REPORT AND RECOMMENDATIONS FOR THE NUEVA CANAAN SETTLEMENT, CHAPARE, BOLIVIA

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REPORT AND RECOMMENDATIONS FOR THE NUEVA CANAAN SETTLEMENT, CHAPARE, BOLIVIA

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INTERTECT
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I. SUMMARY OF FLOODING PROBLEMS AND CONSTRAINTS

The flooding problems which confront the settlers of Nueva Canaan are compounded by several additional problems, other than just the simple overflow of the river. In order to select the best approach and to understand the recommendations that are made subsequently, it is necessary to understand the problems that face the settlement and also confront the planner in trying to develop strategies and approaches for reducing the threat of inundation.

A. Erosion:

Each year, extensive erosion takes place on the west bank of the river stream (the east bank of the Nueva Canaan settlement). The residents of Nueva Canaan have noted as much as 200 meters of erosion within the last five years. From preliminary observation, it is clear that erosion is due to changes in the stream bed caused by two factors: the normal meandering of the river and, to some extent, stabilization of the embankment on the eastern, upstream side of the river, just south (upstream) of the bridge which spans the river at the southeastern boundary of the project area.

The erosion rate is likely to slow within the next few years; but erosion will continue until such time as the stream has reached a natural level in the drainage basin, or until such time as there are other changes in the channel which divert the water back into the center of the stream bed.

The extent of the erosion poses two immediate problems. First, erosion of the bank itself is difficult to control, and continued

erosion will undoubtedly cause the loss of more crop land. Second, and more important in consideration of the flood control, is the fact that any levee system which could be economically built by the residents themselves must be built on top of existing crop land, set back some distance from where the bank is now. If the extent of erosion is not correctly anticipated, future flooding will continue the erosion rate and undercut the levees, causing them to collapse at key points and allowing flood waters to enter the settlement.

B. Downstream Flooding:

Any watershed must be viewed as an entire system; when any part of the system is tampered with, it affects all those parts downstream and some adjacent and upstream. Any plan for the protection of Nueva Canaan must provide for a course of action chosen in such a way as to make sure that any flooding which occurs downstream is minimized. At this point, the extent of settlements further downstream is not known. However, in the development of plans, it is necessary to anticipate not only possible flooding in the downstream areas, but also what effects the options might have on adjacent settlements. The residents or representatives of those settlements should participate in the development of flood protection plans for Nueva Canaan.

C. Lack of Topographic Data:

One of the major factors currently hampering plans is the lack of good, accurate topographic data for Nueva Canaan and the surrounding area. A number of topographic and geologic maps have been found which can be used for planning activities in relation to the entire watershed; and once funding is secured, satellite imagery and aerial photographs will be obtained. However, these photographs and images will only be able to provide information at a fairly large contour interval. Therefore, a ground survey will be necessary in order to actually plot the exact course of the levee system.

D. Lack of Funds for Extensive Actions:

The primary constraint which has been taken into consideration in the development of recommendations (section III of this report) is the lack of funds for carrying out extensive actions in this area. The Nueva Canaan settlement has no more than 500-600 resident families, and the amount of money available from other sources is extremely limited. Thus, whatever option is finally chosen must take into account a realistic appraisal of the amount of money likely to be available, and a plan must be developed which can be carried out over several years at the lowest possible cost.

E. Lack of Personnel for Extensive Actions:

The small number of families living in the area limits the number of people who will be available at any one time to work on the flood protection system. Normally, when manpower is limited, the difference can be made up by using heavy equipment. However, an examination of the costs of using such equipment indicates that extensive use of heavy machinery is not feasible, if not entirely prohibitive. Therefore, any system which is developed must take into account the fact that the majority of the labor will have to be carried out by hand, or with limited access to equipment resources, by the residents themselves. This also argues for a project which can be carried out sequentially over a long period of time, and one which utilizes simple technology.

II. OPTIONS

In order to develop a complete flood protection system, two primary factors have to be determined: first, how to control the erosion; and second, how to provide the flood protection.

A. Erosion:

As far as erosion is concerned, there are generally four basic options:

1. Allow the stream meandering to seek its own boundaries. With this option, nothing is done to try to change or stop the meandering of the river, on the assumption that it will eventually reach a point where the stream will begin to move back in the other direction and erosion, on its own, will stop.

   The advantages of this approach are:

   a. There is no large capital investment required;

   b. The system is left in its natural state and no abrupt changes are caused downstream.

   The disadvantages are:

   a. Residents along the stream will continue to lose land until the stream changes course again;

   b. No one knows when or where the erosion will stop, or even whether the rate of erosion will slow.

2. Stabilize the stream bank. There are various ways by which the stream banks can be stabilized. Unfortunately, all are expensive. The usual way of stabilizing stream banks is by constructing a concrete wall at key points along the river bank where the force of the water is greatest. In some cases, it is necessary to build a concrete wall along the entire length of the bank. Simpler embankments have been made by stacking stone along the bank, but this requires continuous maintenance because the river can get behind or under the stone (in a process known as "scour") and collapse the embankment. During periods of prolonged flooding, large areas of embankment can be swept away. A third possibility, which has been used more recently, is the placement of large plastic sheets (sewn together) along an embankment, weighted down with a heavy rock wall. Of all the methods available, the last two are the only ones considered economically feasible for Nueva Canaan.

   The advantages of bank stabilization are:

a. No more land will be lost;

b. Once the embankment is stabilized, flood protection levees can be built right at the bank, again causing no loss of additional land.

The disadvantages are:

a. High cost;

b. Bank stabilization requires a large, concentrated commitment in both manpower and materiel. It cannot be accomplished on a step-by-step, pay-as-you-go basis over a period of years.

If bank stabilization is undertaken, extensive hydrologic information must be gathered to determine those points where stabilization should take place.

3. Upstream diversions or cuts. An examination of the total watershed may show that it is possible to construct a series of diversion floodways to provide a means of escape for flood waters in excess of the carrying capability of the main channel, directing them into emergency or auxiliary channels which would carry the water into other streams. The diversion of excess water from one river to another is practicable only if the flood flow can be carried safely to the other river. Any proposal for flood diversion must be so planned and effected that the benefits at one point are not offset by increased damage elsewhere.

Advantages to this approach include:

a. Adequate diversions could possibly be effected in such a way as to reduce the need for any embankment program, or could significantly reduce the height to which an embankment would have to be constructed;

b. Flood diversions would reduce the amount of water and also the force of the current, thereby reducing erosion.

The disadvantages include the fact that diversions are expensive, especially if another stream is not close by. They require large capital and labor investments.

If this course is chosen, extensive hydrologic data will have to be developed for the entire watershed.

4. River Channel Improvements. The improvement of the river channel (by clearing, straightening, widening, deepening) can be undertaken to decrease the length of the river and to improve its conveyance ability. Work can also be undertaken to increase the effective slope of the channel or to reduce stream bed and bank friction by the elimination of sand bars, the smoothing of bank contours, and the enlargement of the natural channel by dredging and the removal of obstructions or bends. All are beneficial in increasing the velocity of the river flow and consequently in lowering the flood stage.

Advantages:

a. Cost is minimal;

b. Work can be done without extensive capital and labor investments.

Disadvantages:

a. The activity must be done constantly;

b. Flooding caused by large storms upstream will still pose a potential threat;

c. Continuous stream maintenance may compete with other activities of higher priority in the settlement, such as agriculture. In short, stream bed maintenance cannot be put off until a more convenient time.

B. Flood Protection:

For the Nueva Canaan settlement, there are several options available for construction of a flood protection system. In examining these options, it should be realized that any one or all of these

can be built, and that the actions of individuals to protect their own land can be beneficial to the entire system.

1. Embankments. Embankments (or levees) are among the oldest and most widely used measures to protect land from floods. In the Nueva Canaan region, embankments are the only feasible method of preventing inundation and are perhaps the cheapest structural protection.

   In most cases, the criteria for the design of embankments are based on the maximum recorded flood. As more hydrological data becomes available and as past maximum floods are replaced by new and larger floods, the planning and design criteria are modified accordingly. Normally, flood control embankments are not designed and constructed to afford complete protection against infrequent and extraordinary floods, as the cost of such embankments would exceed the economically justified benefits.

   The design of embankments is normally determined by making assumptions based upon measurements of the stream flow and sediment transport of the river. (Such detailed hydrologic analyses, however, are not overly necessary for a system which is to be built up gradually and is based upon a trial-and-error procedure.) However, it should be realized that the flood stage of the river will rise proportionately to the increased height of the river embankment; thus, it is necessary to determine the possible consequences of flooding across the river and downstream with each corresponding increase in the height of the levee. As mentioned earlier, embankments should be considered as part of a complete flood control program, so planned and effected that the benefits at one point are not offset by increased damage elsewhere.

   Another point to consider is that water from rainstorms that normally drains freely across the flood plain into the river may accumulate behind the embankments. It may be necessary to have an adequate system to drain this water into the river through sluice gates. Small tributaries which run

through the project area and join the main river at a point which must be included in the main embankment system will require special attention, as floods in the main river will back up the tributaries. To offset this effect, backwater embankments may be necessary.

Finally, the long-term variations in the river's behavior must be taken into account when planning both embankments and anti-erosion measures. And once a protection system has been installed, the behavior of the river should be monitored so that, if any need for additional work arises, it will be recognized in advance.

While the construction of embankments is, in the end, the lowest cost method, it is by no means cheap. Such a system may not have a high construction cost, but the land which is necessary for the system can add up to quite extensive acreage. Once the embankment is built, that land is no longer usable for agriculture. Therefore, in order for the system to have the greatest benefit, it should serve a dual function; it must not only provide flood protection, but should also serve some other economic benefit for the community. One of the best means for making a levee system economical, at the same time ensuring that it will be constantly maintained, is to construct the main parts of the levee system in such a way that they serve not only as flood embankments, but also as roads.

The advantages of an embankment system of flood control are:

a. Relatively speaking, it is low-cost;

b. No sophisticated technology is necessary;

c. Work can be carried out either by hand or with the assistance of heavy machinery;

d. The system can be built up progressively over a long period of time;

e. After a certain point has been reached in the elevation of the embankment, flood levels on the inside of the embankment will be reduced with

every corresponding rise in height of the embankment system. In short, the higher the bank, the lower the flood water in the project area.

The additional advantages of combining the embankment with a road system are:

a. The road can serve to economically benefit the area and help justify the costs of installation of the embankment, as well as maintenance costs;

b. Continual use of the road will help maintain the compacting necessary to stabilize the embankment;

c. At a future date, maintenance of the embankment can be taken over by the road department;

d. Maintenance of the embankment can be carried out with equipment used by the road department.

The disadvantages of the levee system include:

a. Upstream changes in land use (such as deforestation or increased agricultural use) may create greater runoff and therefore necessitate continuous increases in the height of the embankment system;

b. All embankments are subject to erosion and subsequent collapse; therefore, a permanent flood-fighting plan will have to be developed, not only for use during construction, but also after the installation of the system.

2. Farm Embankment System. A farm embankment system is simply a series of individual levees surrounding each of the individual farms within the project area. Each farm would have its own embankment encircling the land, with areas left between each of the farms for the flood waters to pass through. Design criteria would be similar to those for a major embankment, but the height necessary for each farm would be different.

The advantages of a farm levee system are:

a. The system can be built up progressively by each family, according to their own needs and the availability of time and money;

b. Groups of families can help each other;

c. The construction of hundreds of embankments would reduce the overall threat of large-scale inundation; should any of the embankments collapse during a flood, the water would be contained by the other levees in the area.

The disadvantages of this system are:

a. The protection offered would only prevent flooding from small to intermediate floods;

b. Such a system would not protect those families closest to the river;

c. The total time necessary to construct the system would probably be longer than that necessary to construct the system outlined in #1 above.

3. Individual Protection. The flood protection measures which have been discussed thus far have related to reduced flooding in the region as a whole and thereby protect crops and farmland as well as structures and lives. There are, however, a number of measures which can be undertaken by each family to protect a small localized area, and these should be carried out until such time as a community-wide system can be installed. These measures include:

a. Raising existing buildings above the flood level;

b. Constructing new buildings on fill or columns;

c. Constructing small walls or levees around structures;

d. Relocating or protecting damagable property within an existing building;

e. Relocating existing buildings and/or contents out of a flood hazard area;

f. Using water-resistant materials in new buildings, or repairing and reinforcing existing buildings with such materials;

g. Installing flood forecast and warning systems, and developing an appropriate evacuation plan.

C. Resettlement:

Resettlement of the community may be considered as an alternative. However, viewed on its own and for one purpose only, it is an expensive and probably questionable solution, particularly for the settlers of Nueva Canaan. Yet as flood problems increase, the community as a whole may see a common benefit to moving to higher, safer ground.

Resettlement should be examined within the broader framework of comprehensive development possibilities, and considered against the problems of opening new land for settlement. For example, resettlement may disturb existing economic activities before alternative economic activities are guaranteed. It should also be noted that complex social and economic problems of land acquisition are associated with resettlement. Land tenure and ownership disputes may serve to delay or frustrate resettlement efforts. Consequently, resettlement proposals must have clear and strong governmental support and, if possible, should be accompanied by equitable compensation schemes with sufficient government and/or private financial backing.

Other considerations include:

1. Resettlement schemes may require parts of the population to move to different areas of the country, or simply onto safer ground nearby. In either case, attention must be given to physical and economic, as well as social and cultural, change. Care should be taken to include adequate social,

physical and economic planning when undertaking resettlement.

2. The scale and level of resettlement are important considerations. It is virtually impossible to change the predominant population pattern within a community, except at tremendous capital and social cost.

3. The resettlement of individual communities to safer locations within the same region is not as great a problem, as long as it does not fundamentally alter existing living patterns. The problems associated with individual or ad hoc resettlement schemes involving individual families are more readily definable. Nevertheless, they also call for careful social planning, infrastructure and capital investment planning and assistance.

III. ACTION RECOMMENDATIONS

A. Recommended Approach:

Of those options currently available, INTERTECT recommends that the embankment/road system be chosen as the primary means of flood protection, and that this be accompanied where feasible by farm levees and individual protection measures.

At the present time, not enough information is known about the hydrology of the river, nor the watershed, to be able to determine the best course of action for erosion control. Therefore, it is not possible at this time to make a recommendation as to the best method. However, a research program based on the use of remote sensing has been developed by INTERTECT, in conjunction with Texas A&M University's Remote Sensing Center, to provide that information. (The remote sensing proposal is attached as Part II of this document.) It is proposed that this information be derived as part of a separate research study funded entirely by a scientific research organization. The techniques for conducting such a study have been developed and applied within the U.S., but such a program has not been applied in jungle areas nor utilized extensively in developing countries. It is felt that such a project would be considered highly fundable by any one of a number of scientific research organizations.

Under the approach which has been selected, a number of actions can be initiated without waiting for the results of the study. However, the final scheme cannot be initiated until this information has been obtained.

It is proposed that funds be made available from the research grant to train members of the project staff, as well as other selected persons in Bolivia, in ways of using these techniques and how to integrate them with on-site flood protection planning, so that other communities with similar problems can be helped by those participating in this project.

B. Recommendations for Immediate Actions:

1. Topographic Survey of the Project Area. In order to determine the best location for flood control embankments, a topographic survey of the project area must be carried out. The terrain within the project area is so flat that it is doubtful whether aerial surveys of the area will be able to provide topographic maps of sufficient contour interval to adequately delineate the boundaries of the system.

   There are several options for conducting a topographic survey:

   a. Encourage the government to provide a ground survey team;

   b. Hire a survey team, using funds from the research grant;

   c. Train personnel from the settlement to do the survey on their own.

   Of the three choices, INTERTECT recommends the latter and would be willing to train the survey party and loan the equipment.

2. Installation of a Flood Warning System. It is recommended that a flood warning system be installed as soon as possible. The flooding which has occurred to date has probably not reached its peak; floods which could constitute a threat to life may be imminent. A variety of flood warning systems are available which can be installed and maintained at very minimal cost.

Recommendations on the exact system will be made at a later date.

3. Installation of Individual Protection Measures. INTERTECT recommends that a variety of individual protection measures be undertaken by each individual family within the project area. Appendix B provides descriptions and illustrations of the various protection measures which can be carried out by individual families.

4. Installation of the Farm Levee System. INTERTECT recommends that, where possible, individual farmers begin to develop a farm levee system to protect their individual fields. Any improvements along this line will help to reduce the damage and help the farmers protect their investment until such time as a community-wide system can be installed.

5. Creation of a Flood-fighting Team. For minor flooding, a flood-fighting team armed with no more than sandbags, plastic sheeting, machetes and shovels can provide increased protection to individual sites. INTERTECT recommends that a flood-fighting plan be developed by first identifying areas which can be saved in light flooding (from the data which is derived from the topographic survey), and then by stockpiling basic supplies in areas which can be quickly reached, so that the team can work to reduce the impact of floods when they are alerted by the flood warning system.

IV. STRATEGIES FOR FINANCING CONSTRUCTION ACTIVITIES

There are numerous options by which means the construction activities can be financed, each of which has its own advantages and disadvantages and possibilities. Among the most feasible are:

A. Obtain the Assistance of the Government of Bolivia:

If the Government of Bolivia can be presented with a plan for a

complete project -- completely researched, well thought-out, with all the options covered -- there is the possibility that they would be willing to participate (if not completely, at least to a partial extent) in carrying out the proposed activities. The feasibility of their participation should increase if they are involved in working through the remote sensing study.

B. Acquire Construction Funds Through an International Voluntary Agency:

The possibilities of obtaining funds through an international voluntary agency would likewise be enhanced with the development of a complete and balanced program. However, their ability to provide complete funding is probably doubtful, unless a consortium can be put together.

C. Acquire Funding Through the Inter-American Development Bank, With the Assistance of the Government of Bolivia:

Funding by this method seems at this time to be one of the best potential means of obtaining the funds. Again, if members of the Government of Bolivia, as well as the IADB staff, are involved in the earlier stages of the research and planning, the chances will be enhanced that they will provide the end construction funds.

D. Self-Financing Efforts:

None of the activities which have been recommended are beyond the possibility of being funded by the residents of Nueva Canaan themselves. There are literally hundreds of examples of communities which are developing extensive flood protection networks on their own. However, due to the limited number of people who could contribute labor and other commitments that the settlers will have, construction of the embankments by this method would prolong the date of completion by many years.

There are some short-cuts in the self-financing option, however, and if no other funds are available, INTERTECT makes the following suggestion. A portion of the funds which are available from the research grant have been set aside for training and for the ground truth ele-

ment. The total amount of funds available from a combination of salaries, equipment, per diem expenses, etc., for Bolivian personnel is projected to amount to approximately ten thousand dollars. If all the participants were willing, this money could be paid out according to the requirements of the grant; but the recipients, rather than keeping the money for their own use, could channel the funds into a community account which could be saved and used to rent heavy equipment such as bulldozers, trucks, etc., when it is needed. The money could also be used as matching funds for any granting sources that would participate on a sharing basis.

V. SUMMARY AND CONCLUSION

After examining the various options, it is INTERTECT's conclusion that adequate flood protection measures can be developed for the Nueva Canaan settlement, and that these measures can be installed at a reasonable, although not low, cost relative to the financial capabilities of the residents themselves as well as to the assisting agencies.

Regarding the decision as to whether or not to resettle the community, as opposed to staying and attempting to develop adequate protection measures, INTERTECT feels that the latter course is more desirable for the residents of Nueva Canaan. A substantial investment of time, effort, money and aspirations has already been put into the community; and the advantages of moving the community are far outweighed by the advantages of remaining in place and developing flood protection.

An adequate flood protection system cannot be developed until more hydrologic data has been obtained. It is the feeling of INTERTECT that this information can be obtained through the grant procedure outlined in Part II of this report.

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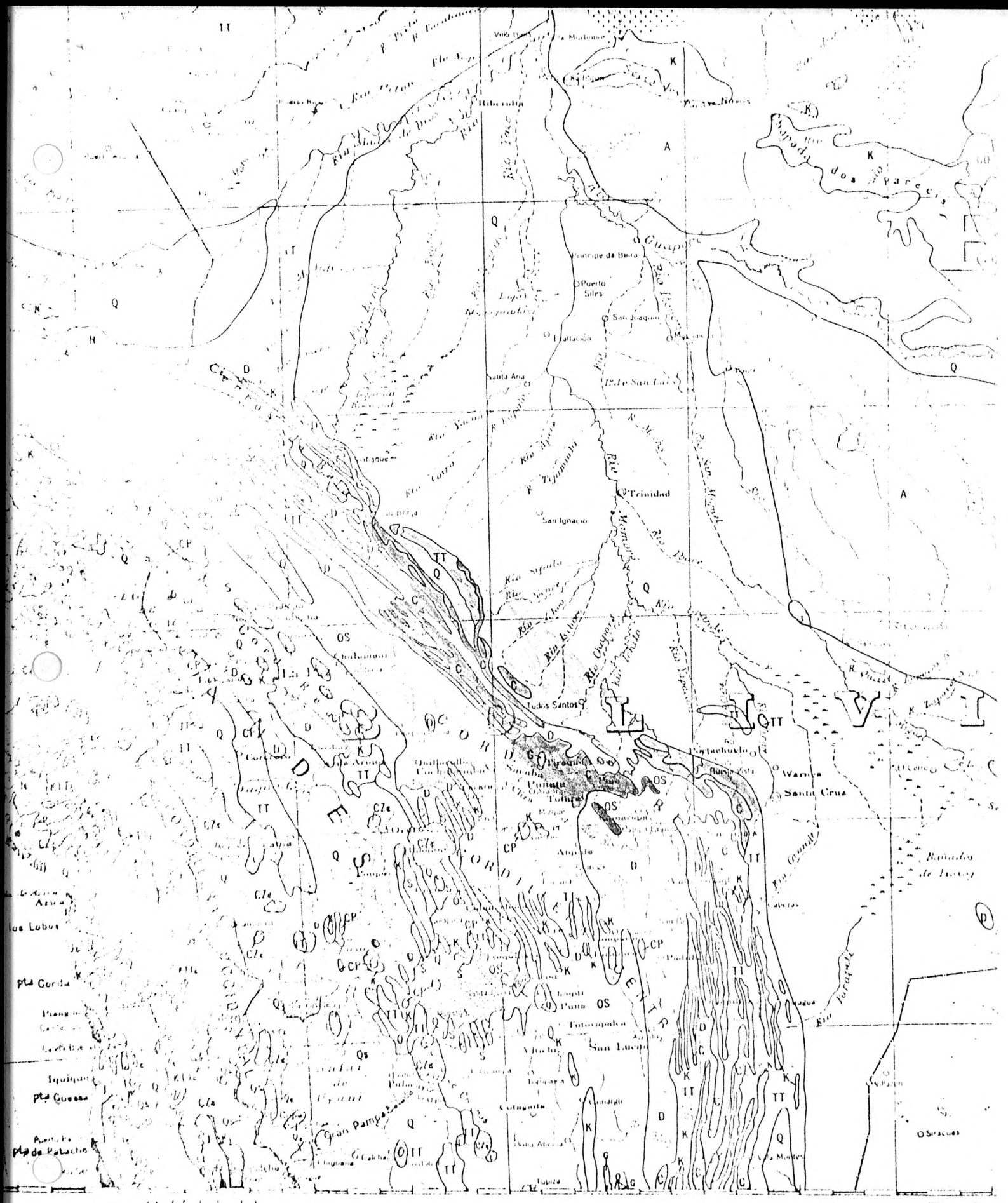
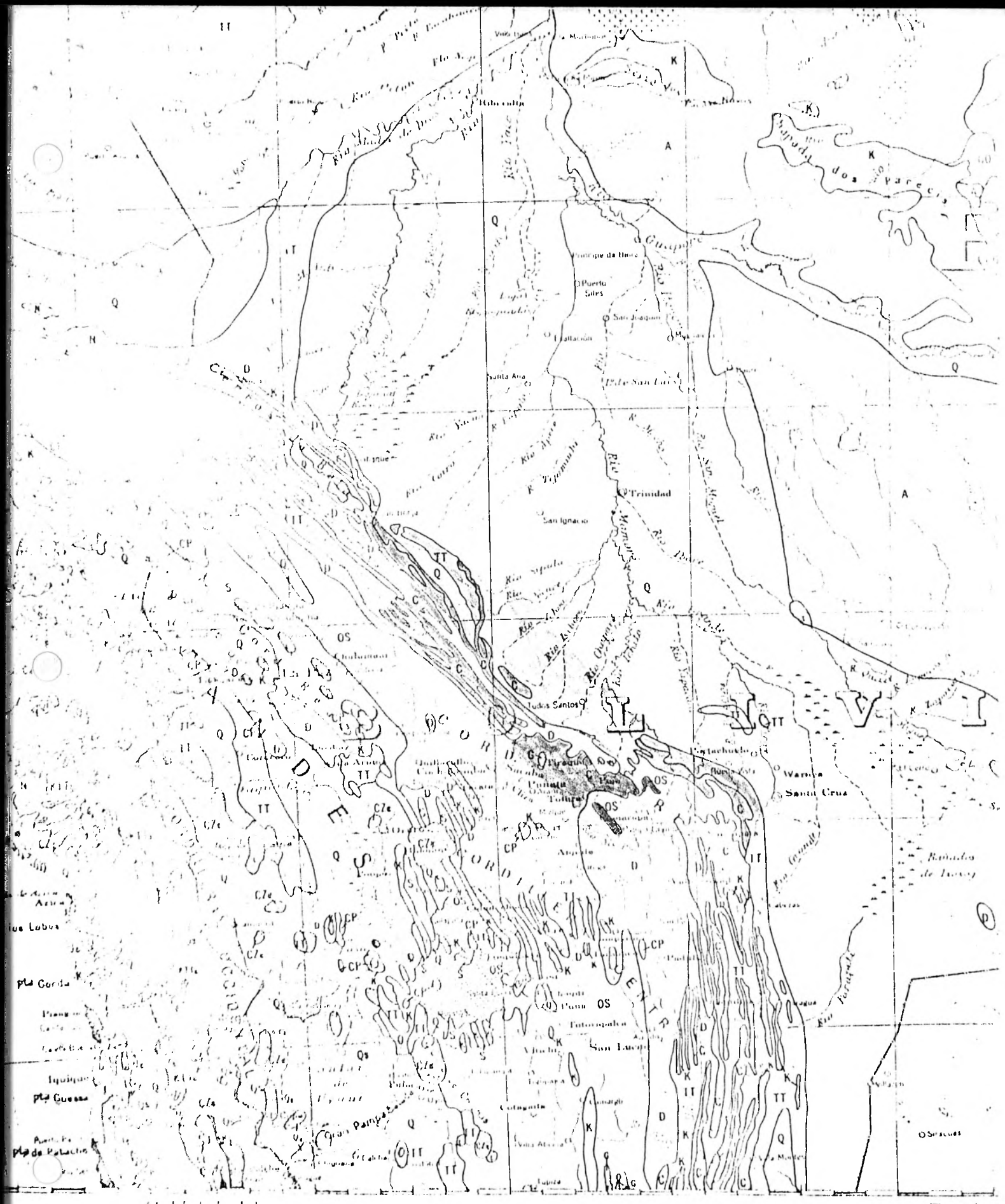
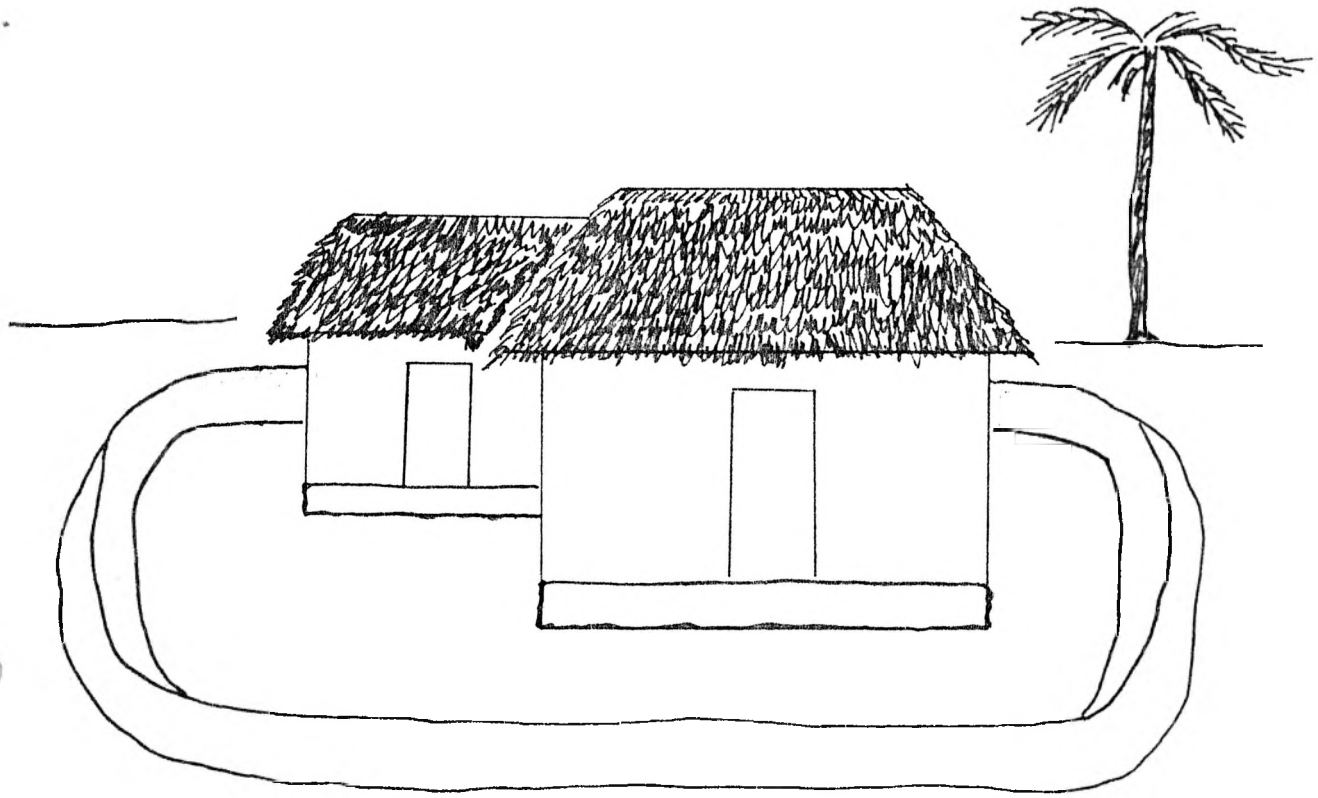


APPENDIX A: GEOLOGIC MAP



APPENDIX A: GEOLOGIC MAP

APPENDIX B: INDIVIDUAL PROTECTION MEASURES



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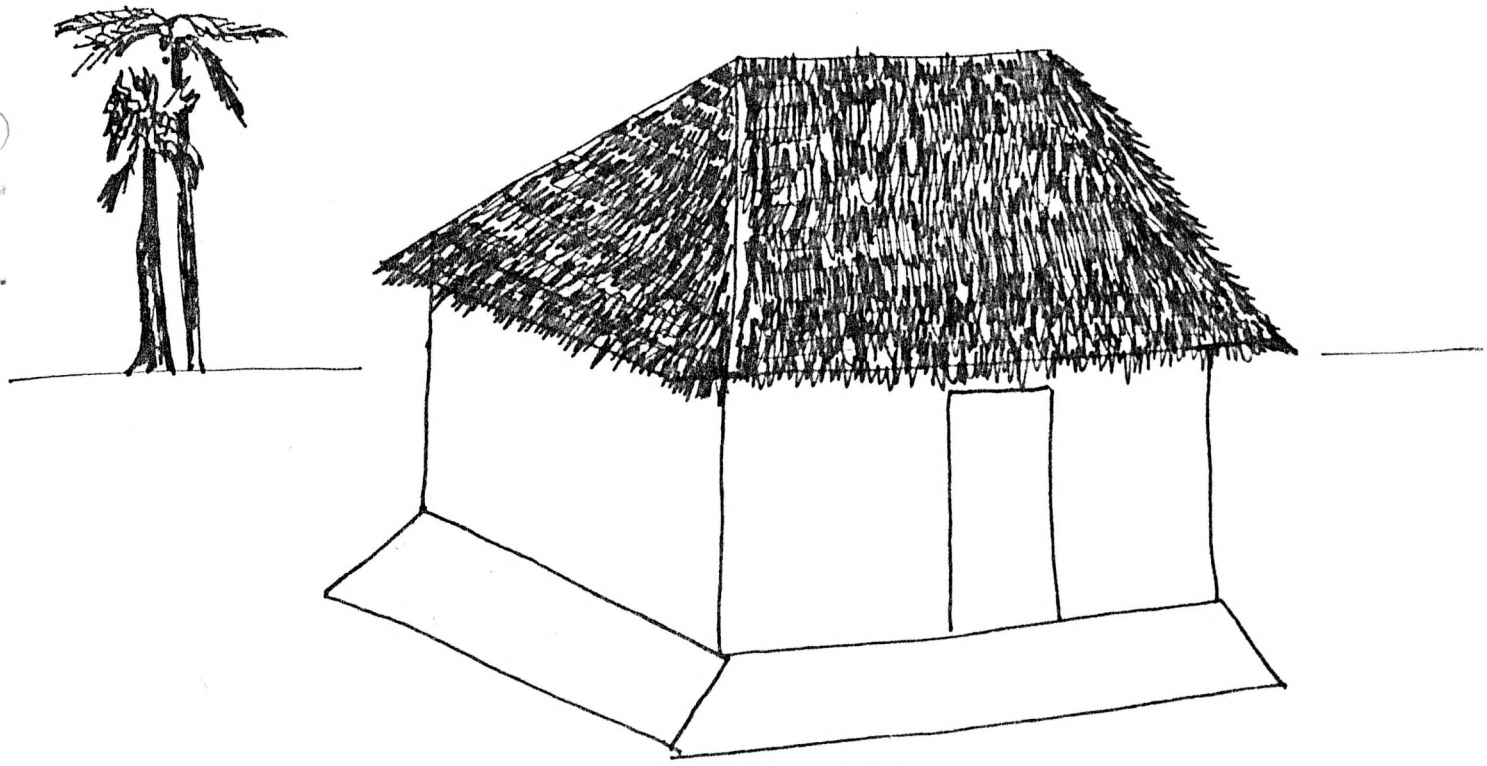

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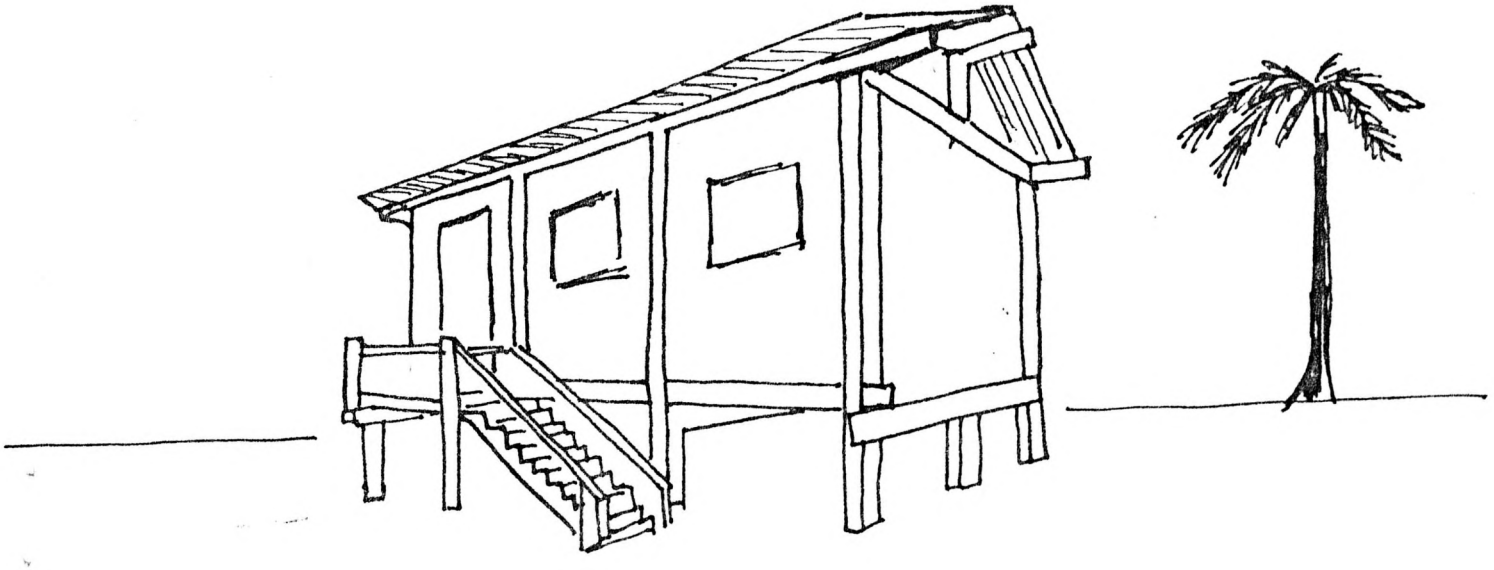

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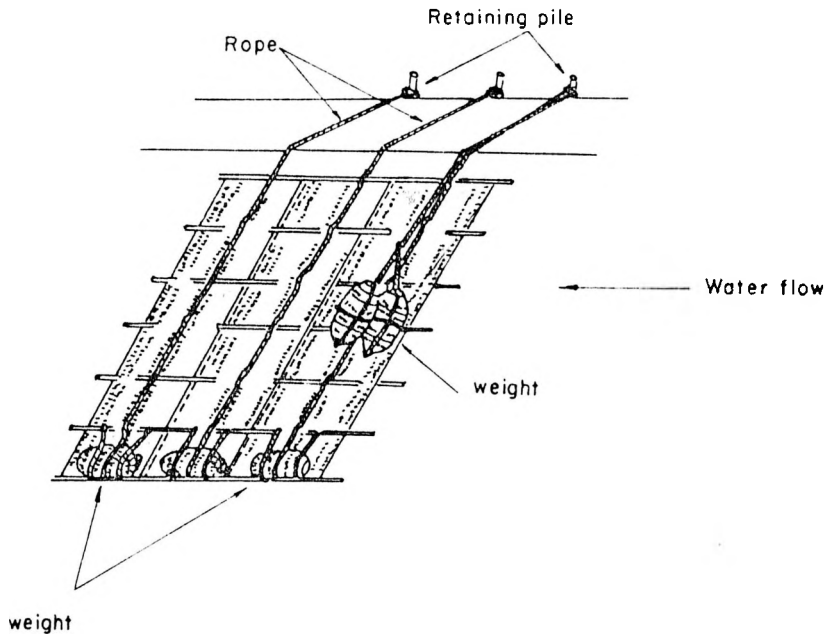

APPENDIX C: THE USE OF PLASTIC SHEETING FOR EROSION CONTROL

PART II

Preliminary Proposal:

THE USE OF REMOTE SENSING FOR FLOOD CONTROL PLANNING

September 1978

INTERTECT
P.O. Box 10502
Dallas, Texas 75207
(214) 521-8921

Preliminary Unsolicited Research Proposal
Submitted to: _____

Name of Organization: INTERTECT
(International Disaster Specialists)
P.O. Box 10502
Dallas, Texas 75207 U.S.A.

Title of Proposed Project: The Use of Remote Sensing for Flood Control Planning

Amount Requested: _____

Proposed Duration: Two Years

Requested Starting Date: 1 January 1979

Name of Principal Investigator: Dr. J. Clifford Harlan, Jr.

Social Security No. _____

Title: Associate Research Scientist

Telephone: (713) 845-5422

Organizational Affiliation: Texas A&M University Remote Sensing Center

Name of Project Manager: Frederick C. Cuny

Social Security No. 449-68-2291

Title: Senior Planner and Executive Chairman

Telephone: (214) 521-8921

Organizational Affiliation: INTERTECT

Endorsements: Principal Investigator	Other Endorsements (Formal Proposals)	Approving Administrative Official
Name J. Clifford Harlan, Jr.		
Signature		
Title Asso. Research Scientist		
Date		

This Organization is a small business concern.

Preliminary Proposal:

THE USE OF REMOTE SENSING FOR FLOOD CONTROL PLANNING

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Preliminary Proposal:

THE USE OF REMOTE SENSING FOR FLOOD CONTROL PLANNING

I. Background

The purpose of this project is to explore the use of remote sensing as a tool for planners in assisting remote, rural areas of the developing countries to examine existing and potential flood problems and to determine options for disaster mitigation.

The use of LANDSAT imagery for planning flood control and flood prevention measures in developed countries has been demonstrated in numerous instances. LANDSAT imagery has been used to locate sites for dams, levees, dikes and other devices for flood control; and it has been utilized in studies of large regional watersheds. However, to date it has not been demonstrated whether LANDSAT imagery can also be used to assist small, rural communities in isolated areas in the development of simple and affordable flood control schemes.

The area selected for this study is the Chapare region of Bolivia, which lies approximately 90 kilometers northeast of Cochabamba. The region is a jungle area which rests on a flat plateau at the base of a high ridge on the eastern slope of the Andean Mountains. The Government of Bolivia has offered free land to settlers who will move from the populous mountain plateaus into the Chapare region, and new settlements have been formed throughout this area during the past 15 years. A settlement called Nueva Canaan serves as a distribution center for a number of small farms in the surrounding area. Approximately 2,500 people have moved into this area during the last 15 years, and they are attempting to establish small farms.

The primary crop in this area is bananas, although recently tea has been introduced. Other crops which have been tried have failed due to the flooding which occurs every year during the rainy season.

The population is largely made up of Quechua-speaking Indians who moved here in search of land. Previously, most had been landless peasants working on marginal land in the Altiplano. The average income in the area is approximately $150 per year.

In other resettlement schemes in the surrounding area, a variety of crops have been introduced which have proven successful, and incomes in these regions are slightly higher.

The primary problems in the area are largely due to the flooding; each farmer faces the fact that substantial portions of his crop will be wiped out when the river overflows its banks and inundates much of the farm land. This has led several families to return to the highlands, and others are now considering relocation.

With the exception of the flood problems, Nueva Canaan is ideally situated as it lies adjacent to a hard-surface road which connects the settlement to markets both in Cochabamba and the river port. Furthermore, a number of small gravel roads have been built by the residents, enabling carts and small trucks to reach the farms.

The regional flooding poses two main problems. First, the flooding waters threaten not only the crops but also the population, as heavy rains upstream often cause flash flooding. Parts of the area have been known to flood to a depth of two meters, and the water has destroyed not only crops and trees but also numerous houses.

The second problem caused by the flooding is the rapid erosion in areas lying adjacent to the river course. Within the past ten years, the stream bed has widened over 400 meters. Families who live near the river banks worry that their farms may be destroyed by this erosion.

In April of 1978, a representative of INTERTECT visited the area at the request of a voluntary organization which is working with the residents of Nueva Canaan. In the course of the discussions and on-site investigation of the problem, it was clear that development of a flood

control plan was hampered by several factors:

A. Lack of geologic and hydrologic data about the region;

B. Lack of topographic information about the region;

C. Lack of information about land use patterns upstream;

D. Lack of historical information about the flooding in the area;

E. Lack of information relating to the environmental and ecological consequences, should flood control measures be put into effect;

F. Lack of basic information needed to establish flash flood warning systems and flood control measures.

During this visit, it was determined that the only historic photographic evidence of flooding and stream bed changes would be available from remote sensing imagery taken over the last seven years. It was determined that LANDSAT imagery, as well as new radar sensing techniques and conventional aerial photography, might provide information upon which to base recommendations for flood control measures, at a cost affordable to both voluntary agencies and the Government of Bolivia. Therefore, it was decided to attempt to explore the capabilities of remote sensing as a planning tool. A number of the private voluntary organizations working in Bolivia, as well as the Government of Bolivia, will cooperate in providing information for the study.

II. Project Objectives

The primary goal of this project will be to explore the use of LANDSAT imagery as a tool for analyzing flood problems and for the development of effective low-cost flood protection measures for the Nueva Canaan settlement of the Chapare region of Bolivia. The objectives are:

A. To demonstrate the use of LANDSAT imagery as a tool in disaster prevention and mitigation;

B. To demonstrate to private voluntary organizations the use of remote sensing for practical applications in development activities;

C. To demonstrate the use of radar imaging as an addition to LANDSAT;

D. To develop a methodology for the concurrent use of LANDSAT imagery with other data sources in planning simple and practical flood control measures;

E. To provide Bolivian personnel with an orientation to remote sensing and to transfer a variety of remote sensing skills to the participating organizations.

III. Project Plan

In order to prepare final flood control recommendations, five activities must be completed:

A. Analysis of historical flood data.

When exact dates of past floods are known, a search of the LANDSAT records will be made to determine what images are available on those dates, and also whether images are available for the immediate days after the floods. (Flooding is often caused not by rains in the immediate area, but by rains in the mountains.) The available images will be analyzed to determine:

1. The general boundaries of the flood plain (outside timbered areas);
2. The extent of the erosion of any one flood (by using images before and after);
3. Changes in the stream bed;
4. Factors which increase or reduce flooding in the stream course, through land use changes;
5. Predictions of possible flooding boundaries based on stream changes.

B. Acquisition of cloud-free images in order to study land use patterns.

Cloud-free images will be obtained of the entire Chapare watershed in order to determine land use patterns, deforestation patterns and other upstream developments which might affect future flooding conditions.

C. Acquisition of radar images.

LANDSAT satellites utilize only direct, visual and infrared wave lengths. Therefore, during periods of high cloud cover, flooding is usually obscured, and studies of the exact flood situation are not feasible. Microwave radar systems provide the capability of imaging through the cloud cover and thus give a more complete picture of the flooding.

A program for radar imaging for the flood-affected region will be developed, and an attempt will be made to acquire images of a flood in progress. As required, the radar imagery will be compared with multi-spectral scanner (MSS) imagery, and composites will be made which are hoped will provide a new tool for use in the study of flood problems.

D. Acquisition of Aerial Photography (from existing sources).

In the past decade, a number of organizations (both governmental and private) have taken extensive aerial photos in Bolivia, and some of these may include all or part of the project area. While these photographs were taken for purposes (such as natural resource exploitation, cartography, etc.) other than to obtain data in relation to flooding if the area has been photographed, the information provided could prove valuable to the study. Among the organizations that have conducted aerial surveys are:

1. Various oil companies;
2. Various timber companies;
3. The Inter-American Geological Survey (IAGS).

E. Ground Truth Plan.

Continuous on-site verification of the remote sensing data will be carried out by INTERTECT with assistance from the staff of COMBASE (an interdenominational Protestant social service organization that provides various services to the Nueva Canaan community) and World Neighbors (an American international service agency also active in the area).

A ground truth plan will be jointly developed to provide field data which will serve as both baseline data and verification of remote sensing-derived data. The development of the ground truth data will be carried out in conjunction with a small-scale training program to demonstrate to Bolivian personnel the capabilities and methodologies of using remote sensing.

IV. Organization and Management

A. Management:

Overall responsibility for coordination of the project will be assigned to INTERTECT. The project manager will be Frederick C. Cuny of INTERTECT. The principal investigators for the project will be Dr. J. Clifford Harlan, Jr. (Associate Research Scientist, Texas A&M University Remote Sensing Center); Dr. John P. Claassen (Associate Research Engineer, Texas A&M University Remote Sensing Center); and Dr. Bruce J. Blanchard (Hydrologic Engineer and Director, Texas A&M University Remote Sensing Center).

B. Participating Organizations:

The following organizations will participate in the project:

1. The Texas A&M University Remote Sensing Center
2. INTERTECT
3. COMBASE (an interdenominational Protestant social service organization in Bolivia)

4. World Neighbors

5. The Government of Bolivia

A curriculum vitae for the project manager and for each of the principal investigators is attached as Appendix A.

V. Schedule of Activities

The proposed work schedule for the project is attached as Appendix B.

VI. Budget

The budget for the project is attached as Appendix C.

FCC:jwp

APPENDIX A

(All appendices omitted)