SDS/DIU/DT 165

PROJECT EVALUATION SUMMARY

(Submit to MO/PAV after each project evaluation)

1. Mission or AID/W Office Name	2. Project Number
USAID/Nicaragua 524Ø1Ø4ØØ15Ø1	524-0104 26p

3. Project Title

Center for Earthquake Hazard Reduction

4. Key project dates (fiscal years) a. Project Agreement	b. Final Obligation	c. Final input	5. Total U.S. funding - life of project
Signed 3 Nov 73	14 Dec 76	delivered	$ 257,000

6. Evaluation number as listed in Eval. Schedule	7. Period covered by this evaluation		8. Date of this Evaluation Review
	FROM: Nov 73	TO: March 31, 1978	
	Month/year	Month/year	month/day/year

9. Action Decisions Reached at Evaluation Review, including items needing further study (Note--This list does not constitute an action request to AID/W. Use telegrams, airgram, SPARS, etc., for action)	10. Officer or Unit responsible for follow-up	11. Date action to be completed
1. Terminate project on schedule (March 31, 1978).	Paul Groves, DPA	April 15, 1978
2. Contract the Ministry of Public Works regarding the possibility of using the reimbursable technical assistance mechanism for any additional U.S. services required for this project.		

12. Signatures:

Project Officer	Mission or AID/W Office Director
Signature: Gussie L. Daniels for P Groves	Signature: Harry G M
Typed name: Paul Groves, DPA; Gus Daniels, DPA	Typed name: Harry G. Wilkinson, A/Director
Date	Date

Memorandum

UNITE STATES AID MISSION TO NICARAGUA
AGENCY FOR INTERNATIONAL DEVELOPMENT
AMERICAN EMBASSY
MANAGUA, NICARAGUA

TO : See Distribution Below

DATE February 9, 1978

FROM : Gussie L. Daniels III, Evaluation Officer

SUBJECT: Evaluation of the Center for Earthquake Hazard Reduction Grant (524-0104)

Attached for your review and comment is a draft evaluation report prepared by Rebecca Acoli, USAID/ROCAP, and David H. Harlow, USGS, the original copy of which was received by the Mission in September 1977. This was a regularly scheduled evaluation. The evaluation report, prepared after several unstructured interviews with GON personnel and extensive reviews of GON and USAID documents, is completely in line with the Project Paper in terms of study design, scope and issues discussed, although it is being submitted for review eight months after the originally scheduled date.

Background:

The Earthquake Hazard Reduction grant project, approved in 1974 for implementation over a four year period, aimed at reducing the effects of earthquakes and volcanic eruptions by establishing, equipping, staffing and training a central core of personnel to operate an institute for applied seismic and geological research. Among the principal rationales for the project was the need to detect and evaluate on a continuing basis seismic risks for the entire country in order to reduce dangers to the population and dislocations in the national economy through improved site selection and building design. To accomplish this objective the then existing network of three seismic stations was to be increased to fifteen monitoring stations and a sufficient number of qualified personnel was to be assigned to an earthquake center to analyze and interpret data.

The total U.S. contribution to this activity, amounting to $257,000 over the four year implementation period, was used to finance: 1) a PASA with the U.S. Geological Survey to provide technical advisory services in the areas of geophysics, instrument maintenance and geology; 2) specialized training in the U.S. and third countries for professional and technical employees of the institute; and 3) technical equipment for monitoring seismic activities. During the same period the GON contributed with more than $400,000 to cover the cost of personnel salaries, facilities and other local costs.

Progress to Date:

Project inputs were largely furnished as originally planned, outputs were produced on schedule and the project purpose has been achieved.

TO :

DATE

FROM :

SUBJECT:

The Seismic Investigation Institute (IIS) has been firmly established as an autonomous unit in the Ministry of Public Works. Equipment for the operation of the center has been received and installed, and the staff at the center augmented through the employment of five professional, five technicians and support personnel. This number is expected to increase significantly as five professionals and one technician return from studies abroad to assume positions at the center. A seismic network consisting of sixteen stations located in various areas of Western Nicaragua and connected by a radio link to the central station outside Managua has been established and is functioning. To date, the seismographic network operated by the Center has detected an estimated 2,500 micro-and several significant earthquakes. The staff working at the Managua station are analyzing this data and have produced several studies on areas of high seismic activity. In addition, it is believed that the center could pinpoint the exact hypocenter of an earthquake within one and a half hours.

Inspite of the substantial achievements at the inputs, outputs and purpose levels, two problems have been encountered in attaining the project goal. These are as follows:

1. Inability to attract qualified full-time personnel to work at the new and unproven Institute.

2. Gradual acceptance and underutilization of data and reports produced by the Institute.

The first problem was related to reluctance on the part of qualified persons to work on a new untested activity and the limited opportunity to obtain a second job because of the Institute's 8 hour work-day requirement. The evaluation report indicates that the problems are being resolved with the addition of new personnel. The second problem related to the difficulty of establishing the Institute within the Ministry of Public Works and the lack of sufficient personnel to analyze data, oversee its publication and distribution. This problem is also likely to be alleviated with the assignment of additional personnel in the near future. In summary, the return of technical and professional personnel from training abroad and continued support will make it possible to focus

more attention on analytical requirements, the crucial element for achieving the project goal.

Lessons Learned:

The evaluation report summarizes several lessons for planning and implementing similar activities. These are as follows:

1. The project design should make the assumption that qualified personnel will have to be developed with the project rather than be available at the beginning of the project.

2. When extensive in-country training is required, the T.A. advisor should be available on a full-time basis.

3. Future proposals of a similar type should include provision for educating the specific recipients and the general public on the use and value of data.

4. A substantial amount of support is necessary to foster the development of a new institution.

Evaluation Issues:

The Earthquake Hazard Reduction project received its last input of grant funds in FY 1977, although spare and repair parts and intermittant TA are still being provided. The evaluation report recommends continuation of USAID/Nicaragua support at the level of $25,000 per year over the next three years in order to continue technical and commodity support for the Institute and to help in the achievement of the project goal. This level of support is judged necessary for several reasons:

1. Specialists returning to the Institute would receive the specialized on-the-job training originally contemplated at an early stage of the project, but delayed due to lack of personnel.

2. Continued support is necessary to ensure that spare parts and supplies will be available as needed, particularly during an emergency.

3. IIS may need outside support to protect its interests. In addition,

the evaluation points out several technical reasons for continuation of the project including the USGS's prohibition on a direct contract with the IIS.

Basically the Mission has three options with regard to this project. These are as follows:

1. Extend the project for an additional three years. This approach would require approval by the AA/LA and completion of a Congressional Notification/Advice of Program Change. The attached evaluation could provide the justification for the extension and necessary documentation could be prepared on short notice. The issue with regard to extension is whether USAID/N would want to continue grant assistance for an activity which is well within the financial capacity of the GON, but nearly beyond its ability to respond.

2. Use the reimbursable technical assistance (RTA) mechanism to finance the services of U.S.G.S. to the Institute. The Mission has been advised to tentatively identify opportunities for using reimbursable T.A. (RTA) in Nicaragua. Although activity would appear to fit the criteria for RTA, neither the general concept or specific procedures have been discussed out with the GON. Hence, this approach would require initiation of discussions with appropriate agencies of the GON and several months may pass before it is clear whether this alternative is viable.

3. Allow the project to terminate upon delivery of remaining commodities and services (3/31/78). This risk in this approach is that personnel assigned to the center may not receive the training required for optimum analysis of data and thus be forced to continue to carry out this activity on a trial and error basis. Under these circumstances GON support is likely to remain at a constant level and the project goal may never be achieved.

Recommendation: This activity differs from ordinary projects in the sense that it is aimed at helping the GON minimize loss of life and damage to property and facilities on a long term basis. The GON has continued and increased its support of the project and while USAID/N has no obligation to continue its own support for this activity beyond the projected termination date, our assistance may be a crucial element in adding additional analytical and predictive capabilities to the existing data

Memorandum

UNITED STATES AID MISSION TO NICARAGUA

AGENCY FOR INTERNATIONAL DEVELOPMENT

AMERICAN EMBASSY

MANAGUA, NICARAGUA

TO :

DATE

FROM :

SUBJECT:

collection and analysis capabilities of the Institute. Therefore, it is recommended that this project be extended for a three-year period and that DPA and FIS staff prepare necessary documentation for approval by the AA/LA. A meeting has been scheduled in the Director's Office on Wednesday February 22, 1978 at 11:00 a.m. to review the attached report.

Cleared by: DPA:MMrovec
FIS:WOdle
CONT:RSleep

cc: DPA:DJickling
FIS:BBlackman
CONT:JIto
DD:HWilkinson
DIR:AWHudge

Summary:

Earthquakes and volcanic eruptions which cause loss of life and extensive property damage have frequently and most probably will continue to occur in Nicaragua. Therefore this project was designed with the goal of mitigating the effects of these natural disasters. The purpose was the establishment of a seismic network throughout the tectonically active areas of Nicaragua in order to obtain good seismic data which could be used to develop seismic risk maps and construction codes.

During the past four years the Seismic Investigation Institute (IIS) has been established as an autonomous entity in the Ministry of Public Works of the GON, and the GON is supporting the IIS at levels considerably above those called for in the Project Agreement. The equipment has been purchased and installed as originally planned and is now functioning. The personnel of the IIS have received extensive training from the USGS, and working relations between these two groups are excellent.

The IIS is obtaining good quality seismic data and is publishing them. The data collected during the first two and a half years of operation of the seismic net clearly show zones of high seismic activity that are potential sources of destructive earthquakes. The results of preliminary analyses are focussing research on the relationship between the deep and shallow earthquake zones and may lead to a better understanding of the fundamental causes of earthquakes in Nicaragua. As the science and techniques improve the seismograph network may provide data from which future volcanic eruption can be predicted. The project purpose has been effectively achieved.

Although the purpose has been fulfilled, the project has not fully attained its goal due to two major problems encountered throughout the life of the project. The first was the inability to attract persons with the desired level of education and experience to work for the Institute. This problem is beginning to be resolved. The personnel trained by the USGS are now able to handle the daily operation of the IIS, so that the data obtained from the continuously operating instruments are preliminarily processed on a regular schedule. Furthermore, participants are beginning to return to the IIS and do the analysis which is necessary to utilize these data. In the next three or four years the IIS should be capable of providing the necessary data in the proper forms for the full achievement of the project goal.

The second major problem which is being overcome is the gradual acceptance and utilization of the data by the intended recipients. This problem was not fully anticipated in the project design; however the IIS is beginning to grapple with it. Actions have been taken and are being planned to heighten the awareness of both the public and the government of the utility and importance of the data. This is crucial to the realization of the project goal.

Because the project is so close to accomplishment of its goal and

its progress has been steady in spite of these two major problems, the evaluation team recommends that AID continue its support of the project for another three years. The proposed level of funding is small, $25,000 annually, but it is critical to the achievement of the project goal. The rationale for continuing the project is discussed in detail on the following section.

Justification for Continuing the Project

The original impetuses for initiating the project were the extensive loss of life and property which resulted from the December, 1972 earthquake in Managua. This earthquake emphasized the need for the determination of seismic risk factors for all of Nicaragua so that future hazards to the populace and future disruptions of the economy could be reduced through better site selection and building design. In response to this need a seismic network, comprised of seismographs to detect minor tremors and accelerographs and seismocopes to record strong ground motions, was established in Nicaragua. During the past two and a half years good seismograph data which locate many microtremors have been obtained. No large earthquakes have occurred so no strong ground motion data have been recorded.

During this final evaluation some doubts were raised about the desirability of continuing the project. These doubts were raised primarily in relation to economic justification of the project, particularly in view of Nicaragua's status as a relatively poor nation. This attitude was supported on the assumption that the data collected during the life of the project are adequate for the proposed planning purposes. (It also reflects the fact that Nicaragua is a relatively poor nation and questions whether the maintenance of a seismic network is economically justifiable).

The evaluation team disagrees strongly with the premise that a seismic network is a luxury which only rich nations can afford. The following paragraphs discuss the reasons for continuing the project and the potential value of the project to the GON:

1. It is not possible to locate all of the dangerous faults at one time. The rate of locating new potentially dangerous faults decreases with the increasing length of the seismograph network operating time, and all the dangerous faults may never be located. The occurrence of seismic activity along a given fault is not constant. A fault may be completely inactive for a considerable period of time and then resume its activity; therefore continued monitoring is necessary in order to locate previously undetected and potentially dangerous faults. An interesting example of this is the fact that seismic activity in the Managua area is very low now, although it is well established that many active faults occur in this area.

2. Continuous monitoring of seismic events provides a good history from which recurrence times of specific events can be extrapolated. For example, fault X may be known to slip every 50 years causing an earthquake of approximately magnitude 6. The earthquake records in China which

extend back 4000 years have provided excellent data for calculating recurrence times. Based on these data several successful predictions of large earthquakes have been made.

3. Since prediction of earthquakes based on recurrence times requires an extensive data bank which must be gathered over a long period of time, other methods of earthquake prediction are being sought. Seismologists are trying to gain a deeper understanding of tectonic activity and learn the causes of earthquakes. Data obtained from the Nicaraguan seismic network are very valuable for this work since the geology of Nicaragua is extremely complex. For example the seismic data indicate that the portion of the ocean floor which is subducting under Nicaragua is segmented and that these deep seated breaks correspond with offsets in the Central American volcanic chain and with many prominent faults. The relationship between these surface and deep features cannot yet be explained, but it is believed to be important in understanding the regional tectonic activity.

4. The accumulation of a good data bank techniques from the national seismograph network will allow Nicaragua to immediately utilize any breakthrough in earthquake prediction developed elsewhere in the world. These theories are based on extensive analysis of past records and data and thus can be extrapolated to a new region if the local parameters for the region are determinable.

5. It is particularly important to continue the data collection program in order to build on the data obtained to date. The data must be considered in an overall framework which should be revised constantly to reflect increasing knowledge. For example analysis of seismic data collected before other large earthquakes has shown that a quiet interval frequently precedes the major event. Therefore some earthquake predictions currently are being attempted based on observations of lack of seismic activity in areas known to be very active normally.

6. Continuation of the monitoring of the strong motion instrumentation network is extremely important because good strong motion data are very scarce. Since these instruments only function in response to moderately strong earthquakes, years may pass before their operation is recorded. Therefore it is important that they be maintained to assure that the instruments will function, should a big earthquake occur. The majority of the instruments in both the Managua and the Guatemala earthquakes did not function and the valuable data which might have been obtained was not recorded. Therefore, for best results, a strong motion network requires a long term regular maintenance program administered by an organization dedicated to earthquake research such as the INS.

7. The existance of an active seismology institute maintains and creates interest in seismic activity by continually reminding both professionals and the general public of the ever present seismic and volcanic activities and possible hazards. The institute can also

facilitate the establishment of appropriate building codes and zoning laws.

8. Since seismic activity generally increases tremendously before eruptions, early warnings of possible eruptions can be given. As a recent example, the eruption of Concepción Volcano was preceded by warning activity five months in advance.

9. In addition to monitoring volcanic activity, the seismology institute can also perform risk studies to ascertain the potential hazards presented by each volcano to surrounding areas. The IIS has begun this work. A U.S. graduate student was employed by the IIS while he studied the hazards of the San Cristobal Volcano.

The US would also benefit from the continued operation of the seismograph network in Nicaragua since seismic activity is considerably greater in Central America than in the US.

In summary, when a senior level scientist of the USGS was asked why Nicaragua should continue operating the seismic network, he responded, "When you live in a snake pit, you study snakes."

External Factors

No external factors other than those considered as assumptions in the project paper have affected the project significantly. The validity of each of the assumptions is discussed in detail below (note that the original assumption is underlined):

A. None of Nicaragua's major cities will be abandoned for safer sites. Therefore the establishment of guidelines for safer site selection and improved construction practices is essential.

This was a valid assumption. Although the reconstruction to date has resulted in a widespread dispersal of the city around the destroyed central core; the center has not been rebuilt because the GON is issuing building permits in accordance with the rather strict new anti-seismic building code regulations, patterned after the Zone II California Code, and utilizing geologic data and a zoning plan which was developed by Woodward Clyde Inc. (WC) in its study of Managua completed in 1976. Under this overall plan, the GON is preparing a low density street plan for the old downtown area which will include public and private buildings and an allocation of land for parks and recreational use. Based upon these activities and as soon as private property rights can be verified within the plan it is assumed that construction in the old area will gradually increase.

B. A seismic zoning system, based upon the data developed in the WC study, has been established and is being used by the Vice Ministry of Urban Planning (VIMPU) to determine land uses and types of construction based upon potential seismic risk. All building permits are reviewed in the context of this system and the implementing regulations.

Although the IIS is collecting and is beginning to analyze and publish seismic and geological data of professional and usuable quality, this information has not been widely used in the decision making processes of either the GON or the private sector. It is believed that there was an initial lack of appreciation for the significance of this data due possibly to the short time that such information has been available and because initial plans and codes have been established recently utilizing the WC data. This attitude is changing as the integrity of the IIS is established and an appreciation of its uses evolves. See examples of recent uses under Goal.

In terms of warnings which might be given to the populace relative to high seismic or suspected pre-earthquake activity officials are reluctant to release such information because of the disruptive impact that the knowledge of potential danger might have. This phenomenon is not limited to Nicaragua and is a natural human reaction since the responsible official is equally fearful of being either right or wrong.

The reluctance of government officials to take action after being informed of a potential hazard has been observed recently in Nicaragua. On several occasions the IIS has sent warning letters to the Minister of Public Works regarding increased earthquake activity in specific zones. Two such instances involved earthquake swarms around the Concepción and the Momotombo volcanoes and are discussed in detail under Purpose. Another example is the earthquake swarms, including one felt event near Masaya. The IIS is currently studying these latter swarms in detail. In each of these situations, no official action was taken to warn the concerned populations of the possible hazard or to prepare disaster relief efforts in case these should become necessary.

Both problems, the lack of understanding of the seismic data on the part of the recipient and the reluctance to use it for fear of upsetting the populace as stated earlier, are not unique to Nicaragua. Indeed they are common in the U.S., and only recently has the scientific community begun to try to resolve them. Efforts are being made to make the planners aware of the data which exist and their usefulness, while at the same time scientists are focussing on the practical aspects of their studies. Also recent sociological studies suggest that the general public prefers to be informed of natural hazards and that effective public education can allay the negative effects caused by fear created in an atmosphere of ignorance.

C. Adequate capability will exist for developing and implementing the zoning plans and building codes which are necessary to make the available seismic information effective.

The capability of the GON to develop and implement zoning plans and building codes is closely related to B above. Experience shows that the data given to planning agencies must be very complete and ready to use, i.e. the planning must have been done already. For example, the maps of earthquake locations were initially published by the IIS on

outline base maps to avoid alarming the general population. However future earthquake location maps will be published on existing topographic maps so that the relationship between areas of high seismicity and cities, towns, and other cultural features can be clearly seen. Thus, while the recipients are becoming more accustomed to the use of seismic data, the information published by the IIS will be in a more readily usable form.

D. Qualified persons are interested and can be made available to work on a continuing basis in the IIS.

This realization of this assumption took some time. Qualified persons were interested in the project, but they were not attracted to the jobs because, among other reasons, it was considered a gamble to work on a new and unestablished project. Also the opportunities of the positions were limited to the salary offered. That is, the employees of IIS were expected to work an 8 hour day and therefore not be able to work two jobs as is frequently the practice. This was true in spite of arrangements made to pay above average salaries to professionals working full time on the project. As a result, out of the three qualified people identified in the project paper, only the present director of IIS had the vision and courage to join and stay with the project.

The IIS also experienced difficulty in hiring a qualified geologist. The working relationship with the first geologist deteriorated rapidly after his training in the U.S. He did not want to work full time, departed in March 1975 and the position remained open until September, 1976. A similar problem occurred with an electronic technician who had received two months training in the U.S.

E. The organizational design and administrative functions of the IIS will supply adequate support to the investigations being conducted.

The organization of the IIS as originally established with the IIS existing within the Instituto Geográfico Nacional (IGN) was not satisfactory. The problem is described in more detail under Inputs and Outputs. However the IIS eventually became an autonomous entity within the Ministry of Public Works. This change necessitated a substantial expansion of the staff in order to replace the lost IGN support services. Although the staff is much larger due to the reorganization, a much more efficient and manageable working environment has been attained.

Also the original project plan did not include provisions for efficient personnel to generate the anticipated outputs. Thus several of these outputs have been and are still being delayed until more professionals are added to staff. The seismic risk maps are one example of this.

The VIMFU is imitating geological studies in the satellite cities of Managua (Masaya, Granada, Tipitapa, Diriamba Jinotepe) with financing from the Managua Reconstruction Loan (029). This will provide the basis for urban planning studies in these cities.

Goal:

The project goal was: "to minimize death, damage and disruption of public services caused by earthquake and volcanic events in Nicaragua by incorporating the best possible seismic information in locational and design decisions".

The goal achievement indicators were defined to be the use of the IIS data both by the GON to establish zoning plans and design codes and by the private sector even when not legally required.

To date the data have not been widely used either by the public or the private sector. This is primarily due to the fact that the IIS has not had the staff necessary to publish the data in a readily usable form, and to provide training in its uses. However this situation is changing, the current staff now operates the network and performs a preliminary analysis of the data on a daily basis. From this information seismicity maps showing the epicenters of small earthquake can be drawn. In the near future several new seismologists who are currently studying outside Nicaragua 1/ will be added to the staff. These persons will be able to devote the necessary time to developing seismic risk maps and to conducting special studies of unusually active areas, i.e. to putting the data into a readily usable form.

A second reason for the under-utilization of the IIS data to date is that the recipients are not aware of its significance. Although the IIS was not specifically organized to perform duties beyond the point of information dissemination, public education programs are already underway. During the past two years extensive newspaper coverage has been given to the IIS and even some television time when an earthquake prediction by a well known local engineer unnerved the public. In addition to technical publications, Ing. Arturo Aburto, Director, and Dr. Argeñal, Geophysicist, have spoken to the society of Engineers and are planning a series of explanatory articles for the engineering society bulletin.

Since January 1977, progress toward the goal has increased; both the data generated by the IIS and the professional knowledge of the staff have been utilized for the direct benefit of the populace. Several hazardous areas have been discussed in published reports, or are under study and reports will be issued in the near future.

1/ The OAS is currently financing scholarships for three seismology students studying in Mexico and one geology student in Costa Rica. The Japanese government gave scholarships to an earthquake engineering student who has subsequently returned to the IIS and to a seismology student who still is in Japan. These students are obligated to work for the IIS upon their return to Nicaragua.

Additionally, IIS, in late 1977 and early 1978, has been contracted to provide studies such as the three summarized below:

COPALAR Dam

The Agri-Science Company, the executing firm of COPALAR Dam project in Matagalpa including construction of the dam and installation of the turbines, has requested the Institute to study and advise on the possible risk of a fault which passes through the proposed dam site and on measures which could be taken to assure the security of the dam against such risk. The work will be carried out in two phases: an evaluation of the degree of risk to the proposed dam due to seismic activity of the fault as well as in the surrounding area and the installation of a network of seismographs to facilitate constant monitoring of seismic activity.

Industrial Park

The Instituto de Fomento Nacional (INFONAC) has requested the Institute to prepare a seismic and geological report on an area between Mateare and Los Brasiles at Kms. 17-18 on the new highway to Leon, which is being considered for the construction of an Industrial Park. The request specified that the report compare the seismic probabilities of this area with those at Las Mercedes. As a minimum the report should contain: an evaluation of possible maximum and probable minimum intensities of earthquakes, a calculation of probable acceleration, and an estimation of the return periods for each region.

Momotombo Geothermal

This request for IIS services involves an evaluation of the volcanic and seismic activity and possible risk in the region of the geothermal project, as necessary to design the installation to withstand the estimated effects of volcanic and/or seismic activity on the project. It also calls for the installation of permanent monitoring equipment.

In summary, although the goal has not been fully accomplished to date, real progress is being made.

It should be pointed out that the achievement of the goal is not a static but rather an evolutionary process in which as better data is produced, analyzed and disseminated and as knowledge and appreciation of the potential uses increases progressively greater utilization will be made.

Purpose

The purpose of the project was:

"To create, equip, staff, and train an organization, including a modern seismograph network, for applied seismic and related geological research in Nicaragua with the capability of predicting (within the

state of the art) the potential frequency, location, and destructiveness of seismic and volcanic events."

The progress towards each End-of-Project Status condition is described below (note that the original EOPS condition is underlined):

A. The Earthquake Center, including the network of seismographs, accelerographs and seismoscopes, will be a functioning entity having adequate local funding.

The IIS has been established as an autonomous entity in the Ministry of Public Works and now manages a national seismic network consisting of:

1. Sixteen sensitive seismograph stations which transmit continuously to the central station in Managua via VHF radio. These are distributed throughout the technically active areas of Nicaragua.

2. Twenty-one accelerographs and 26 seismoscopes which are triggered only by strong motion. These are located in eight major cities and their future expansion areas.

The GON funding commitment of $81,000 for the first year and $70,000 annually thereafter has been exceeded considerably. The GON portion of IIS budget has increased from $81,000 in 1974 to $183,571 in 1977.

B. Preliminary maps of seismicity, seismic risk and geologic hazards will have been prepared and distributed to appropriate agencies in the public and private sectors for use in planning and design and in preparation of a realistic building code.

The IIS has published the following reports concerning seismic activity and geologic hazards:

1. Reporte de los Temblores Ocurridos en Nicaragua los meses de Marzo a Junio de 1975. Published October, 1975.

This first bulletin of the IIS contains a list of the location data for 352 earthquakes and preliminary interpretation of the results. The data show that:

(a) A zone of earthquake 15 to 25 Km thick extends from shallow depths beneath the Pacific Ocean to a depth of 190 Km roughly below the coast line. A change in the strike or orientation of this deep seismic zone appears to correlate with superficial geologic features which form a trend through Managua that includes the tiscapa fault (the source of the December 23, 1972 Managua Earthquake). To date there is no direct evidence pointing to a dynamic process that could explain this correlation. This seismic feature, therefore, will be the object of

future research because it undoubtedly is related to the fundamental causes of earthquakes in the vicinity of Managua.

(b) A second group of earthquake that locate at depths shallower than 20 Km occurs along the chain of active volcanoes. The trends formed by these events are important data because they indicate the location of active shallow faults that are the potential sources of damaging earthquakes similar to the one that destroyed Managua in 1972. Areas of high seismicity occur at the San Cristobal, Momotombo, Masaya, Apoyo Crater, Mombacho and Concepción volcanoes. Cities and towns located at or near relatively high seismic zones include Masaya, Granada and the Diriamba-Hinotepe area. Interestingly, seismic activity in the vicinity of Managua is comparatively low.

These data are providing new and detailed information about the seismic activity in western Nicaragua. Areas of future studies have been clearly delineated and work in this direction is proceeding.

By the end of 1977, all earthquake location data through June, 1977 will have been published. This will be an important record and the benefits of long term data collection will start to be realized. One of these benefits is the compilation of space-time histories which are important in understanding tectonic processes and which are being used in California in earthquake prediction research.

2. Investigación Geológica de la Falla Las Mercedes. Published July, 1977.

This study was proposed by the IIS to the director of Las Mercedes Airport after several consultants could not explain or did not care to investigate the cause of buckling floor tiles and wall cracking that have occurred in the airport terminal building since the Managua earthquake. Trenching was done at the airport employing the methods of Woodward-Clyde Inc. The results show that a fault trace passes beneath the terminal building. The report concludes with a suggestion that a series of closely spaced survey monuments be placed across the fault trace and that these be periodically resurveyed to determine if the fault is actively creeping. (The IIS does not possess the equipment or expertise to do this work).

3. Amplificación Espectral en Suelos de la Ciudad de Managua. (In print).

This study discusses the dynamic soil parameters and explains how they vary with the amount of deformation. Amplification spectra are calculated for both small and large deformations of several soil deposits in Managua. The computed spectra correspond well with actual spectra obtained during the 1972 Managua earthquake. This shows that reasonable amplification spectra can be computed for the city of Managua using current analitical techniques. This will be important in the establishment of future construction codes.

4. Informe sobre Grupo de Temblores que Ocurrieron en el Area del Volcán Momotombo "Proyecto Geotérmico".

1er. Informe - Septiembre, 1975
2do. Informe - Febrero, 1977
3er. Informe - Julio, 1977

These three letters were presented to Empresa Nacional de Luz y Fuerza (ENALUF) on the initiative of the IIS and contain diagrams of the earthquake locations near the geothermal project at the base of Momotombo volcano. A proposal for a more detailed study accompanies each letter.

5. Estudio Magnético del Area del Pacífico de Nicaragua. (Study in process.)

This study of magnetic anomalies in Nicaragua was begun in mid-1976 by a Ph.D. in geophysics employed part time by the IIS. The value of this work is that magnetic data can be used to delineate active faults and tectonic features and therefore add to the data necessary to understand tectonic processes.

6. (a) Estudio de la Falla de Cartago en el Area cerca de la Ciudad de Masaya. (Work in progress.)

(b) Estudio del Area Sísmica de la Laguna de Apoyo cerca de las Ciudades de Diriomo y Diria, Departamento de Granada. (Work in progress.)

Each of these studies is the direct result of earthquake data which were collected by the seismic net as described above in 1. of this section. The purpose of these studies is to investigate in detail the seismicity and geology between the cities of Masaya and Granada so that the risks indicated by zones of high seismicity can be evaluated. The need for this work is underscored by a swarm of earthquakes which occurred near Masaya in May, 1977 and included an earthquake that was sharply felt by the inhabitants.

7. Determinación del Espesor de la Corteza Terrestre Bajo la Red Sísmica de Nicaragua. Published June, 1976.

This is the senior thesis of a student of the University of Nicaragua who is now doing post graduate work in seismology at the University of Mexico. The thesis presents the mathematical theory used to determine the velocity structure of the earth's crust by employing earthquake data from the Nicaraguan seismic net. A more accurate velocity structure in turn permits the calculation of more accurate earthquake locations. He is continuing this work at the University of Mexico.

8. Geology and Hazards of the San Cristobal Volcanic Complex, Nicaragua. Masters Thesis by Richard W. Hazlett. Dartmouth College, Hanover, New Hampshire, U.S.A.

As a result of careful study of the geology of the San Cristobal Volcano the author determined that the only direct threat to the nearby urban areas is heavy ashfall. The communities affected would be El Viejo and Chinandega. Other hazards that might affect areas closer to the volcano include volcanic gases, acid rains, lava flows and mud flows.

The author suggested that forecasting of future volcanic activity might be done by means of various geochemical, deformational and seismic techniques. He also mentioned that protective measures such as air and water filters, diversion barriers, systematic clean-up operations etc. could be taken to reduce the effects of the above mentioned hazards during eruptions.

Seismic risk maps have not yet been developed by the IIS. However a group headed by Dr. Shah from Stanford University has made some preliminary risk maps based on historical records of seismic activity. The IIS now has sufficient data to begin correcting them in order to eliminate the historic bias of better reporting of old earthquake in the regions of high population density. This work will start when the new seismologists are available.

The geologic hazard research was hampered during the early years of the IIS due to the difficulty in attracting a good geologist to work for the IIS. The geologist now employed is well qualified; he formerly worked for the Ministry of Planning and was involved with the Woodward-Clyde studies. As mentioned above, several special geological hazard studies have been made. Examples of these are:

(a) A study of the Las Mercedes Airport Terminal made for the GON. In this instance creep of a fault underlying the terminal building was damaging the structure.

(b) A study of the local geology around Masaya. The IIS has begun this study on its own initiative due to the occurrence of several earthquake swarms in the vicinity of that city.

C. Information about building response to strong ground motion will be collected systematically. As noted above, accelerographs and seismographs have been installed throughout Nicaragua. These are being periodically maintained. To date no large earthquakes have occurred to trigger these instruments; therefore no data have been collected although the system is completely prepared.

In addition the earthquake engineer, who returned approximately one year ago from studying in Japan, is analyzing the available data

concerning the dynamic response of the soil deposits in Managua. Also he is writing computer programs to extrapolate the bedrock motion from future accelerograph records. These data will be the basis for an eventual building code incorporating dynamic considerations.

D. Monitoring of the seismic activity of Nicaragua's most important volcanoes will have been established on a continual basis. In response to the shallow intrusion of magma beneath a volcano prior to an eruption, the number of small unfelt earthquakes generally increases dramatically and the volcano "swells" causing measurable ground tilts. Historically, even though the prediction of the exact date, time, and force of an eruption is yet to be realized, the long term monitoring of seismic activity and ground tilt has proven to be the most reliable and practical method of detecting the awakening of a dormant volcano. Therefore seismic stations were installed on or near San Cristobal, Cerro Negro, Masaya, and Concepción, four of the most active Nicaraguan volcanoes.

Daily records of the very small unfelt microearthquakes are kept so that any conspicuous increase in activity can be noted. An example of this is the March, 1977 eruption of Concepción volcano. A large increase in seismic activity was observed in October, 1976, five months before the eruption and the Vice-Minister of Public Works was notified of this activity by letter in early November. Fortunately the eventual eruption was very small, however, this illustrated the lead time that could be available to prepare for a potentially larger and more dangerous eruption.

The seismic net is also sensitive to slightly larger events from the other volcanoes in Nicaragua. In fact, due to three swarms of earthquakes including several felt events, the most seismically active area in Nicaragua is the Momotombo volcano which is 23 Km from the nearest seismic station. Historic accounts indicate that many earthquakes were felt prior to the last eruption of Momotombo in 1905. Because a volcanic eruption represents a risk to the geothermal energy project being developed at the base of the volcano, a letter was written to ENALUF after each swarm proposing that the power company fund a more detailed seismic study of Momotombo through the installation of three additional seismic stations in the vicinity of the volcano. It is well known that seismic activity is high in geothermal fields, and the addition of these stations would provide valuable data with which to evaluate potential volcanic and seismic risks. Also techniques are being developed to use detailed seismic studies as an exploration tool and this should serve to increase the percentage of costly drill holes that become "producing" as opposed to dry wells. So far there has been no response from ENALUF.

In addition to seismic monitoring of the volcanoes, three biaxial tiltmeters, inherited from a previous USGS project, have been installed and are operating on San Cristobal, Masaya, and Concepción volcanoes,

and the IIS maintains them. Hopefully improved prediction and a better understanding of volcanic processes can be realized from the combined use of seismic and ground tilt data.

Liquid condensates from fumarols at San Cristobal and Cerro Negro volcanoes are regularly collected by the IIS and sent to Dartmouth College for chemical analysis. The chemical content of these condensates is being developed as a potential indicator of coming eruptions.

In summary, the monitoring of Nicaragua's volcanoes is proceeding on a continual basis and some productive results have been realized. The original program of only seismic monitoring has been expanded to include ground tilt activity and chemical analysis of fumarol gases.

E. The IIS will have research capacity; it will be contributing to the knowledge and sharing its knowledge of the relationsips between earthquakes and regional geological features.

Although the research capacity of the IIS is limited due to the lack of qualified personnel, the IIS is serving a very important data gathering role in the research regarding the relationships between earthquakes and regional geological features in Central America. These data are being shared with all organizations interested in Central American tectonics through the publication of periodic bulletins and special reports. Also the director of the IIS has participated in several international meetings and has reported on the data and the network setup.

Guest researchers are welcomed by the IIS. In the case of the Dartmouth student who wrote his Masters thesis on the geology and hazards of the San Cristobal volcanic complex, the IIS paid him a small salary and per diem, and provided an assistant, a vehicle and a driver.

In summary the actual end-of-project status of the IIS completely fulfills the original expectations established in the project paper.

Inputs and Outputs:

The projected inputs were supplied to the project as planned. No particular contractual difficulties were encountered and all commitments were honored.

Comments regarding the anticipated project outputs are given below for each output (note that the original output is underlined).

A. The IIS will be staffed by four Nicaraguan earth scientists and engineers who will have been partially trained and assisted by USGS specialists. The current IIS staff includes five professionals, five technicians and support personnel. This will be increased in the near future to include an additional five professionals and one technician who are studying outside the country. (Three of these persons are on the payroll of the IIS while pursuing their studies.)

The primary reason for the considerable increase in staff above the originally anticipated level is that the work load was grossly underestimated. A second factor is that the majority of the staff were new to the work expected of them and thus their output is relatively low since they are still learning.

B. A network of twelve sensitive seismographs will be located throughout the tectonically active and more populous western portion of Nicaragua. The data will be relayed by radio to a central station where it will be analyzed. Seismic events could be located roughly within minutes after they occur. The seismograph network located throughout western Nicaragua and connected by VHF radio to the central station in Managua is functioning well. To date more than 2,500 earthquakes have been detected. The IIS personnel working in the Managua station are capable of analyzing the data and determining the location of the earthquakes. In case of an emergency the exact location of the hypocenter could be given within one and a half hours.

C. Existing seismic data will have been computed and new data from the seismograph network will be correlated to them.

As mentioned, Dr. Shah's group have compiled the historical data. The IIS data are ready to be correlated to Dr. Shah's study, but this work cannot be started until the new seismologists are available.

D. Continuous monitoring of the seismic activity of the Nicaraguan vocanoes will have been established as a possible means of providing early warning of eruptions.

This is discussed in detail above.

E. A network of 10 accelerographs and 30 seismoscopes will have been installed in five Nicaraguan cities, including some limited instrumentation in the tall buildings in Managua. The purpose of the system is to yield useful engineering information.

The strong motion instruments have been installed as proposed in the five cities and in three additional cities. The status of this output is described in more detail above.

F. Detailed geologic work to locate faults will be performed in order to develop a regional understanding of the pattern of faults and other structures and to locate regions of potential hazards.

This work is being carried out as planned now that the IIS has a competent geologist on its staff. Several examples were mentioned above. Also a detailed fault study is being planned for Leon, the second largest city in Nicaragua, since the seismic data show activity in the vicinity

of this city. The study will produce zoning maps similar to those developed by Woodward-Clyde, Inc. for Managua.

The significant management experiences encountered during the life of the project mainly concerned the problems involved in creating and sponsoring a new organization within an older one. The IIS was originally formed as a separate unit within the Instituto Geográfico Nacional (IGN); the support services of the IGN were to be shared with the IIS. Unfortunately several severe problems arose under the IGN administration: for example, the IIS field crews frequently could not obtain gasoline or per diem payments. The IAGS representative, who was working part time with AID/N as project manager for this project, helped resolve many of these situations.

However working within the IGN became counter productive and with USAID support the IIS became a separate dependency within the Ministry of Public Works.

The separation of the IIS from the IGN, while relieving one problem, in turn caused another because a significant increase in the IIS budget for 1976 was needed to cover support services previously provided by the IGN. The Director of the IIS notified the Minister of Public Works of this problem in January, 1976. The GON portion of the IIS budget was subsequently increased from $125,143.00 to $183,714.00.

A third instance of the need for AID intervention to protect the fledgling institute occurred in mid 1976. The IIS had constructed its own building with an antenna outside to receive the signals from the seismograph stations and special air conditioned rooms to house the recording equipment. Thus the Director of the IIS was very shocked when the Minister ordered the IIS to move into the IGN buildings. Such an action would have severely disrupted the IIS activities since it would have involved realigning all the radio antennae of the seismograph stations in addition to relocating all the equipment. He protested this order to the Minister without success. Finally he appealed to the USAID and a letter was sent to the Ministry requesting their intervention and the order was rescinded.

In summary the management experience in the project primarily has been that of deciding when to intervene for the good of the project without affecting working relationships. The examples mentioned above definitely indicate that some form of assistance is required by a new organization until it becomes established enough to defend its own rights.

The actual progress of the project was somewhat slower than originally scheduled. Again this was primarily due to the extensive on-the-job training required because trained and experienced personnel were not available. The instrumentation and associated hardware were installed and functioning by April, 1975, but the daily processing of

the data did not become a smooth routine operation until two years later. This in turn delayed the beginning of the analysis work which is needed to produce detailed maps. However the project is progressing well; achievement of the project goal is in sight.

One of the major successes of the project has been the development of the IIS personnel. USGS senior scientists, some of whom have previously had discouraging experiences in Central America, are very impressed with the accomplishments and the present operating capabilities of the IIS. Prior to the beginning of the project no one on the present IIS staff had had any training in seismology. Now they are capable of successfully operating and maintaining the seismic network and processing the data on a daily basis. The staff is very enthusiastic about the work, and frequently will work on holidays if a station is out of order or important data needs immediate processing.

A great deal of the success of the project is justly attributable to the Director, Ing. Arturo Aburto. He has worked with the project since the beginning. Although his training is in civil engineering, he has become well versed in basic seismology. Equally important for the IIS, he has shown himself to be a very dedicated and resourceful individual, and is an honest and competent administrator. His example of hard work has undoubtedly inspired a considerable amount of the enthusiasm exhibited by the staff.

Unplanned Effects:

The project has had no unplanned effects.

Changes in Design or Execution:

The evaluation team recommends that USAID/N not terminate the project funding as planned, but rather continue to support the project in the following two ways:

A. Continued AID commitment of $25,000 annually for the next three years, FY 78 through FY 80. These funds would be used to station USGS technicians in Nicaragua for 4 to 5 man months per year and to provide emergency equipment support of approximately $1,000 annually to the IIS.

The continued presence of USGS technicians is important to the project. The university trained personnel are beginning to return and will be available for specialized training. The USGS had initially been scheduled to give specialized training during the life of the project but this effort was frustrated by the lack of adequately trained personnel and by the need to concentrate on very basic training. Now that a smooth daily data reduction process has been achieved, the training can concentrate more on the analysis work which is crucial to achievement on the project goal.

The emergency equipment support fund would allow the USGS to send urgently needed spare parts to the IIS as necessary. Despite the fact that the seismograph network was set up with a good supply of spare parts emergencies occasionally occur for which the parts are not immediately on hand. It is a tremendous asset to the IIS that the USGS will obtain the necessary item and air freight it to Nicaragua.

B. Continued AID contact with the IIS in the future in order to provide some political backing if it should be necessary. The IIS appears to be fairly well established, but a situation could still arise in which a show of interest on USAID's part would be most useful.

The need for continuous AID support beyond the first four years of the project has been acknowledged since the beginning of the project. The project paper described an unsuccessful AID/USGS project in Costa Rica and concluded that:

> "this experience underscores the need for establishing a program for a specific number of years with firm commitments made by all agencies involved as to their obligations. We believe that the USGS should provide consultation services for a period of at least ten years in order to assure that adequate data are collected and that a reasonable economic return will be made on the initial investment for equipment and training."

A subsequent section of the project paper further states that:

> "Although it is estimated that the program will be fully operational at the end of three years it may take much longer to assemble a seismic data bank needed for adequate seismic mapping and investigation required for country-wide planning of land use and public works. The Center consequently will need to continue its contacts with USGS after the first three years."

Unfortunately the authors of the project mistakenly assumed that the GON could pay for the USGS services required after the initial years of the project. The USGS charter does not permit it to work outside the U.S.A. unless contracted by another U.S. government agency, in this case AID.

The report of the Area Auditor General, Latin America, dated July 3, 1975. also mentiones the need for long term training. His recommendation was that:

> "USAID/Nicaragua, in programming any additional funds for this project, include financing for long term training and also request the Nicaraguan Government to provide funds to assist in this training so the required number

> of professionally educated technicians will be available to operate the Center in the manner contemplated in the project agreements."

The rationale for continuing the project is discussed in detail in the summary section.

Lessons Learned:

A. For a similar project the assumption should be made that qualified personnel will be difficult to attract at the beginning and that they will instead develop with the project. As discussed before, the key problem in the establishment of the IIS has been the difficulty in attracting qualified personnel. This problem was recognized early in the project as is shown by the following quote from the Area Auditor General's report, July 3, 1975:

> "One concern is the present shortage of qualified technical personnel.....the USGS advisor believes these personnel are essential if the Center (IIS) is to eventually analyze and publish, in a meaningful manner, the data which are being recorded. Efforts are being exerted by the USAID, USGS, IAGS and the Center (IIS) to secure enough adequately trained personnel."

Repercussions from this problem were observed throughout the life of the project. The USGS advisor, whose primary function was anticipated to be organizing the data reduction process, was required to spend extra time training the inexperienced personnel. When persons in whom the extra training had been invested left the IIS, a significant setback was sustained, and another period of time devoted solely to training was necessitated. (This happened with a geologist and an electronics technician.)

The problem of lack of trained personnel is slowly being alleviated. People trained in seismology are now beginning to return from university programs, but this has taken three years to accomplish.

B. When extensive in-country training is anticipated in a project, the advisor should be scheduled for full time assistance. Because the extra training required by the IIS staff was not originally foreseen, the USGS advisor was scheduled for intermittent visits throughout the life of the project. This set up consequently affected the continuity of the training program. In one instance, months of data had to be reprocessed because it had been done incorrectly. If the advisor had been available, the errors would have been spotted immediately and the persons involved could have been taught the proper method of analysis.

Another aspect of the argument for a full time in country advisor is the advisor's well being. Better work output can be expected from a well adjusted person that from one who is torn between the project's need for him on site and his family's need for him in the U.S.A. When more than five or six months of in country time is planned per year, this aspect should be considered.

C. Future proposals for similar projects should include provisions for educating the specific recipients and the general public in the use and value of seismic data.

This role had been considered in the planning of the ITS, but was rejected because other government agencies expressed hostility saying that the ITS would become "political" and regulatory in nature. However experience has shown that it is necessary. The majority of the intended recipients of the ITS data had little understanding of the value of the data and consequently have been slow to incorporate them in the planning process. As a result, the ITS has had to expand its scope of activity to include some aspects of public education.

D. A substantial amount of political backing is necessary from USAID in order to foster the development of a new institution within a foreign government.

This is discussed in detail under Inputs and Outputs. Since the project has generally accomplished its objectives, the support given by AID/W throughout this project can be viewed as representative of the support level needed for similar projects.