for individual coordinate systems. The version of Pfinder used in the tests (V. 2.4) can export data in 20 different formats. When exporting to AutoCad, a DXF format is used. This is then imported into an AutoCad drawing with all attribute information attached to its reference point. Pfinder also allows data to be output in a user-defined ASCII format. The ASCII output feature allows the user to create an ASCII file from coordinate data within the database which can then be used in spreadsheets, text reports, and databases.

APPENDIX A
SURVEYING CURRICULUM
AT TIRANA POLYTECHNIC UNIVERSITY

COURSES	YEAR 1		YEAR 2		YEAR 3		YEAR 4		YEAR 5	
	Sem 1	Sem 2	Sem 1	Sem 2	Sem 1	Sem 2	Sem 1	Sem 2	Sem 1	Sem 2
Engineering methods	2/3*	-	-							
Foreign language	2/2	2/2	2/2	2/2						
Informatics	2/2	2/2								
Physical training	0/2	0/2	0/2	0/2						
Mathematics	4/5	5/5	2/3	2/3						
Physics	-	2/3	2/2/1	2/2/1						
CAD I	-	2/3	1/3	2/2						
Theoretical mechanics			2/2	2/2						
Chemistry			3/1	3/1						
Geology & geomorphology			2/2	-						
Topographic drawing			-	0/4	0/4					
Surveying equipment					4/2	3/3				
Least squares theory					3/1	2/3				
Physical & math geodesy					3/2	-				
Triangulation					2/4	-				
Leveling					-	3/4				
Surveying adjustments					-	1/3				
Astronomy					2/2	2/1				
Cartography					-	2/2	2/2	2/2		
Sociology					-	2/0				
Fieldwork training					0/3	0/3	0/3	0/3	0/2	0/3
Topography							3/4	2/6		
Urban & civil construction							3/2	3/2		
Ecology							-	2/1		
3-D geodesy (GPS)							2/1	-		
Photogrammetry							2/3	2/3	2/3	-
Hydrography							-	2/2		
Urban planning							2/2	-		
Photo lab							1/2	-		
CAD II							-	2/2		
Mining technology							3/2	-		
Hydrotechnic construction							3/2	-		
Road & railway surveying							-	3/4		
Urban planning in altitude							2/1	-		
Surveying engineering							3/2	2/2		
Cadastre							-	3/3		
Remote sensing							-	2/1		
Digital mapping							2/2	-		
Market economy							-	2/2		
Underground construction									2/2	-
Legislation									-	2/1
Planning									-	1/1
Weekly workload	24/30		32/32		32/34		34/36		33/32	
Total hours/year	810		960		990		1050		975	
Projects					30		40		40	
TOTAL HOURS 4895 (in 5 years)										

* First number refers to lecture hours per week, and second number to discussion or laboratory practice.

APPENDIX B

Legislative Act for Surveying and Mapping in Albania for Cartographic and Topo-Geodetic Work, Decision of Council of Ministers, No. 110, 17 May 1984

(translated by Gezim Gjata)

- Art. 1. The Defense Ministry in consultation with the other ministries is assigned to prepare and publish within the year 1984, the booklet of regulations entitled “Cartographic and Topo-Geodetic Work in the Peoples Socialist Republic of Albania”
- Art. 2. All topographic and cartographic activities must be done in accordance with the requirements of these regulations.
- Art. 3. Institutions and enterprises which carry out topo-geodetic and cartographic work based on the technical parameters of these regulations must prepare all technical procedures within 1985 for all activities in which they are involved.
- Art. 4. Institutions and enterprises which carry out topo-geodetic projects and work are obliged to send, within 3 months of completion, one copy of the technical documentation to the Military Topographic Institute as listed below:
- ◆ general planimetrics (after the location of natural features is fixed on them) of industrial construction, socio-cultural objects, hydropower, irrigation systems, hydrographic data, and forest boundaries;
 - ◆ coordinates and heights of road and railway centerlines, of irrigation systems, of pipelines and all other surface and underground lines as well as the initial points of bridges and tunnels;
 - ◆ catalogues of coordinates and heights of densified geodetic networks which serve to support large mapping projects as well as for other purposes in which other institutions or enterprises are interested to support the economic and military arm;
 - ◆ catalogues of coordinates and heights of geophysics exploration points for gas.
- Art. 5. Enterprises and institutions during the month of June of each year must send to the Defense Ministry sketches (cartograms) of areas mapped at scales 1:1,000 to 1:10,000, when these areas are greater than 100 hectares, as well as present for signing all other scale maps that are to be published, regardless of their destination and scale.
- Art. 6. The Military Topographic Institute must display immediately on a map copy at scale 1:25,000 all changes of terrain which are sent in by institutions, enterprises and military topographic units.
- Art. 7. The Military Topographic Institute within the year 1986 must finish a catalogue of coordinates and heights of the national geodetic network (triangulation and national leveling network) and distribute to all institutions and enterprises of Albania which are involved in large topogeodetic works.
- Art. 8. The Defense Ministry during the month of February each year must inform ministries and central institutions of new cartographic publications by the Military Topographic Institute.

This decision is to take effect immediately.

STANDARDS AND PARAMETERS FOR TRIANGULATION, LEVELING, AND MAPPING

I. Triangulation (National network)

- ◆ Covers all Albanian territory.
- ◆ Based on Krasovskij ellipsoid.
- ◆ Map projection: Gauss transverse cylindrical projection, 4th zone (6° belts), central meridian is 21° .
- ◆ Origin is the intersection of central meridian (21°) and equator.
- ◆ National network consists of three orders (all in orthogonal coordinates).
- ◆ Triangle is base figure of Albanian triangulation network.
- ◆ Heights of triangulation network are orthometric heights.

TABLE 1. Triangulation parameters

Orders	Average distance of triangles (km)	Mean square error of horizontal angle measurement	Misclosure of triangles
I	15	$\pm 0.90''$	$\pm 3.0''$
II	8	$\pm 1.5''$	$\pm 6.0''$
III	4	$\pm 2.5''$	$\pm 9.0''$

The baselines (the initial line for computation) are located every 100 km and are measured with a precision of 1:1,000,000.

TABLE 2. Baseline parameters and equipment

Parameters	Equipment	
	High precision (1st order)	Medium precision (2nd & 3rd order)
Telescope magnification	42x	31.5x
Sensitivity of horizontal level bubble	4–7''	20''
Sensitivity of vertical level bubble	10''	20''
Sensitivity of spherical bubble	2'	8'
Smallest division of micrometer	0.2''	1''
Microscope magnification	37x	31x

Series and combination are two methods used for angle measurement.

In the following table the results using the series method of angle measurement (with two kinds of equipment) are given:

TABLE 3. Standards for horizontal angle measurement

	2nd Order		3rd Order	
	Instruments			
	High precision	Medium precision	High precision	Medium precision
Horizontal angle misclosure	6"	8"	6"	8"
Difference between arcs	7"	10"	7"	10"
Collimation error (CL/CR)	10"	14"	10"	14"

- ◆ 2nd and 3rd order points are based on the first order network.
- ◆ Each triangulation point covers 14 sq km.
- ◆ Heights of triangulation points are determined as follows:
 - spirit leveling in the fields [flat areas];
 - geodetic leveling in mountainous areas (height misclosures are $f=\pm 30$ cm in vertical traverses).

II. National leveling network

- ◆ The origin of this network is the tide gauge point at Durrresi which defines mean sea level.
- ◆ This network is run along the main roads of Albania through leveling traverses with a mean perimeter over 500 km.
- ◆ Second order leveling network is created inside the first order network (over 300 km in perimeter).
- ◆ Other leveling traverses are open and less than 200 km.
- ◆ Leveling points of any network are established every 2–4 km.
- ◆ Leveling instruments for first and second order networks have the following parameters:
 - telescope magnification 40 x;
 - bubble sensitivity 12"/2mm;
 - smallest division of optical micrometer 0.1 mm.
- ◆ In the first order leveling network the MSE for 1 km is less than ± 1 mm, and the systematic error less than 0.15 mm.

TABLE 4a. Parameters of national leveling network

Order of network	Length of leveling traverse (km)	Telescope magnification	Sensitivity of level bubble	Misalignment between telescope and level bubble
I	500	40x	12"	±20"
II	150	40x	12"	±20"
III	80	30x	15"	±20"

TABLE 4b. Parameters of national leveling network

Order of network	Distance between 2 legs of leveling station (m)	r distances to station (m)	r distances in sector (m)	No. of stations per km	Tolerance r forward and back loops	Tolerance misclosure in leveling traverse
I	50	1.0	3.0	<15	±4√L	±4√L
				>15	±5√L	±√L
II	50	2.0	5.0	<15	±12√L	±√L
				>15	±15√L	
III	75	3.0	10.0	<15	±20√L	±20√L
				>15	±√L	

L = distance of leveling lines or traverses (closed).

V. Mapping at scales 1:500 and 1:1000

a) Local Geodetic Network (densification range)

For mapping of cities (or towns), construction sites, hydrotechnic works, mining construction, etc., a local geodetic network must be created to fit the requirements of mapping at 1:500 and 1:1000 (LGN is densification based on the NGN that is appropriate for mapping of cities).

- ◆ The coordinates of these networks must be on the same system as national networks of coordinates and heights.
- ◆ Tolerance for triangle misclosures of LGN is 0.1 mm * scale.
- ◆ The geometric forms used for LGN are:
 - triangles,
 - trilateration (with EDM),
 - electro-optical traverse,
 - combined forms (with EDM).

TABLE 5. Parameters of triangles in local geodetic network

Ranges	MSE of angles	Relative error in baseline (initial base)	MSE of baseline angles	Relative error in baseline	Relative error in weakest line	Baseline distance in rhombic form
I	±2"	1:2,000	±1.5"	1:400,000	1:100,000	$\frac{1}{4} * b$
II	±3"	1:100,000	±1.5"	1:300,000	1:50,000	$\frac{1}{4} * b$

Ranges	Triangle misclosure (w)	r misclosure in horizontal for $\frac{1}{2}$ of series	Collimation error	r directions between series	Distance of traverse lines
I	±7"	±8"	±10"	±8"	2–3
II	±10"	±8"	±10"	±8"	0.8–1.2

b) Mapping at scales of 1:500 and 1:1,000

- ◆ Accuracy of topographic plans at 1:500 and 1:1,000 scales for contours must be less than $0.44 \text{ mm} * \text{scale}$. For unimportant objects tolerance may be $1 \text{ mm} * \text{scale}$ (maximum).
- ◆ Traverses used for the process of mapping in the field (e.g., stations) must have an accuracy of $0.2 \text{ mm} * \text{scale}$.

TABLE 6. Parameters of traverses for field mapping

Traverse components	Mapping scale	
	1:1,000	1:500
Traverse distance	1.5 km	0.8 km
Traverse misclosure	0.50 m	0.25 m
Angular misclosure	±1'∫n	±1'∫n
Misclosure of vertical traverses	1.5 n	1.5∫n

n = number of traverse points (stations).

- ◆ Distance of traverse line is 20–150 m.
- ◆ Accuracy of angle measurements in traverses is 0.5'.
- ◆ Accuracy of distance measurement in traverses estimated in relative error ratio is 1:5,000.
- ◆ Measurement of horizontal and vertical angles for points of detail is done with one position of the telescope and the distances of these points are measured optically.

TABLE 7. Accuracy requirements for topographic survey

Mapping scale	Distance between points of detail	Largest distance from instrument to staff (m)		
		Major contour line	General contour line	Terrain detail
1:500 h=0.5	15–20 m	50	80	100–150
h=1.0	20–30 m	80	80–100	150–200

h = contour interval.

- ◆ Plans at scales 1:500 and 1:1,000 are mapped on sheets with dimensions of 90 x 60 cm and 50 x 50 cm.

VI. Mapping at scales of 1:2,000 and 1:5,000

- ◆ Low order triangulation network (LTN) is the proper densification of points to support traverses for mapping at scales 1:2,000 and 1:5,000 (especially in cities).
- ◆ MSE in reciprocal position of LTN points is $\pm 0.15 \text{ mm} * \text{scale}$, and for heights $\pm 1/10 * h$ (h = contour interval).
- ◆ Traverses are based on LTN for field mapping. Distances of traverse lines are 100–250 m with an accuracy of 1:300–1:4,000.
- ◆ Angular misclosure in traverses $\pm 40' \sqrt{n}$ (n = no. of traverse points).
- ◆ Field mapping at scales 1:2,000 and 1:5,000 is performed by tacheometry, planetable methods, photogrammetric methods (terrestrial and aerial), and combined methods.
- ◆ Largest MSE in object location should [not] be more than $\pm 0.3 \text{ mm} * \text{scale}$, and for contour lines $\pm 0.4 \text{ mm} * \text{scale}$.
- ◆ Contour interval:

TABLE 8. Contour interval

Scale	Contour interval			
	Main contour lines	Intermediate contour lines	Field contour lines	Mountainous area contour lines
1:2,000	1.0 m	0.5 m	0.25 m	0.50 m
1:5,000	1.0 m	0.5 m	0.25 m	1.25 m

TABLE 9. Distances between instrument and staff

Scale	Largest distance between detail points		
	Important contour lines	Unimportant contour lines	General detail points
1:2,000	100 m	150 m	250 m
1:5,000	150 m	250 m	350 m

APPENDIX C
Proposal
**Development of a Prototype "Digital Cadastral Surveying
Technique" Using GPS and Total Station Technology**

Grenville Barnes
Department of Civil Engineering
University of Florida in Gainesville
1993

GOAL:

To develop a methodology or prototype system for surveying land parcel corners using a combination of GPS and Total Station technologies. This prototype system will be designed so that cost-efficiency is maximized under conditions typically found in Albania and other Eastern European countries undergoing massive privatization.

OBJECTIVES:

- a) Formulate a set (3 or 4) of approaches using different GPS techniques (rapid static, kinematic, etc.) and varying levels of GPS and total station use (from basic control to key boundary points to all parcel corners);
- b) Test these approaches under controlled conditions taking into account time, costs, and accuracies achievable and select the most cost-effective (the prototype);
- c) Define a step-by-step procedure to implement the prototype in Albania (including both office and field procedures);
- d) Train a team of Albanian surveyors to be proficient in implementing the prototype;
- e) Implement the proto type in a pilot area in Albania, simultaneously monitoring costs, times,
- f) Evaluate the performance of the prototype against approaches that are currently being implemented (primarily tacheometry) to ascertain how appropriate it will be for defining parcels outside the pilot area in Albania and elsewhere in Eastern Europe.

JUSTIFICATION:

Albania is in the process of privatizing most of the land that had been collectivized into state farms and cooperatives under the previous regime. This will involve over 2 million parcels. There is a vital need to survey these parcels and register rights to them before land transactions take place. Although dealing in land is currently forbidden, it will inevitably take place as Albania moves into a market-oriented economy. There is therefore a strong need for a cadastral surveying methodology that is quick, but which at the same time provides an unambiguous definition of parcel boundaries.

Given the availability of qualified surveyors and the history of tacheometric surveys in Albania, the most logical short-term solution is to use a tacheometric approach that relies on the graphic control of existing large-scale maps. However, initiatives to update this skill base and test the applicability of more modern

technologies must start now so that the most cost-effective approach is used for the tremendous task of surveying all parcels in Albania. Electronic tachometers and total stations are certainly more efficient than their manual and optical equivalents (theodolite, tape, etc). GPS has also proved its cost-effectiveness (and accuracy) for geodetic control densification. The extent to which GPS can be used to determine the coordinates of parcel corners (i.e., for cadastral survey purposes) directly can only be ascertained by testing different approaches and evaluating them in terms of speed and costs. This project will carry out these tests and define what is termed a prototype digital cadastral surveying system.

METHODOLOGY:

1. Select and demarcate a controlled study area in the Gainesville district so that it simulates the cadastral conditions in Albania. In particular, the parcel sizes in the study area will be based on typical dimensions of parcels found in rural Albania. An attempt will also be made to emulate types of boundaries (monuments, canals, crop rows, etc).
2. The first phase of the project involves designing three or four promising digital cadastral surveying approaches. These approaches or options will differ both in terms of the GPS techniques used (static versus kinematic) as well as in the way that GPS is combined with total station measurements. One option will involve surveying all parcel corners using only GPS, the remainder will use GPS less intensively (concentrating on key corners only) by supplementing measurements using a total station.
3. Survey all parcels in the study area using four different options, recording time and personnel requirements in each case.
4. Compute coordinates of all points using four sets of measurements.
5. Compare results in terms of time, accuracy, cost (hardware, software), geodetic control and personnel requirements.
6. Select the option that performs best (giving particular weight to time)—this will be termed the prototype system.
7. Develop a step-by-step procedure for all components of the prototype, including: reconnaissance, office preparation, observing procedure, fieldbook recording procedure, field checks required, post-processing procedures, coordinate listing, and parcel mapping. This information will be contained in a progress report to be delivered at the end of the sixth month.
8. Acquire any necessary equipment and material not available in Albania (this may include GPS receivers and software, total station unit(s) and accessories, fieldbooks, etc).
9. Set up the prototype in Albania and train a team of Albanians on all necessary procedures and requirements.
10. Provide support for implementation of prototype in pilot area in Albania.
11. Write up final report to be delivered at the end of the ninth month.

PERSONNEL REQUIREMENTS:

The success of the project hinges on the integration of expertise in the two areas of Cadastral Surveying and GPS/Geodesy (most GPS projects have focused almost entirely in the second area). Dr. Grenville Barnes will provide the cadastral surveying perspective and will coordinate the project and serve as

APPENDIX D
DATA COLLECTION FORMS
(field and office)

DAILY LOG (FIELD)					
Date:	Weather:	Party chief:		District:	
Fieldbook no.	Map sheet no.	Komuna		Village:	
Field team:	___ Surveying engineers	___ Surveying technicians	___ Drivers		
	___ Laborers	___ Chainmen	___ Others (list)		
Times:	Hours	Minutes	Comments		
Travel time to site					
Survey time					
Reconnaissance					
Control					
Boundary survey					
Corner point id					
Down time (explain)					
Total for day					
Terrain (circle)	flat	hills	mountain	other (state)	
Land use/cover (circle)	urban/reside	agriculture	olive grove	forest	other (state)
Equipment used (circle)	theodolite (___sec)	tape (___meters)	rod/staff	EDM	other (state)
Surveying technique (circle)	tacheometry	theod/tape traverse	map and tape	theod/tape radial survey	other (state)
Parcels surveyed (list parcel id's)					
Total area surveyed (hectares)					
Problems (explain)					

Objectives: To measure the resource input, degree of difficulty in field, and productivity using a specific surveying technique.

- 1) It is essential that parcel identifiers be allocated on a systematic basis before survey. These should preferably be the identifiers that will be used for registration purposes.
- 2) It is advisable that the time be noted in the fieldbook for each set-up of the instrument.

WEEKLY LOG (OFFICE)								
Date:		Office location:			Recorder:			
	Personnel (number)			Hours worked				
Activity	Surv. Eng.	Surv. Tech.	Other (state)	Surv. Eng.	Surv. Tech.	Other (state)	Total hours worked	Map sheet reference
Retrieving existing data								
Computations								
	Personnel (give no's)			Production				
Mapping activities	Surv. Eng.	Surv. Tech.	Other (state)	Total hours worked	Map sheet reference	% map sheet completed	Fieldbook references	
Computations								
Quality control (comps)								
Map drafting								
Quality control								
Map production								
Training (explain)								
Other activities								
Problems (explain)								

Objectives: To measure personnel inputs (and related costs) and productivity of office personnel in terms of each individual mapping process.

Notes:

- 1) Project manager should maintain a chart illustrating the progress of the project as it advances through the various mapping stages.
- 2) The log should be expanded to contain any activities that require significant time or money expenditure.
- 3) It is essential that clear cross-references be established between fieldbooks, map sheets, and parcel identifiers.
- 4) The unit of measure for office productivity is the map sheet.

APPENDIX E
WORKSHOP:
DIGITAL CADASTRAL SURVEYING USING GPS

308 Reed Lab
Surveying and Mapping Program
University of Florida
Gainesville

Objective:

To define and develop a methodology for surveying land parcels using GPS so that cost-efficiency is maximized under conditions typically found in Albania. Specifically, this workshop is designed to integrate the knowledge and experience of the participants in the two fields of GPS and cadastral surveying. It will consist of a roundtable discussion as opposed to formally structured presentations.

Participants:

Grenville Barnes, Assistant Professor, University of Florida
Bruce Chaplin, Geodetic Engineer, MSI, Denver
Eric DesRoche, President, MSI, Denver
Mark Eckl, Graduate Student, University of Florida
Michael Sartori, Graduate Student, University of Florida
Ramesh Shrestha, Associate Professor, University of Florida
Representative (Trimble)
Representative (Leica)

Workshop materials:

Prior to the workshop, general background material will be provided to all participants. This will serve two purposes. Firstly, it will facilitate discussion at the workshop as all participants will be familiar with the issues to be discussed. Secondly, this material will also be used for training purposes in Albania. Ultimately, we would like a good reading package that can be used for training and reference purposes by individuals who are not necessarily GPS experts. The focus will be on basic definitions, techniques, applications and experience relevant to Albania and other countries contemplating the use of GPS for cadastral purposes. Please feel free to contribute papers at any time.

Output:

The output of the workshop will be the definition of between one to three candidate methodologies which appear to be most appropriate for Albania. These three methodologies will

then be tested and compared to identify the one that best meets the evaluation criteria. The definition of the methodologies will include details on reconnaissance, control requirements, field procedure, fieldbook recording, post-processing, checks, adjustment of redundant observations, point labeling, hardware and software requirements, and so forth.

AGENDA

Wednesday, June 1, 1994

10:00 a.m.-12:00 p.m.

Introduction (Barnes)
(background, workshop structure and materials)

Cadastral Environment and Issues in Albania (Barnes)
(land allocation, parcel sizes and boundaries, control, etc.)

Discussion

1:00 p.m. - 5:30 p.m.

GPS Techniques and options (DesRoche and Shrestha)
(private sector and academic perspectives, potential techniques and advantages of each, post-processing requirements)

Discussion

Thursday, June 2, 1994

8:30 a.m. - 12:00 p.m.

Vendor perspective (Leica)
(products, support and maintenance in Albania, training)

Selection and definition of candidate methodologies

1:00 p.m. - 5:30 p.m.

Problem areas and issues

Workplan for evaluating candidate techniques and reporting on workshop findings

Friday, June 3, 1994

8:30 a.m. - 12:00 p.m.

Miscellaneous (if needed)

SUMMARY OF WORKSHOP FINDINGS

1. INTRODUCTION

A brief overview of the cadastral environment was presented. Size and physical characteristics of the “typical” Albanian parcel was estimated to be one-tenth to two-tenths of a hectare, ranging from treeless and relatively flat cropland to mountainous and rugged terrain. The evaluation of competing methodologies for parcel surveying in Albania should be based on the following criteria:

- ◆ speed,
- ◆ cost,
- ◆ match with skill base,
- ◆ employment level,
- ◆ attainable precision, and
- ◆ dispute resolution.

The current method of creating land parcel maps in Albania is referred to as the traditional method. This method consists of updating an existing parcel map or schematic by using a tape to measure the dimensions of the new parcels and drawing the new boundaries onto the map. This method is relatively inexpensive, and requires no training beyond that which already exists in the field and in the office. This method also has many problems, not the least of which are:

- (i) Existing maps, covering approximately 80% of the country, are badly out of date.
- (ii) The reference ellipsoid is different in different areas - the Bessel ellipsoid is used in some places, the Krassowsky ellipsoid in others.
- (iii) Institutional control of these existing maps is by different government agencies which historically do not cooperate well with each other.
- (iv) The output of the traditional method is an updated copy of an existing paper map with questionable relative and absolute positional accuracy—not a digital product on a worldwide or country-wide datum.

2. GPS TECHNIQUES

Some of the main concerns for any GPS based parcel surveying technique are as follows:

- ◆ the selected methodology must be user-friendly,
- ◆ technology transfer is an important consideration, and
- ◆ Albanians get computer training that applies to all aspects of surveying as well as specific GPS software training.

GPS surveying methods generally involve a trade-off between occupation time and positional accuracy. Several different GPS techniques were discussed, each with different hardware, software, and training requirements. Each technique varies in its suitability to different applications and yields varying levels of positional accuracy. These techniques and their suitability for use in Albania were summarized briefly as follows:

- a) **Classic static:** Requires at least two single or dual frequency geodetic receivers.

Occupation time varies from 45 minutes to several hours. Geodetic (centimeter) accuracy is obtainable. Basic application is control densification. Receiver costs range from \$15,000 (single-frequency) to \$25,000 (dual-frequency) per unit. Not practical for parcel mapping due to very low productivity.

b) Rapid static: Requires at least two dual-frequency geodetic receivers. Occupation time is cut to 10–20 minutes to get centimeter accuracy. Still not practical for large-scale parcel mapping due to low productivity and high equipment cost.

c) Kinematic: Requires at least two geodetic receivers. Centimeter accuracy is obtainable in seconds, but this method requires a very high degree of coordination and expertise both in the field and in the office to be productive. Not recommended for this reason.

d) C/A code differential positioning (Basic Pathfinder): Requires a single geodetic receiver as base station and less expensive rover units. Occupation time is in the three minute range but accuracy is 2–5 meters. The productivity is high but questions remain as to whether the positional accuracy is high enough for cadastral surveying.

e) C/A code differential positioning with carrier smoothing and advanced processing (Pathfinder Pro XL): Requires a geodetic base station receiver with an advanced processor and Pro XL Rovers and data collectors. Occupation time is 30 seconds to one minute. Average accuracy is submeter. This is the recommended hardware, with availability being the main concern as the Pro XL has only recently been released.

The level of accuracy needed for parcel mapping in Albania is dependant on a number of factors such as parcel size, value, and location. At the time of the workshop it was not known if Trimble's new line of submeter GPS equipment known as the Pathfinder Pro XL series would be available for use in Albania; therefore several alternative methodologies were discussed.

3. GPS-BASED ALTERNATIVES

A representative from Leica presented an overview of the Leica System 200. System 200 consists of a dual frequency receiver with a data collector known as a controller. The software is known as SKI. This is a Rapid Static configuration, yielding centimeter accuracy in 10 to 20 minutes of occupation time. Base cost for two units plus software is \$68,000.

Three options emerged as GPS-based alternatives to the traditional method.

a) Option 1

One promising methodology was a three-team approach for the establishment of a “block map.” Team one, the “Geodetic Team,” would recover existing geodetic control and set new control points using the classic static technique (single frequency geodetic receivers) as necessary. This geodetic control would be provided on a map sheet by map sheet or “block” basis, two to four points per block. Team two, the “Map Team,” would proceed on a sheet by sheet basis (within the block) establishing control on topographic features and key parcel corners using Basic Pathfinders with 2–5 meter accuracy. Each block would have a minimum of four to six of these points. Team three, using traditional methods (tapes and theodolites), would map the final parcels within each block, tying into any and all previously established control.

Equipment required:

One single-frequency geodetic receiver as a base station. Four or more Basic Pathfinder (2–5 meter accuracy) as the roving units. Two 486 - 25Mhz PC's or better, PFINDER software, range poles/ tripods/ tribrachs/ batteries. Theodolites and tapes.

Advantages:

3-minute occupation times, inexpensive equipment, unified datum.

Disadvantages:

Questionable use for all but the most rural of parcels due to the low accuracy.

b) Option 2

This was a briefly considered method, using only the classic static technique to survey all parcel corners.

Equipment required:

Four or more single-frequency receivers used in static mode. Two 486 - 25Mhz PC's or better, Trimvec and GEOLAB software, range poles/ tripods/ tribrachs/ batteries.

Advantages:

Greater accuracy (5–15 cm)

Disadvantages:

Long (45–75 minute) occupation times means unacceptable productivity

c) Option 3

This was the preferred option, depending only on hardware availability. The existing network of geodetic control would be utilized as reference stations and the Pathfinder Pro XL would locate all parcel corners to submeter accuracy, with occupation times of 30 seconds to 1 minute.

Equipment required:

Pro XL Pathfinder. Needs geodetic base station (with appropriate chip), four or more Pathfinder Pro XL Rovers with data collectors, PFINDER Version 2.5 software, Rangepoles /Tripods /Tribrachs /Batteries Two 486 - 25Mhz PC's or better.

Advantages:

Submeter accuracy, 1 minute occupations.

Disadvantages:

Availability of hardware is questionable.

4. REDUNDANCY ISSUES

The output from GPS Pathfinder surveys would be coordinates. Mistakes in antennae height readings at the rover or base stations, occupying the wrong point or inputting the wrong control coordinates would result in inaccurate or wrong parcel coordinates. Therefore quality control and rejection criteria for parcel corners must be established.

The use of two base stations would provide a check for all but rover antennae errors but would effectively double the office work load and increase the initial hardware costs.

5. DESIGN OF FIELD TESTS

Field tests to determine attainable positional accuracy of the Pathfinder Basic and, if possible, Pathfinder Pro XL in actual use were discussed. A number of variables were to be studied for their effect on positional accuracy and productivity, among them: Type of hardware (Pro XL versus Basic), length of baseline between the reference and remote receivers, and technique employed (rapid static, kinematic).

APPENDIX F

RESULTS OF CONTROLLED TESTING ON UNIVERSITY OF FLORIDA TEST SITE

TEST AREA

In May 1994, a parcel test area containing 49 capped iron rods was surveyed on the campus of the University of Florida. Each rod was 15 inches long and was set flush with the ground. The points were set as to approximate average agricultural parcel sizes in Albania, ranging in area from 0.10 hectare to a maximum of 0.23 hectare.

A static GPS survey was performed to establish State Plane Coordinates on six of the parcel corners using two control points—ROOF and A109. ROOF is a high precision station located on the roof of Reed Lab, 2 kilometers northwest from the test site, and A109 is an Alachua County GPS control point (Second Order) 2 kilometers southwest from campus. A total of 27 vectors was observed and a network adjustment was performed holding the two control points fixed. Standard errors of less than 5 millimeters were obtained on five of the test parcel corners, 8 millimeters on the sixth point.

Each of the 43 remaining parcel corners was then surveyed independently from two different control points with two Top-Con total stations, yielding two sets of coordinates for each remaining point. If the calculated distance between each pair of coordinates was less than 2 centimeters, the control coordinate was fixed at the halfway mark. If the calculated distance was more than 2 centimeters, the point was resurveyed.

PATHFINDER PRO XL

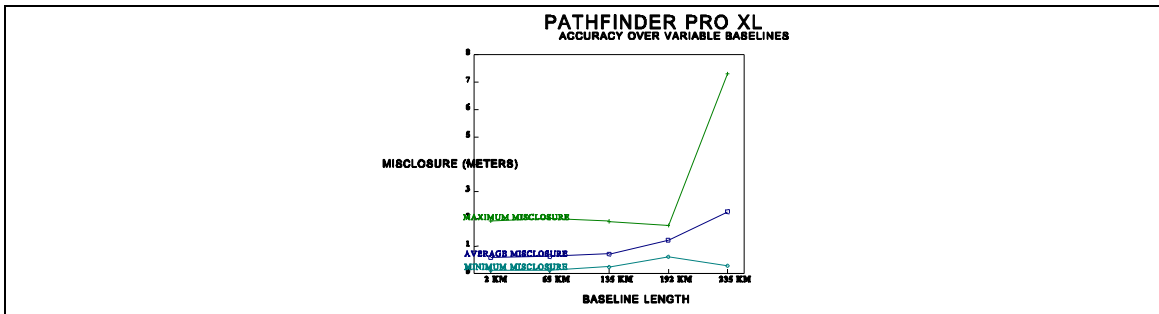
The TRIMBLE Pathfinder Pro XL is representative of the “next generation” of GPS equipment, combining improved positional accuracy with wide-ranging and flexible data collection capabilities. Due to the limited number of these units available from the manufacturer prior to departure to Albania, field testing was restricted to a single 5-hour session; the cables and software for downloading and processing were not available until the following week. Consequently, it was not until field testing in Albania was completed and the equipment back in Gainesville that extensive testing of the Pro XL could begin.

The objective of the testing in Gainesville began on 21 July, with the focus being to determine the maximum length of baseline separation that would still allow for submeter positional accuracy.

In the first series of tests, increasing baseline separations of 2, 65, 135, 192, and 235 kilometers were observed and the rover data from the Pro XL was differentially corrected. Only one dual frequency TRIMBLE 4000SSE geodetic receiver was available for testing, making simultaneous occupation of the 2 kilometer baseline impossible. Rover positions were occupied for 30 seconds with a 5.0 second logging rate. PDOP was always less than 6.0 and averaged 3.0.

Satellite elevation masks were set at 10 degrees at the base and 15 degrees at the rover to ensure that the rover was collecting a subset of the satellites being observed by the base receiver. Signal to noise masks were also set at manufacturer recommendations. Results are graphically summarized in Figure 1.

FIGURE 1



Figures 2 through 5 show the distribution of points in various ranges of positional accuracy across increasing lengths of baseline separation for differentially corrected data collected by the Pathfinder Pro XL. Tables 1 through 4 summarize the average positional accuracies obtained, as well as the standard deviations, maximum, and minimum misclosures.

FIGURE 2

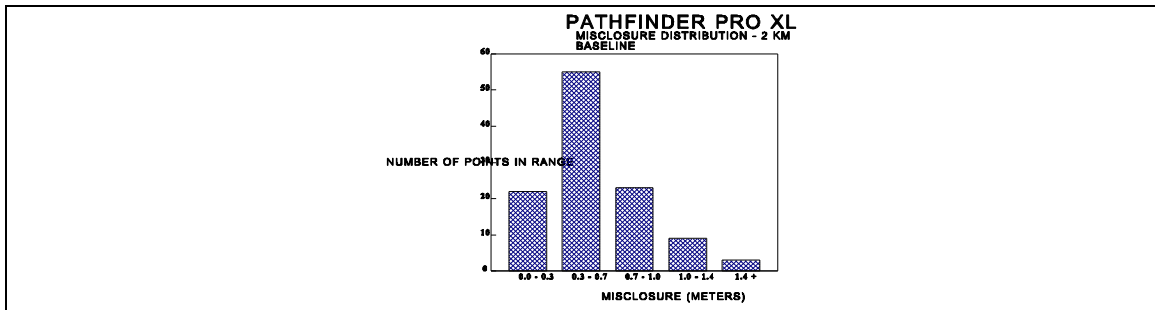


FIGURE 3

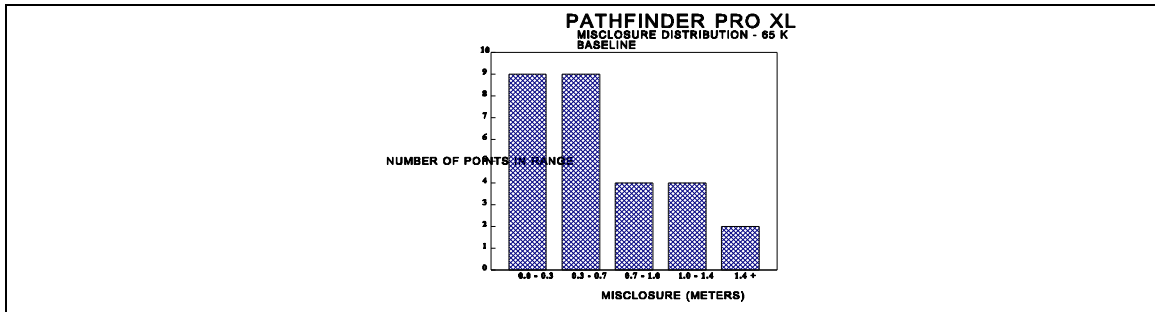


FIGURE 4

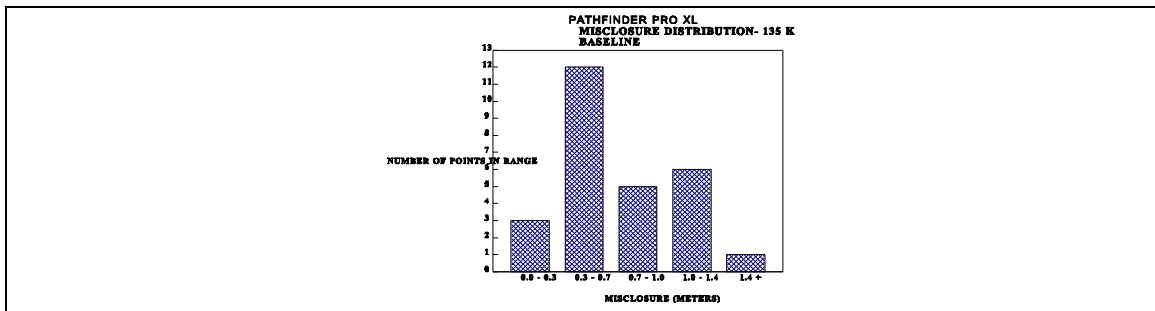


FIGURE 5

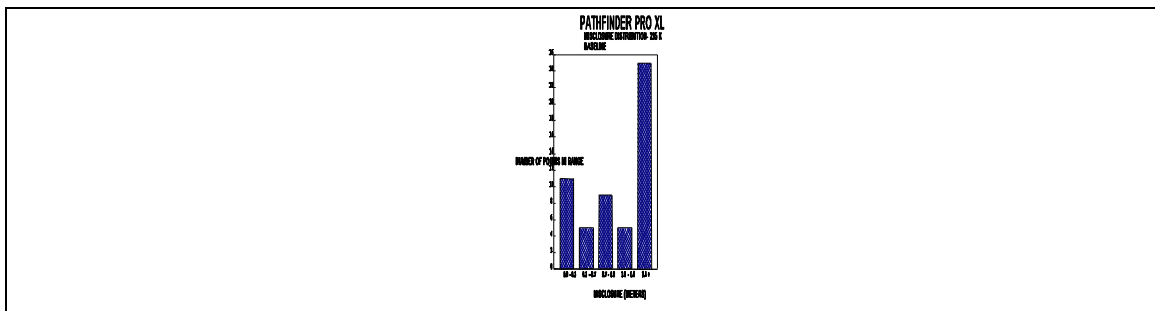


TABLE 1 Pathfinder Pro XL: Positional accuracy over 2 km of baseline separation

MEASUREMENT	2 KM BASELINE
Average misclosure	0.59
Standard deviation	0.32
Maximum misclosure	1.92
Minimum misclosure	0.11

All values in meters.

Total points measured: 112.

TABLE 2 Pathfinder Pro XL: Positional accuracy over 65 km of baseline separation

MEASUREMENT	65 KM BASELINE
Average misclosure	0.63
Standard deviation	0.47
Maximum misclosure	2.01
Minimum misclosure	0.12

All values in meters.

Total points measured: 28.

TABLE 3 Pathfinder Pro XL: Positional accuracy over 135 km of baseline separation

MEASUREMENT	135 KM BASELINE
Average misclosure	0.72
Standard deviation	0.39
Maximum misclosure	1.91
Minimum misclosure	0.25

All values in meters.

Total points measured: 28.

TABLE 4 Pathfinder Pro XL: Positional accuracy over 192 km of baseline separation

MEASUREMENT	192 KM BASELINE
Average misclosure	1.22
Standard deviation	0.32
Maximum misclosure	1.76
Minimum misclosure	0.61

All values in meters.

Total points measured: 4.

GENERIC BASE RECEIVERS

Another series of tests was performed concurrently with the increasing baseline tests using a single frequency ASHTECH geodetic receiver as the base station. The purpose of this test was to determine if a lower cost receiver could be used as a base station without a significant loss of positional accuracy. The ASHTECH receiver has no L2 capability as well as no advanced electronics comparable to TRIMBLE'S newest generation of central processors. By use of RINEX, which is an ASCII-based GPS data exchange format, differential corrections based solely on code phase pseudoranges can be used to correct the rover positions. The results are summarized below (Figure 6).

FIGURE 6

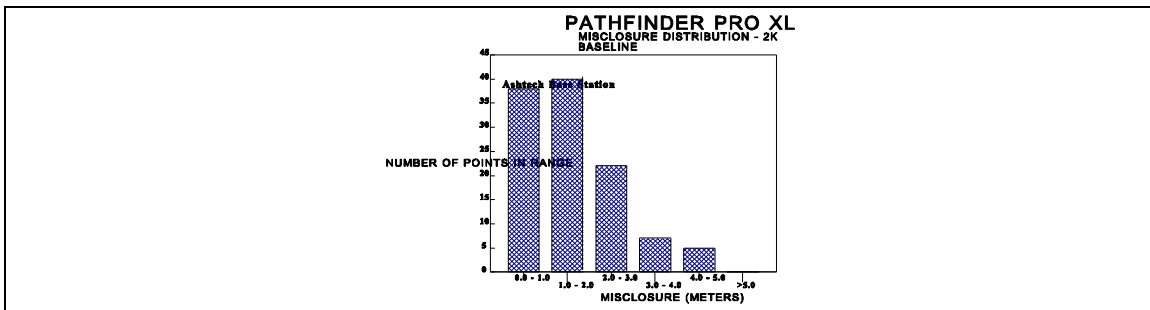


TABLE 5. Pathfinder Pro XL: Positional accuracy over 2 km of baseline separation, using an ASHTECH base receiver

MEASUREMENT	2 KM BASELINE
Average Misclosure	1.58
Standard Deviation	0.84
Maximum Misclosure	4.52
Minimum Misclosure	0.09

All values in meters.

Total points measured: 56.

ANALYSIS AND RECOMMENDATIONS

The Pathfinder Basic was found to yield positional accuracy of less than 5.0 meters 95 percent of the time with baseline separations of 50 kilometers or less with 3 minutes of occupation time (based on a normal distribution with mean value ± 2 Sigma). For rural or mountainous conditions in Albania, with cost as a primary consideration, this option could be viable. The primary argument against using the Pathfinder Basic is its accuracy level of 2–5 meters. Given the small land parcels in Albania, this kind of inaccuracy is significant, especially when the dimensions of the sides of a parcel are in the 10-meter range. Additional considerations:

- (i) The Basic Pathfinder requires 3 minutes of occupation time as opposed to 30 seconds with the Pro XL.
- (ii) The Basic Pathfinder performs best with 1-second datalogging rate which significantly increases memory requirements in the base receiver.

Tests conducted reveal that the Pathfinder Pro XL will yield positional accuracy of less than 1.50 meters 95 percent of the time (normal distribution, 2 Sigma) with baseline separations of less than 135 kilometers and 30-second occupation times. At separations longer than 135 kilometers significant degradation begins to appear, and at the 235 kilometer distance and 95 percent confidence level the misclosure distance is 5.5 meters; the Pathfinder Basic yields 7.2 meters at the same confidence level at a slightly longer separation of 260 kilometers.

These numbers indicate that in areas that require high positional accuracy such as high growth urban and suburban areas, and valuable agricultural areas with small plots, the Pro XL is a more justifiable option provided that baseline separations are kept below 135 kilometers.

The use of a single-frequency base receiver other than the TRIMBLE 4000SE such as the ASHTECH MD-XII could result in a hardware savings, but at the cost of at least 1 meter of positional accuracy. The processing of data collected by receivers of different manufacturers also adds complexity and time to the office procedures.

APPENDIX G

GPS EQUIPMENT SPECIFICATIONS FOR PARCEL MAPPING IN ALBANIA

1. SOFTWARE

1.1 MISSION PLANNING SOFTWARE

The GPS mapping system should include software that provides satellite visibility information for given locations and times, that is, mission planning software. The mission planning software should display position dilution of precision (PDOP) versus time. The software should allow the user to simulate visibility masks produced by topographical features, for example, buildings, tree cover, and the like. The mission planning software should accept satellite almanac information uploaded from the GPS receiver to a personal computer (PC).

1.2 POST-PROCESSING SOFTWARE

The post-processing software should be capable of differentially correcting individual positions to yield median accuracy of 1 meter or less. The software must be able to differentially correct those positions that were not corrected in real-time via the RTCM-compatible radio link.

The software should utilize a method of differential correction that does not require that the base station and the rover be tracking exactly the same satellites. The base station should be free to track all satellites above the elevation mask, while the rover should be free to use those satellites that yield the most accurate position, that is, the lowest PDOP.

Differential correction should be possible in post-processed mode, without the use of a communications link between base and rover receivers. The software should be able to convert base data files from RINEX format for use in differential correction. There should be an additional package available to post-process the carrier phase GPS data.

1.3 GIS SUPPORT SOFTWARE

The GPS system should include software that allows the following:

- ◆ complete definition of geographic features prior to fieldwork,
- ◆ storage of data in a GIS-compatible, structured format during data collection and on the PC,
- ◆ generation of structured GIS interchange files, and
- ◆ provision of selected output to GIS interchange files based on feature name or attribute values.

The software should also allow the following:

- ◆ storage of points in a file,

- ◆ creation and editing of points on the PC, and transfer to the receiver, and
- ◆ creation of new points on the PC by reading points from an ASCII file.

The software should organize and segregate data files via a “project-based” working environment, which allows the user to create projects and relate DOS directories to projects.

The software should provide a function for combining multiple data files into a single file.

The software should allow a function for averaging positions of features in a file to create a new file with a single mean position for each feature.

The software should allow the computation of the following for each file:

- ◆ number of records,
- ◆ mean position,
- ◆ maximum and minimum positions, and
- ◆ standard deviation of mean position.

The software should allow the computation of the area enclosed by positions in a file.

The software should allow the output of data in the following forms:

- ◆ user-defined ASCII files,
- ◆ standard GIS/CAD interchange formats, and
- ◆ graphic displays which can be transferred to all standard printers.

The user must have control over the units of measurement and the decimal precision.

The following coordinate systems should be supported by the software:

- ◆ geographic latitude/longitude/elevation, and
- ◆ user-definable coordinate systems.

The software should allow for the creation and use of user-definable ellipsoids.

The following units should be supported for angular measurement:

- ◆ decimal degrees,
- ◆ degrees, decimal minutes,
- ◆ degrees, minutes, decimal seconds, and
- ◆ radians.

The following units of measurement must be supported for distances:

- ◆ meters,
- ◆ feet, and
- ◆ survey feet.

The ASCII output function must give the user control over:

- ◆ data fields to output,
- ◆ location of fields within a record,
- ◆ field, record and string delimiters, and
- ◆ field formats.

2. BASE STATION UNITS

2.1 GENERAL

The system should comprise the receiver, a built-in or external antenna with cables, batteries and battery charging facilities, data download facilities, operators' manuals, and software required for data downloading.

The GPS hardware should be waterproof and dust-proof and should be capable of functioning reliably under extreme and adverse weather conditions. The GPS receiver should have an internal solid-state datalogging capacity of 18 hours of 5 L1 satellite data, at a 15-second logging interval.

The GPS receiver should be capable of tracking both Block I and Block II satellites, both existing and presently proposed.

The manufacturer should provide, at no additional cost, all available software/firmware upgrades for the receivers and software and should provide routine software enhancements to ensure continued operation with any changes in the Global Positioning System for a minimum period of 1 year from delivery and acceptance of the system.

The receiver should be capable of downloading data to an IBM-compatible computer through a standard RS 232 port, even during data collection.

2.2 RECEIVER OPERATION

The receiver should be capable of being powered by either 11.5–35.0 Volts DC or 115/230 Volts AC.

The receiver should perform self-checks to detect electronic malfunction and/or faulty data collection.

The receiver should allow the operator to select the epoch interval to record data as often as once per second, up to as seldom as once per 60 seconds.

The GPS acquisition time should be less than 2 minutes.

The receiver should have an audible alarm to alert the operator of low battery power, too few satellites, high PDOP, and other warnings.

The receiver should be capable of tracking a minimum of 8 satellites simultaneously. The receiver should be upgradable to 12 channels.

The receiver must be capable of tracking the L1 carrier and C/A code and must measure carrier phase, Doppler, integrated Doppler, and pseudo-range data.

2.3 DATA QUALITY AND MEASUREMENT ACCURACY

Time tags should be accurate to within 10 ms. Cycle slips should be detected and quality flags set to indicate that cycle slips have occurred. Observation data from all receivers should be provided at the same receiver clock time.

The GPS receiver shall provide measurements having the following effective accuracies:

- ◆ Carrier phase 1mm,
- ◆ Integrated Doppler 3mm,
- ◆ Doppler 0.001 HZ (0.2 mm/second),
- ◆ Code Phase 1 meter,
- ◆ Time tags 0.1 ms, and
- ◆ Horizontal distance accuracy 1 cm + 2 PPM of baseline distance.

3. ROVER UNITS

3.1 GPS CONFIGURATION

The GPS configuration should consist of the following items, in addition to the GPS receiver and display systems: hard carrying case, remote antenna with cables, antenna mounts, rechargeable batteries with battery charger, automobile power adapter, data download cables, and mission planning and processing software.

The GPS receiver should be waterproof and shock resistant.

The GPS receiver should be a C/A-code receiver, utilizing 8 L1 band channels. The receiver should be capable of tracking at least eight satellites simultaneously.

The GPS receiver should be capable of being upgraded to a 12-channel receiver .

The GPS receiver must be capable of yielding positions with better than 1-meter median accuracy with real-time differential correction or post-processing on a point-by-point basis.

The GPS receiver should have a minimum update rate of 1 second.

The GPS receiver should be able to display and log differentially corrected positions in real-time via a communications link compatible with the RTCM SC-104 standard.

The GPS receiver should be capable of operating continuously on portable battery power for at least 8 hours. The GPS receiver should also be capable of being powered by a standard 12-Volt car battery, with the use of a portable voltage converter, if required.

The GPS receiver must allow selection of a satellite elevation mask, signal level mask, and position dilution of precision (PDOP) mask. Satellites below the elevation mask should not be used in calculating the position; satellites below the signal level should not be used in calculating the position; and positions should not be recorded when the PDOP value is above the mask.

The GPS receiver must automatically select the satellites above the elevation mask that provide the lowest PDOP.

The user should be able to disable the use of specific satellites.

The GPS receiver should have a display option for viewing the following information: elevation, azimuth, signal strength, and User Range Accuracy (URA) for each satellite in view.

The GPS display must display the PRNs used and the PDOP of the constellation of satellites used to determine position.

The GPS receiver must allow the selection of metric, nautical, or English miles and feet units of measure.

The GPS receiver must be capable of storing points for navigational use. The receiver should allow at least 50 points to be stored. It should display the selected point number, the range, bearing, azimuth, and cross-track error from the present position to any selected point number.

The GPS receiver should display the geographic latitude/longitude and height above the ellipsoid relative to the World Geodetic System of 1984 (WGS 84). All information must be updated on the screen every second, assuming a sufficient number of satellites for fixing position.

The GPS receiver must be capable of acting either as a rover or as a base station for differential correction determination. When acting as a base station, the receiver should automatically track the highest satellites in view, up to a maximum of eight. When acting as a rover, the receiver should automatically track the constellation of satellites which yields the most accurate position, that is, the lowest PDOP.

The GPS receiver should have an external antenna, and the display should show the antenna status.

The GPS data logger must transfer data to a personal computer (PC) via a standard communications link, such as RS232, and utilize standard protocols.

3.2 DATA LOGGING

The data logger should record latitude, longitude and ellipsoidal height relative to the WGS 84 datum.

Data loggers for the GPS system should have a minimum of 640 Kbytes of memory, and should be upgradable to at least 4 Mbytes of memory.

The data logger should be able to store positions in the internal memory at a minimum update rate of 1 per second.

The data logger should be capable of continuously and internally storing up to 20,000 positions.

The data logger should allow data to be stored in at least 30 files.

The data logger must cease to log data once memory is exhausted and should not overwrite existing records.

The data logger should be capable of logging data with real-time differential GPS positions, or non-differential GPS positions. These positions should be tagged differently to allow post-processing of only the uncorrected positions in the same file.

The GPS receiver should be capable of collecting carrier phase data at user selected intervals of 5, 10, 15, or 30 seconds.

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