THE QUITO, ECUADOR, EARTHQUAKE RISK MANAGEMENT PROJECT

AN OVERVIEW

Escuela Politécnica Nacional
GeoHazards International
Ilustre Municipio de Quito
ORSTOM, Quito
OYO Corporation

A GEOHAZARDS INTERNATIONAL PUBLICATION

COVER: "LA VISTA DE LA CIUDAD DE QUITO" BY ANTONIO LUCIO-PAREDES

Escuela Politécnica Nacional; GeoHazards International; Ilustre Municipio de Quito; ORSTOM, Quito; and OYO Corporation, *The Quito, Ecuador, Earthquake Risk Management Project: An Overview*. (San Francisco: GeoHazards International, 1994.)

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An Overview

Prepared by

Escuela Politécnica Nacional
GeoHazards International
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ORSTOM, Quito
OYO Corporation

May 1994

Dedicated to the Memory of
Dr. Kunio Suyama
Cofounder and Past President of OYO Corporation

No longer can man afford the luxury of considering only the good of the community in which he happens to live. No one country has a monopoly on the wisdom that is required to build communities in which human life can thrive and prosper. We must harness the resources of all peoples to face our mutual problems together.

— K. Suyama, 1981

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Foreword

In June of 1991, Dr. Kunio Suyama, President of OYO Corporation, and Dr. Brian Tucker agreed to a two-and-a-half-year partnership to explore prospects for creating a nonprofit organization dedicated to reducing urban earthquake risk in developing countries. In February of 1992, Tucker met with Dr. Jean-Luc Chatelain of ORSTOM to discuss a suitable city in which to conduct a pilot project for this organization. Chatelain recommended Quito, Ecuador, for several reasons.

Most important, Quito has a significant earthquake risk, experiencing over the past 250 years several earthquakes with ground shaking intensities so strong that standing becomes difficult. All of these events occurred when Quito was significantly less populated and developed than it is today.

Quito was also recommended because of the reputation of its earth scientists and civil engineers at the Escuela Politécnica Nacional, and the related research that ORSTOM had been conducting in Ecuador for several years. In May of 1992, Chatelain and Tucker went to Quito to discuss the idea of a collaborative project with Professor Hugo Yepes, chief seismologist at the Instituto Geofísico of the Escuela Politécnica Nacional. Yepes agreed with the need for such a project in Quito and introduced Tucker to government and business leaders to gather community support. In July of 1992, Tucker met the city's mayor, Jamil Mahuad Witt, who lent his support. In September of 1992, the mayor convened a group of Ecuadorian and international government, business, and scientific leaders to provide project oversight, and work began. (A summary of the organization, chronology, and accomplishments of the project is in the Appendices).

Major financial and technical support for this project was provided by OYO Corporation, the Escuela Politécnica Nacional, the Municipio de Quito, and ORSTOM. Supplementary funding was provided by Compañeros de las Américas and the Natural Science and Engineering Research Council of Canada.

The Ecuadorian and international advisors and consultants listed at the beginning of this report generously contributed their time and energy. Their expertise distinguishes this project. The encouragement of the following organizations is also appreciated: the International Association of Earthquake Engineering and its World Seismic Safety Initiative; the International Association of Seismology and Physics of the Earth's Interior and its committee on the International Decade for Natural Disaster Reduction (IDNDR); the International Society of Soil Mechanics and Foundation Engineering; the Office of the United Nations Disaster Relief Coordinator; the United Nations Educational, Scientific, and Cultural Organization; and the Secretariat of the United Nations IDNDR.

This project was a cooperative venture involving more than a hundred participants from many countries and areas of expertise, who came together to make the evaluations and recommendations presented here. There is one individual, however, whose generosity and vision made this cooperation possible. When initially approached for financial support, he asked insightful questions about the project's purpose, methods, and participants, and in so doing, improved its design. Only after concluding that the project's goal was worthwhile and the method practical did he ask about cost. The estimate provided seemed to him unrealistic, so he increased it. Then, nine months after being initially approached, he agreed to provide support, stepped back, and let the work begin.

He died before the project was complete. This report is dedicated to him, Dr. Kunio Suyama.

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Acronyms and English translations of organization names can be found in the Appendices.

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Introduction

Quito, Ecuador's capital city, was last damaged by an earthquake on March 6, 1987. While that earthquake resulted in approximately 1,000 deaths and $700 million of property loss outside Quito, damage and injuries within the city were minor. This is the strongest earthquake that current residents of Quito have experienced.

In the previous 250 years, however, Quito has been shaken by many stronger earthquakes, including four that produced ground shaking so strong that it was difficult for residents to stand. These four earthquakes occurred in 1755, 1797, 1859, and 1868, when Quito was significantly smaller in population and less developed than today. In 1868, Quito was home to only 45,000 people, and its population was confined to approximately 4 square km. Since then, Quito has grown more than 25 times in population (to 1.2 million residents), and roughly 70 times in area (Figures 1 and 2).

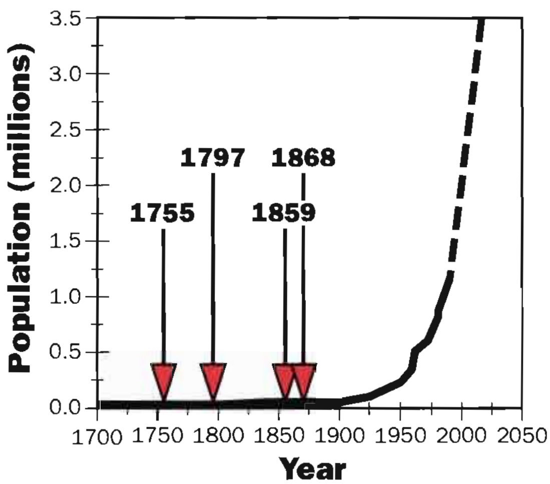


Figure 1. Population growth and major historical earthquakes in Quito.

Quito's Plaza de Santo Domingo, c. 1930.

Efforts to accommodate this growth have resulted in a proliferation of poorly constructed buildings and the development of hazardous areas. Earthquake-resistant design and construction are uncommon, as Quito's building code is not strictly enforced and is otherwise inadequate. Structures have been built on unstable sites, such as *quebradas* (ravines) filled with loose soil. Steep hillsides, previously uninhabited, are now heavily populated (see map insert).

Because of these recent, dramatic changes, past disasters cannot be used to assess the impact of the next destructive earthquake on modern Quito. A large earthquake today will affect not only a much larger urban population, but also completely different types of urban construction, such as mid- and high-rise buildings.

The purpose of the Quito Earthquake Risk Management Project was to provide direction to government officials, business leaders, and the general public in reducing damage and injury in the next major earthquake. To do this, three objectives were adopted:

- Improve the understanding of Quito's earthquake hazard;
- Raise the awareness of the earthquake risk both within Ecuador and internationally; and
- Design self-sustaining programs for managing earthquake risk.

To achieve these objectives, the project was divided into three phases. In the first phase, future earthquakes and their effects on Quito were analyzed. In the second, the impact on life in Quito during the month following one of these earthquakes was described in vivid, nontechnical terms. Finally, based on the first two phases of the project, recommendations for managing Quito's earthquake risk were formulated by a group of Ecuadorian and international specialists. This report provides an overview of these three phases.

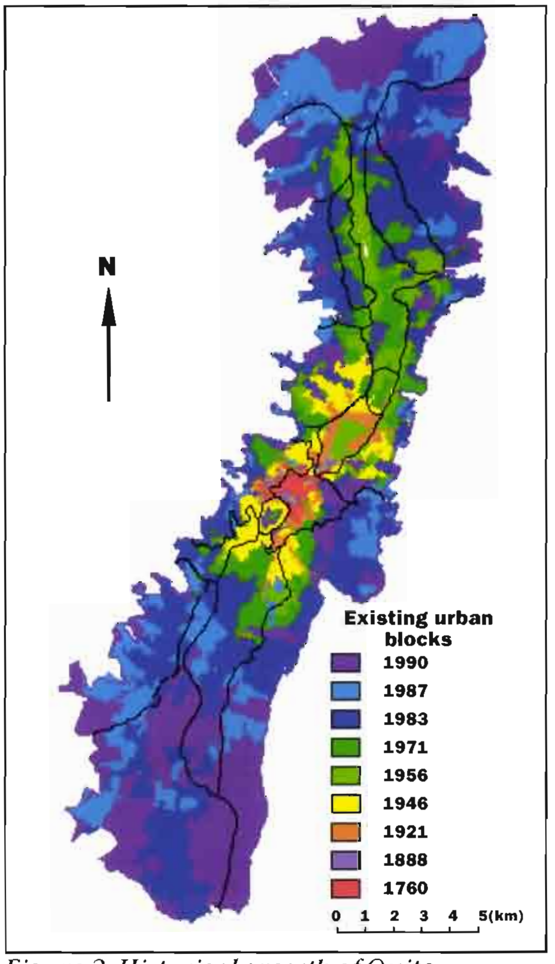


Figure 2. Historical growth of Quito.

A view of modern Quito, looking northwest to the flanks of Mount Pichincha.

Future Earthquakes and Their Effects on Quito

In the first phase of this project, an international, interdisciplinary team of more than 40 seismologists, geologists, soils engineers, structural engineers, and city planners from Ecuador, Canada, France, Japan, and the United States estimated the magnitudes and locations of future earthquakes likely to affect Quito, the level of ground shaking that these earthquakes would create, and the damage to Quito's buildings and infrastructure.

Determining the Earthquake Threat

The amount of shaking, or "ground shaking intensity," that Quito will experience during an earthquake depends primarily on three factors: the strength of the earthquake (magnitude), its distance from Quito, and Quito's ground conditions.

Geologists and seismologists attempted to determine the magnitude and location of earthquakes that would likely damage Quito in the future. They analyzed Ecuador's faults and earthquake records dating back to the 16th century. Three earthquakes, representing the range of possible magnitudes and distances, were selected for detailed assessment (Figure 3):

- A coastal (subduction zone) earthquake of magnitude 8.4 located 200 km west of Quito;
- An inland earthquake of magnitude 7.3 located 80 km east of Quito; and
- A local earthquake of magnitude 6.5 located 25 km north of Quito.

The intensity of ground shaking during an earthquake depends on local ground conditions. For example, when all other factors are equal, soft soils shake more than do stiff soils. In order to account for such effects, Quito was divided into zones based on local ground conditions. The ground shaking intensity of each zone was calculated

Figure 3. Location of the potential coastal (A), inland (B), and local (C) earthquakes with respect to Quito.

for each of the three potential earthquakes (Figures 4, 5, and 6).

The effect of magnitude, location, and local ground conditions on ground shaking intensity is apparent in these figures. Although the magnitude 8.4 coastal earthquake would release over 30 times more energy than the magnitude 7.3 inland earthquake, it would produce less ground shaking in Quito as it is 120 km farther away. Although the local earthquake has the smallest magnitude, it would create the strongest ground shaking in Quito as it occurs so close (25 km from downtown). Its proximity to northern Quito and the characteristics of soft northern soils may result in severe, "MSK intensity 8-" shaking in the north. The MSK scale is one of several ground shaking

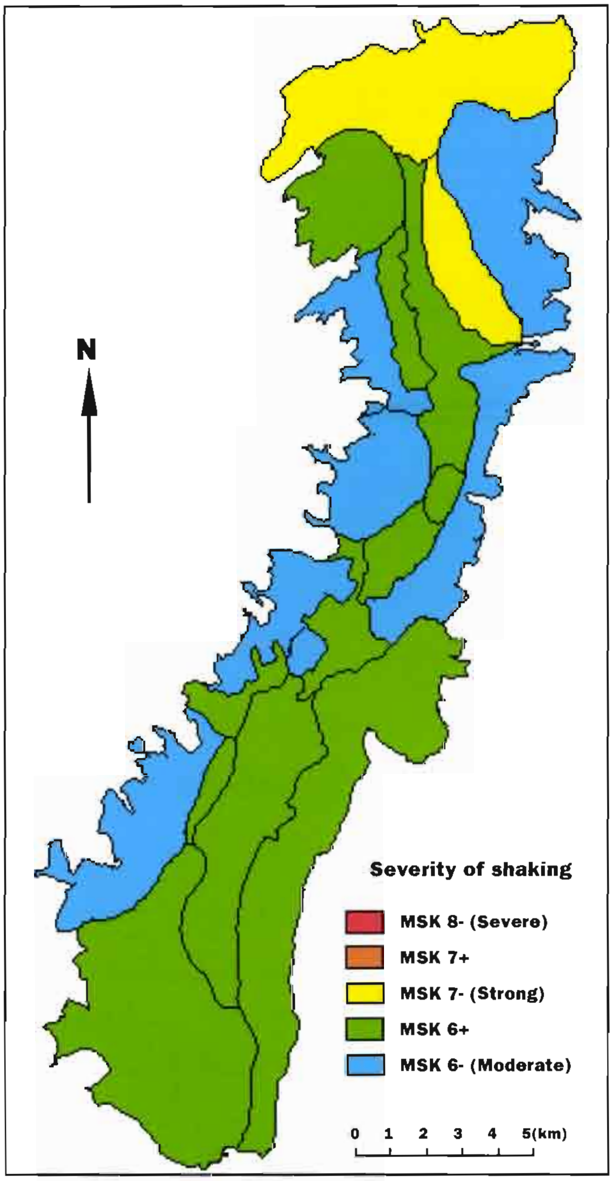


Figure 4. Ground shaking intensities in Quito resulting from the coastal earthquake. Black lines delineate soil zones.

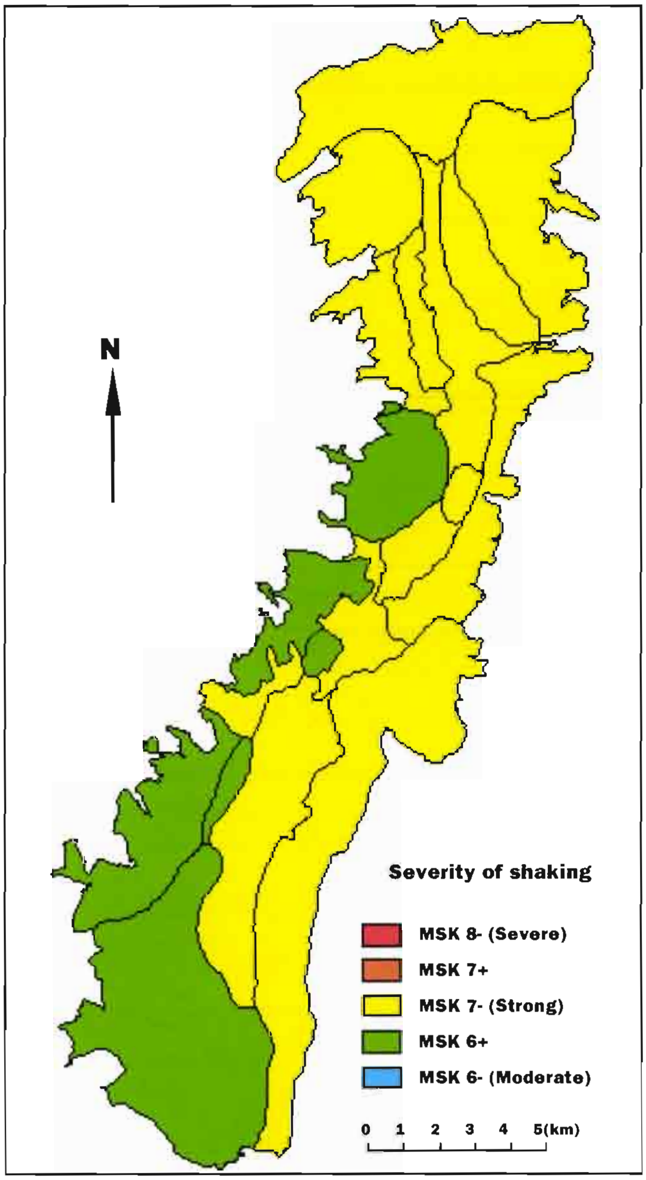


Figure 5. Ground shaking intensities in Quito resulting from the inland earthquake.

intensity scales used by earth scientists and engineers to relate ground shaking to the effects that it has on people, buildings, and nature. During MSK 8- ground shaking, many people have difficulty standing, and the earthquake is clearly felt by people driving. In some cases, tree branches are sheared by the shaking, and heavy furniture moves and sometimes overturns. Cracks form in walls and chimneys of concrete structures. In brick buildings, large cracks form in walls, and chimneys collapse. Parts of and, in some cases, entire adobe buildings collapse. Shaking would be slightly less downtown and even less in the south, but still strong enough to produce moderate damage in poorly constructed buildings.

Other earthquakes of different strengths and locations could occur and would produce different patterns of ground shaking than depicted here. For example, an earthquake occurring on one of the nearby faults to the south of Quito would result in greater shaking in the south than in the north and, possibly, greater levels of shaking than any depicted here.

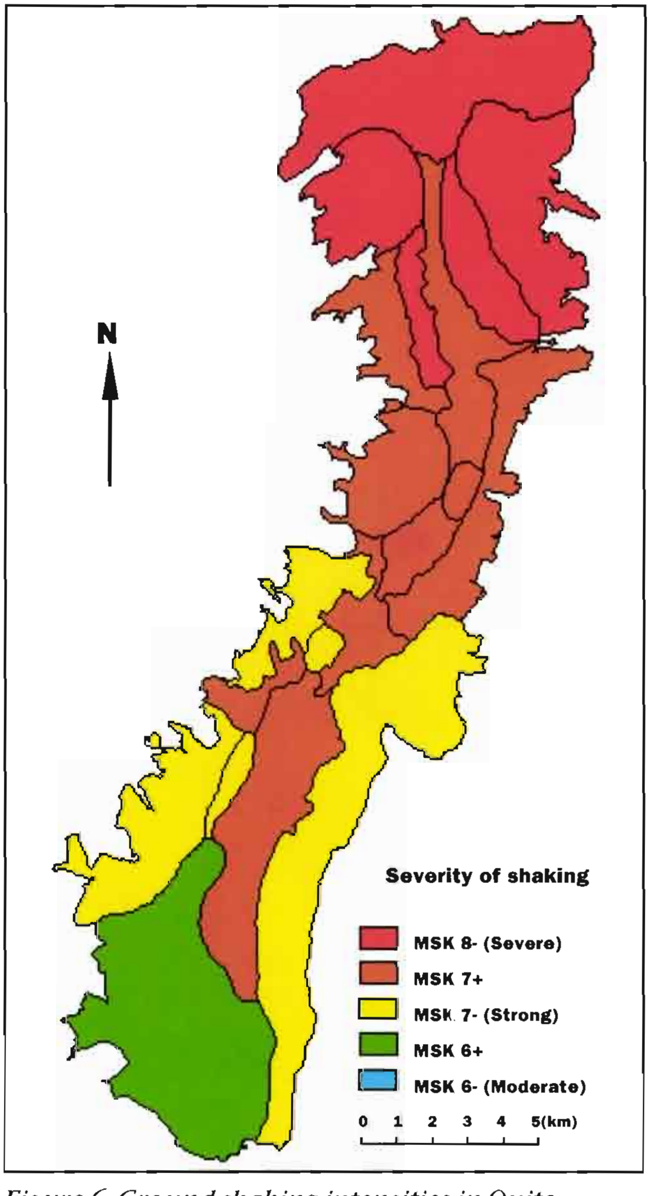


Figure 6. Ground shaking intensities in Quito resulting from the local earthquake.

Assessing Earthquake Damage

Once ground shaking intensity for a particular potential earthquake has been estimated, it is possible to estimate damage to buildings and infrastructure. To do so, it is necessary to inventory the types of structures; analyze how each type of structure responds to various levels of ground shaking; and finally, estimate damage to each type of structure based on the expected ground shaking, earthquake-induced landslides, soil settlement, ground surface rupture, and liquefaction.

The behavior of structures during earthquakes depends not only on the amount of ground shaking, but also on the age, material, design, construction quality, and dimensions of the structure. For example, the behavior of a multi-story building made of concrete reinforced with steel bars ("reinforced concrete") is very different than that of a one-story building made of adobe. For this reason, it was necessary to determine the prevalent categories of buildings in Quito. Buildings were inventoried and classified into 15 types according to materials and design. For simplicity, these buildings have been grouped into five categories: adobe, masonry (virtually all of which, in Quito, are unreinforced), self-built (primarily homes constructed by the owner without engineering considerations), steel, and reinforced concrete (Figure 7 and map insert).

Damage to these buildings, based on ground shaking from each of the three potential earthquakes, was estimated using data sets developed in California and calibrated with data from Central and South America to apply to the buildings in Quito. Damage to infrastructure, including water and power supply systems, sewers, and roads in Quito, was also estimated using similar methods.

The potential for damage due to effects other than ground shaking was also evaluated. Damage from landslides, a major

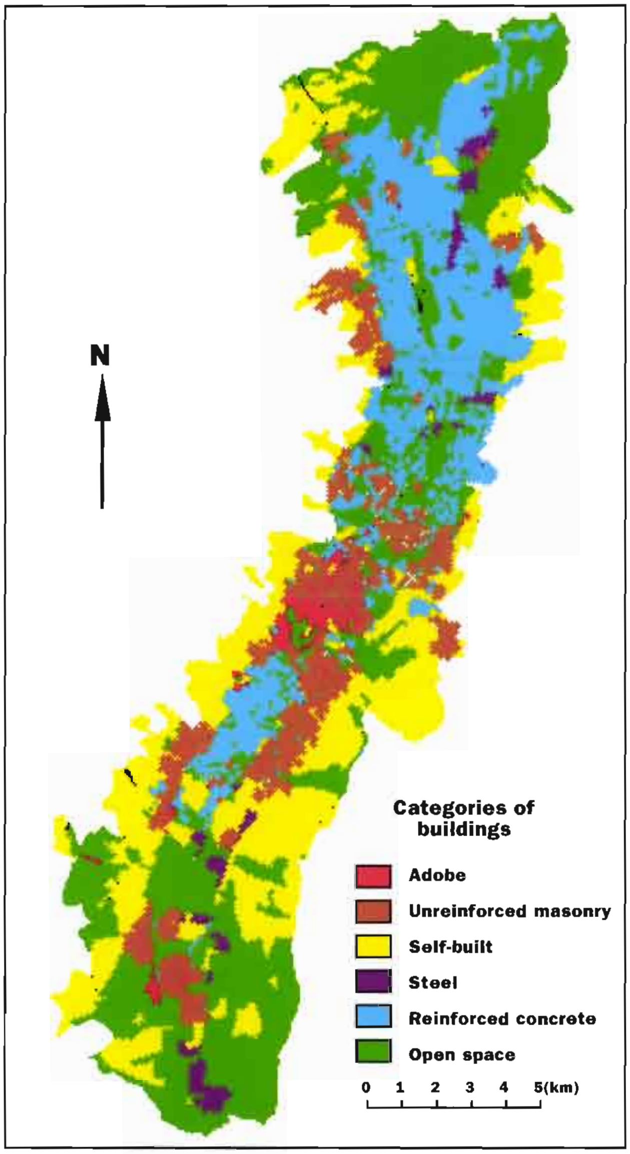


Figure 7. Distribution of building categories in Quito (see also map insert).

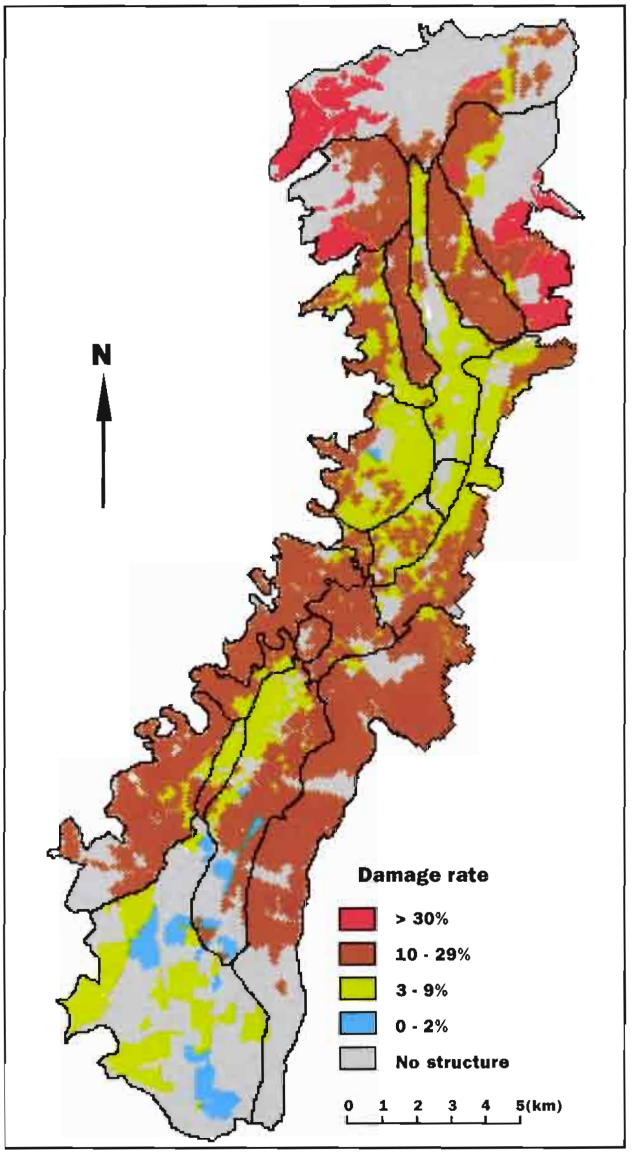


Figure 8. Building damage resulting from the potential local earthquake (see also map insert).

hazard both to structures on top of the landslide mass as well as those below it, and from settlement of the soils in filled quebradas and over sewer pipes, over which many buildings have been constructed, was analyzed. (Details are presented in *The Quito, Ecuador, Earthquake Risk Management Project: A Compilation of Methods, Data, and Findings*.) Because of the distance of the three potential earthquakes from the city, surface rupture due to faulting will not occur. "Soil liquefaction," a condition in which certain soils are temporarily changed from a solid to a liquid state as a result of ground shaking, is, based on available information, not expected to occur as a result of these earthquakes. Additional study, however, is needed.

Of the three potential earthquakes scrutinized here, the local earthquake would create the greatest damage. The damage rate to buildings from this earthquake is illustrated in Figure 8 and the map insert. "Damage rate" is the ratio of the cost of earthquake damage to the replacement cost of the building at current prices. Damage rates are averaged through each zone. For example, the same damage rate may apply to a zone in which all buildings are uniformly damaged and to one in which some are slightly damaged and others completely destroyed.

The potential local earthquake would cause extensive damage to neighborhoods in northern Quito, where ground shaking is greatest and where there are many vulnerable self-built buildings. Structures built on the hillsides surrounding

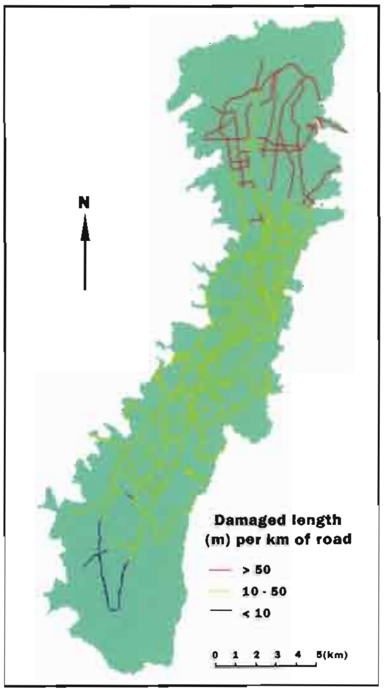


Figure 9. Damage to roads resulting from the potential local earthquake.

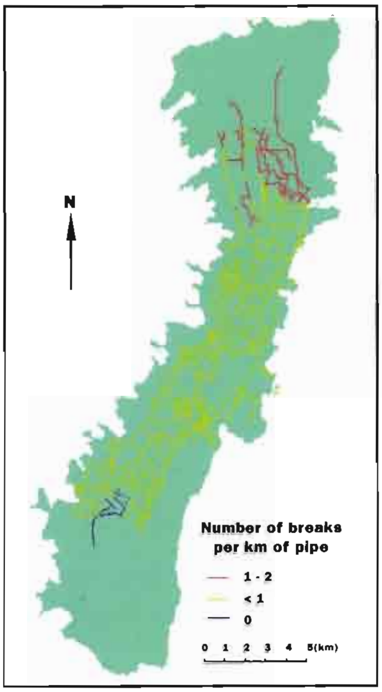


Figure 10. Damage to the water supply system resulting from the potential local earthquake.

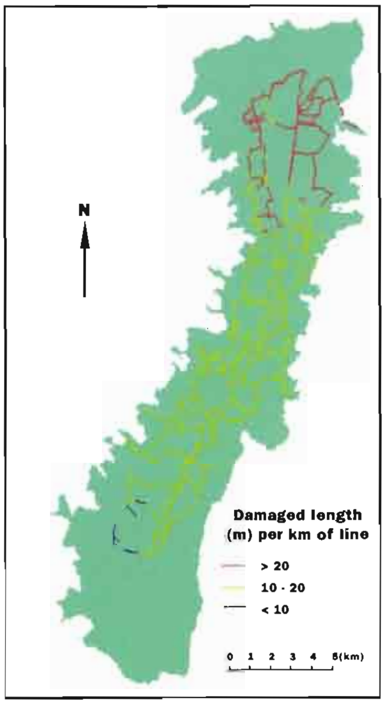


Figure 11. Damage to the power network resulting from the potential local earthquake.

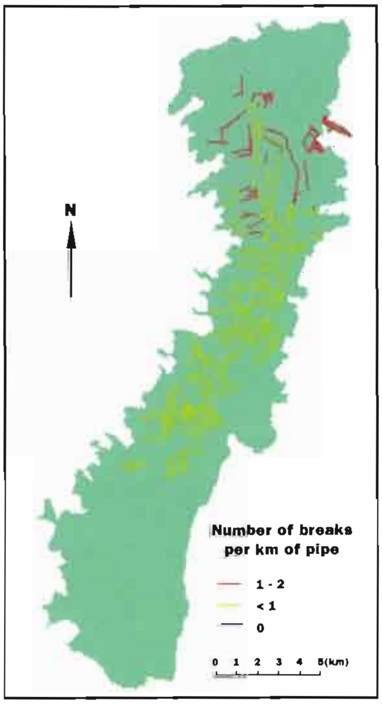


Figure 12. Damage to sewers resulting from the potential local earthquake.

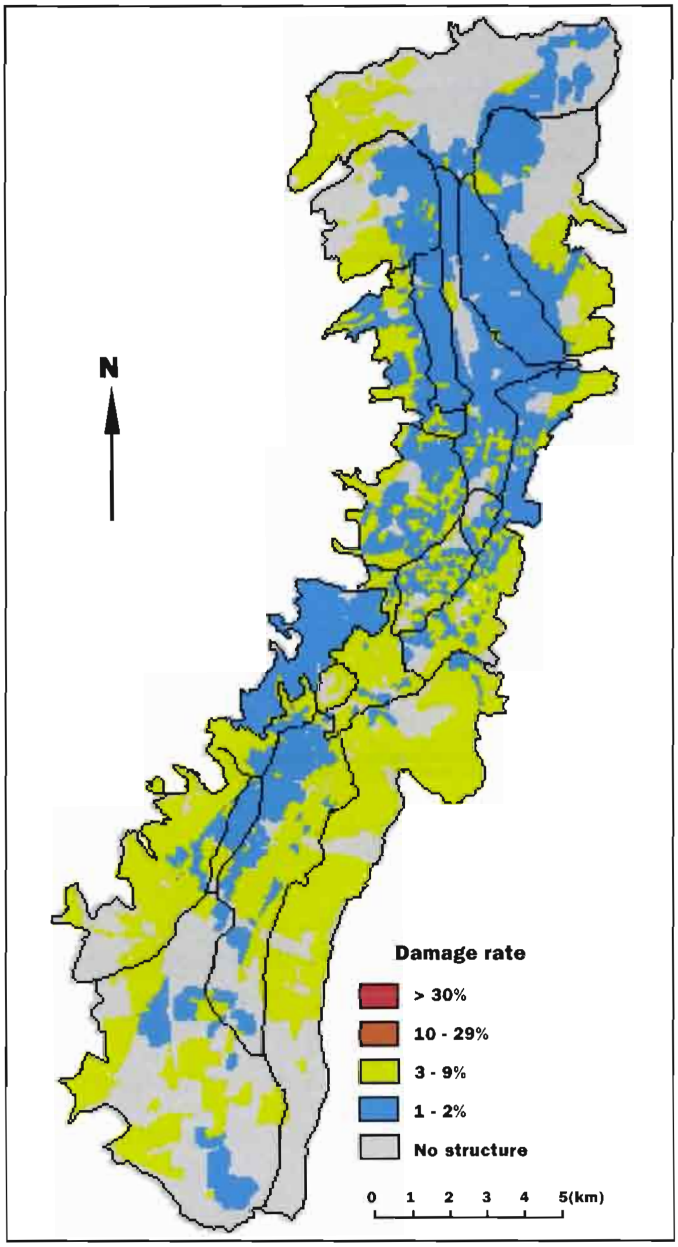


Figure 13. Building damage resulting from the March 1987 earthquake, based on field observations. (Note the much larger damage rate estimated for the potential local earthquake in Figure 8).

the city, many of which are also self-built, would experience significant damage as well. High levels of damage would occur in the Centro Historico, the oldest part of the city, primarily because of the preponderance of adobe and unreinforced masonry buildings. Reinforced concrete buildings would suffer less damage for the same level of shaking.

Damage to the roads, water system, power network, and sewers resulting from the potential local earthquake will likely be severe as well (Figures 9, 10, 11, and 12).

A comparison of the damage from the March 1987 earthquake (Figure 13), which had a magnitude of 6.9 and occurred 80 km east of Quito, with damage forecast for the potential local earthquake (Figure 8), indicates that the local earthquake would cause significantly more damage. The performance of buildings, infrastructure, and emergency response agencies during the 1987 earthquake is not, therefore, a reliable indicator of the consequences of Quito's future destructive earthquakes.

While the consequences of Quito's next destructive earthquake cannot be forecast, they are likely to cause extensive damage to utilities, especially roads, sewers, and water, power, and telephone systems; damage to some reinforced concrete structures, including some new buildings; extensive damage to self-built homes; and total collapse of many self-built, adobe, and unreinforced masonry buildings, and many cultural monuments. The next section describes the possible impacts on daily life in Quito during the month following such an earthquake.

A Month in Quito Following a Future Earthquake

The technical analysis of this project, while providing detailed estimates of damage from potential earthquakes, does not communicate the impact of such disasters. The purpose of the second phase of the project was to describe life in Quito during the month following one of these earthquakes. This description can help government officials, emergency service planners, business leaders, and the general public to visualize the consequences of a future major earthquake, and provide the motivation and understanding required to act.

The following description is based on the technical analysis of the local earthquake and a vulnerability study of Quito's city services, public buildings, and infrastructure. The vulnerability study was performed by interviewing officials from 17 different city organizations, including sewer, water, power, and transportation departments; Civil Defense; and fire and police departments. The locations of critical facilities referred to in the following pages are shown in Figure 14 and the map insert.

View of Plaza de la Independencia, bordered by Ecuador's Presidential Palace (background) and City Hall (not pictured).

CAUTION

The following section describes possible impacts of the potential local earthquake in Quito. Other earthquakes not evaluated in this study would produce different consequences. This is not a prediction of a specific earthquake, earthquake damage, or consequences. This description is intended only for use in planning and preparedness exercises and in raising awareness of Quito's earthquake risk. The authors, advisors, and other contributors to this report are not responsible for use beyond these purposes.

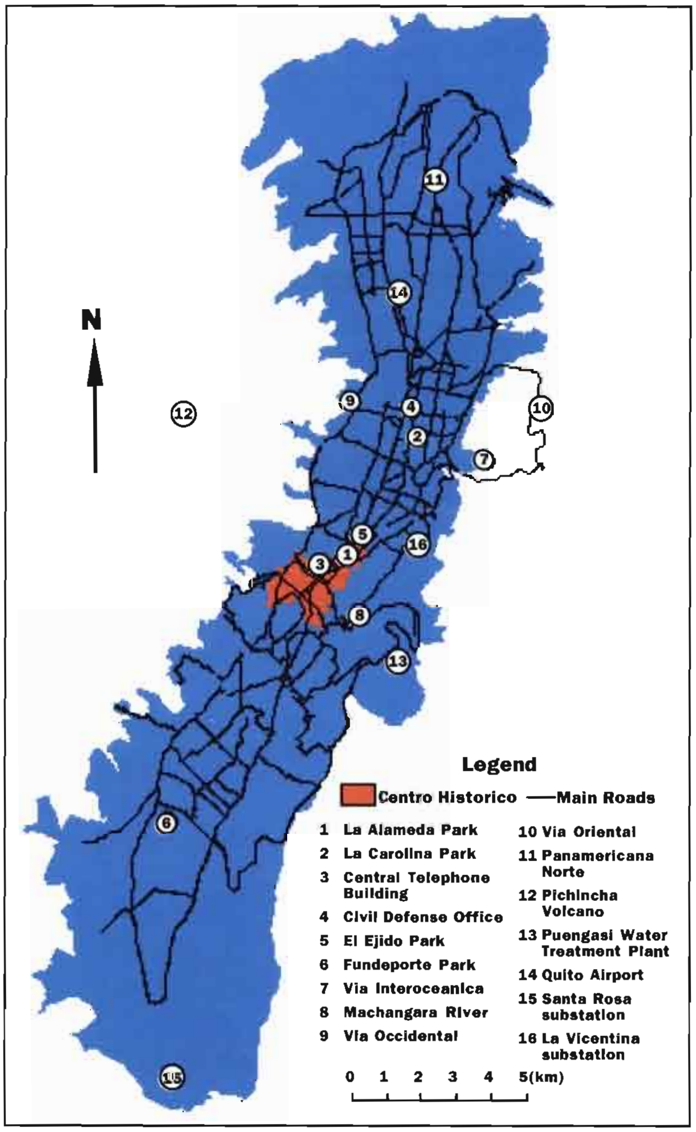


Figure 14. Selected Quito landmarks (see also map insert).

The Earthquake Strikes

It is just after 9:00 P.M. An afternoon of heavy rain has soaked the city; the streets are still wet. Residents of Quito are relaxing with family and friends, having dinner, watching television, or sitting and talking. Older children are studying for the next day of school while the younger ones are asleep in bed.

Suddenly there is a slight jolt, then heavier shaking. Dishes quiver on dinner tables, and windows rattle in their casings. The city trembles as the ground shakes violently. People are initially confused by the commotion, but then realize that Quito is experiencing a major earthquake.

Some people lose their balance; others are thrown to the floor. Cabinet doors swing open, ejecting pots, pans, and dishes onto the floor in a terrible din. Pets run about, frightened. Pictures, lamps, and televisions fall to the floor, causing injury to some people as they try to run from their homes to escape danger. Some doors get stuck in their frames, trapping people inside.

Northern Quito experiences the strongest shaking because of its proximity to the earthquake source. The shaking is so strong that it becomes difficult to stand and nearly impossible to walk. Many bookcases, refrigerators, stoves, and other heavy objects overturn, pinning or crushing some people beneath them. Self-built homes are devastated. Cracks form in walls of many reinforced concrete homes, severely damaging some.

Shaking in the Centro Historico is not as severe as in the north, but is still very strong. The abundance of the vulnerable adobe and unreinforced masonry buildings leaves the area heavily damaged. Some adobe structures collapse, especially those already damaged in past earthquakes and not properly repaired, trapping and killing those inside. Some unreinforced masonry church facades, cupolas, interior walls, and towers crack and collapse. Heavy, tile roofs collapse into homes. Narrow streets become clogged with rubble; frantic people search in the wreckage for loved ones.

Modern buildings between the Centro Historico and the airport escape serious damage. Structures in the vicinity of the airport, however, suffer moderate to severe damage, as do self-built structures on the eastern and western slopes of the southern part of the city. In southern Quito, the shaking is the least intense, but still strong enough to crack brick and cement block walls and destroy chimneys. Practically all unreinforced masonry school buildings in Quito, and several reinforced concrete school buildings with short columns, collapse or are badly damaged.

Adobe buildings in the Centro Historico.

Landslides block Via Oriental and Via Occidental, especially in lanes next to cut slopes. Northern access to the city is interrupted by landslides on Panamericana Norte, the road to the Mitad del Mundo, and the road through Calacali to the coast. Several large landslides and rocks fall on the Tabacundo Highway and Via Interoceanica, making them impassable. A bridge on the Panamericana Norte is heavily damaged, rendering it, too, unusable. Several secondary streets in northern Quito suffer cracking. Northwestern neighborhoods such as Jaime Roldos, Pisuli, and Comite del Pueblo 2 become isolated. Some roads in the northeast are partially blocked; slope failure at the Zambiza garbage dump cuts the only access to that area. Several main north-south avenues are blocked by damaged overpasses. Some motorists, unable to proceed, abandon their cars in the middle of the street. More than a hundred obstructions in the roads of Quito make transit within the city and between northern, central, and southern Quito almost impossible.

Some of Quito's many overpasses.

The airport suffers only minor damage and remains operational, but is difficult to access, especially from the south. Police stations and the Civil Defense building suffer localized damage; fire stations suffer more severe damage. In some cases, emergency

Slopes susceptible to landslides along Via Occidental.

response equipment is damaged or trapped, thwarting timely response. Medicines in hospitals and clinics fall from shelves and spill onto the floor, and medical equipment is severely damaged. Some hospital staff and patients are injured by falling equipment. Two unreinforced masonry hospitals, and older unreinforced masonry wings of newer hospitals, suffer heavy damage and become inoperable. Many factories and warehouses made of steel are damaged when poorly anchored masonry walls collapse. Some industrial buildings suffer heavy damage and a few collapse, in some cases releasing hazardous materials.

Water pipes throughout Quito break, especially at their rigid joints and in places where they cross filled quebradas. Landslides block the open canal that brings drinking water to the Puengasi water treatment plant. Some main sewer collectors—in particular, those located on the western slopes of the city—rupture, damaging buildings and streets above. Landslides along the Machangara River block sewage outlets. Structural damage to the central telephone building results in partial loss of telephone communication within Quito and to the outside world. Power poles fall throughout the city, and more than 500 transformers are damaged. Several distribution substations and transmission cables, especially those in the northern part of the city, are seriously damaged, plunging most of

Fire station.

the city into darkness. Forty seconds after the start of the earthquake, the shaking stops.

One Hour Later

One hour after the earthquake struck, uninjured citizens are removing rubble by hand and with makeshift tools to free victims from underneath collapsed buildings, despite fear of aftershocks. People try to locate family members and apply first aid, with only the light from car headlights. Rescue of those trapped underneath collapsed buildings is hampered by darkness. The injured start to make their own way toward hospitals and private clinics. Because of fear of aftershocks and the unknown structural condition of their homes, many people who are uninjured and have no missing family members head toward open areas such as La Carolina, El Ejido, La Alameda, and Fundeporte parks. A few seek refuge in undamaged churches and convents, despite the danger of aftershocks. Some, taking advantage of the destruction and confusion, loot unprotected homes and businesses.

In several older homes, electrical wiring short-circuits, and fire rapidly consumes old, dry wood. Residents extinguish some fires; thick adobe walls impede other fires from spreading widely. The fire department cannot attend to most fires because of poor communication, blocked roads, heavy traffic, lack of personnel, and lack of water—many water pipes have ruptured, cutting off supply, and many fire hydrants were out of service even before the earthquake. The darkness of night is punctuated by scattered flames.

The few operating commercial radio stations broadcast information to the public. The broadcasters have limited knowledge of earthquake disaster recovery, and incite confusion and panic with erroneous information, including false rumors that a larger earthquake will come in the next few days, that the Pichincha volcano is going to erupt, and that high government officials died in the earthquake.

Hospital hallways are crowded with patients, staff, and fallen equipment. Doctors and nurses attempt to check the safety of previously admitted patients while administering first aid to new arrivals. In the southern part of the city, damage is less severe and fewer people are injured. Access to medical

One of Quito's more modern hospitals.

care is limited, however, because there is only one major hospital in that area.

As there are no automatic shutoff valves within the water supply system, large quantities of water are lost. Quito's water supply is cut off. Water and sewage flood the lower parts of the city and damage some streets. Portions of the telephone system in operation are saturated by calls from people trying to reach relatives, friends, hospitals, and other public services.

No statement about the severity of earthquake damage has been made by government officials, as they are still gathering information.

Aftershocks come frequently, threatening damaged structures with further collapse. People of Quito wait in anguish for dawn.

The First Day

During the first day after the earthquake, citizens realize that roads are blocked, and hence help may not come from rescue organizations in the near future; they begin to organize groups to search buildings for the injured and dead. Rescue operations are hampered by a shortage of heavy equipment to move rubble.

Since the city has no official agency or plan to inspect and evaluate the safety of buildings, several professionals volunteer to determine the amount of damage; no one, however, is authorized to make decisions on the further use of the buildings. Some residents cautiously reenter damaged buildings to search for missing persons or retrieve personal belongings; most, however, do not for fear of aftershocks, and will spend ensuing nights outdoors in the cold weather until temporary shelter can be found. A light rain worsens their situation.

Looting continues in unprotected shops and homes. Businesses and banks are not open; people become frustrated and angry as they try unsuccessfully to withdraw money from automatic teller machines for their immediate needs.

With the help of radio amateurs, emergency response agencies organize rescue units, focusing attention on the devastated northern areas and the Centro Historico. Civil Defense officials are able to broadcast general instructions to the population.

Several roads cave into underlying sewers and quebradas. The city attempts to locate heavy equipment to open blocked and damaged roads. Driving throughout the city is nearly impossible. Within neighborhoods, public transportation is nonexistent with the exception of taxis, which charge many times more than standard rates. Because of damage to the power supply system, traffic lights are out of service, resulting in confusion and increased traffic congestion. Broken sewers flood many vital underpasses.

Relief doctors and nurses cannot reach the hospitals because of road conditions and personal and family injuries, and hospital staffs become fatigued. Many patients with minor injuries are asked to leave in order to free space for the more seriously injured. Medical care is particularly difficult in hospitals without reserve water supplies and backup electrical generators. Undamaged public schools and military quarters are transformed into makeshift emergency health centers to accommodate the large number of injured.

The city's 10-hour water reserve is exhausted. The only water available in the most affected areas is that remaining in household water tanks. In some areas, available water is polluted by sewage. EMAP-Q personnel begin manually shutting off functioning water service for inspection and to prevent further water loss from damaged pipes. Officials realize that in the coming week water will need to

Traffic in the Centro Historico.

be trucked in from neighboring regions. More than three-quarters of the city still is without power; damage to several subnetworks and system overload severely restrict telephone communication. Because of a lack of earthquake preparedness plans, utility repairs are slow and poorly coordinated.

The President of Ecuador declares Quito a disaster area and proclaims a state of emergency. The army is mobilized to participate in emergency rescue and disaster recovery.

Puengasi water treatment plant.

Two Days Later

Two days after the earthquake, thousands of people are homeless; makeshift shelters are not able to accommodate them. Response workers are still attempting to rescue missing persons from beneath the rubble of collapsed buildings. A strong aftershock heightens anxiety and keeps most from returning to their homes. The aftershock causes the collapse of a few buildings damaged in the main earthquake, injuring or killing those taking refuge inside. Nonetheless, a few sleep in their damaged homes or on the street nearby to guard against looters, and some seek divine protection in churches. Many sleep in the parks, risking exposure and sickness from the rain and cold. Some with relatives, friends, or homes in other provinces leave the city, depriving Quito of badly needed emergency response and recovery professionals.

There is an increasing demand for food and medicine, but most stores and pharmacies remain closed; some vendors and store owners greatly increase the price of food, medicine, and equipment. In poor neighborhoods in northern Quito and in the Centro Historico, residents lacking food supplies, especially those whose homes were destroyed, are tired and thirsty. Water is being distributed by the city's six tank trucks because of the large number of ruptured water pipes. There are reports that some private tankers are charging many times the normal price for water. Some citizens, without access to fuel for use in boiling water, become ill after consuming water contaminated by sewage. There is no garbage collection, and garbage accumulates on the streets.

Civil Defense broadcasts increasingly more useful and specific information. The official estimates of casualties and economic losses grow as more information becomes available. The media continues to fuel rumors that, combined with frequent aftershocks, further distress the population.

Some roads are still blocked, limiting delivery of relief supplies. Government workers begin to clear Via Occidental and Via Oriental of debris, as these highways are vital for the response and recovery of the city. A few supplies begin to arrive at the airport, but still there is limited access for pickup and delivery. Supplies also begin to arrive at Latacunga airport, 80 km south of Quito, although there is difficulty in distributing them to the more damaged areas of Quito.

Most of the injured have received some medical attention. Lack of emergency medical equipment, medicines, power, clean water, and prompt treatment in public hospitals results in poor medical attention. Some people die from injuries that under normal circumstances would be nonfatal. Many of the injured are taken to small health centers and Red Cross first aid centers. The death toll increases. As the morgues are full and not readily accessible, dead bodies line hospital hallways prior to identification and burial. Health officials make plans to create mass graves.

Telecommunications center.

Most equipment and supplies for major utility repairs are unavailable due to shortages and inaccessibility. Sewage and rain flood many utility tunnels, damage roads, and make repairs cumbersome and unpleasant. At the central communications building, attempts to make equipment repairs and reestablish telephone service fail, as the staff is unwilling to enter the building for fear of aftershocks; phone service is consequently unreliable. While EMETEL makes telephone service available to government and emergency service facilities, radio communication is found to be more reliable. Financial institutions abroad attempt unsuccessfully to communicate with business partners in Quito.

About half of the city is still without electricity. The main transmission substations, Santa Rosa and La Vicentina, were not seriously damaged, but the northern distribution substations will need major repairs before electricity can be restored there. Some facilities have backup power generators, but are unable to use them because of a lack of fuel.

The role of the military expands to guarding homes and shops against looters; recovering corpses; setting up temporary hospitals and shelters; and distributing food and water. Claims for government assistance increase, and people become angry when their requests are met slowly, inadequately, or not at all.

One Week Later

One week after the earthquake, collapsed buildings—responsible for most of the deaths—are still being searched for bodies. Many people are still hoping that missing relatives or friends will be found alive. Emergency workers remove the remaining victims. Undamaged public school buildings and other temporary shelters are full, and many people are living on the streets and in parks. Undamaged private schools resume classes.

Most businesses reopen. Food is scarce and expensive. Some banks are not permitting withdrawals because of damage to bank computers; customers become angry, and small, isolated disturbances erupt outside of these banks. Products from northern Ecuador, mainly milk and potatoes, are difficult to deliver to Quito. Emergency supplies from the international community, mostly food, clothing, medical supplies, and tents, continue to arrive at the Quito and Latacunga airports. Many donations do not fit local needs, and supplies that cannot be used or easily distributed collect at the airports, burdening relief agencies.

Garbage trucks still cannot reach many parts of the city, and trash and human waste collect in streets and alleys. Many residents

Electrical substation.

develop gastrointestinal diseases as a result of consuming contaminated food and water. Health care in Quito's clinics and hospitals improves after medicines and personnel arrive from Latacunga, Ambato, and Guayaquil, but hospitals still lack beds to accommodate all the injured and sick. Exacerbating the problem, injured people arrive from neighboring towns such as Pamasqui, San Antonio, and Nono in search of better health care facilities.

Public transportation is improving except in northern Quito, where many roads are still closed. The southern roads remain the only dependable access to Quito. Gasoline is now available throughout the city.

Although the main water treatment plants are now fully operable, numerous pipe ruptures within Quito keep water from being widely distributed. Lack of water pipes slows recovery. Damage to the open canal that brings water to the Puengasi plant may take more than a week to be repaired. Some water is trucked in from outlying regions.

Most of the fallen electric poles have been replaced. The city has electricity, with the exception of parts of the Centro Historico and the far northern areas. Phone service is still unreliable. The sewage system also sees only minor repairs because of inundation with rainwater and human waste, lack of equipment, and a limited quantity of spare pipes. Many utilities still wait for key equipment and spare parts, not available locally, preventing complete recovery.

Those who fled the city the first few days after the earthquake begin to return. Residents of Quito start to adjust to their new way of life. They make plans to restore their damaged homes and businesses, although no one knows from where money for such efforts will come.

One Month Later

One month after the earthquake, panic has subsided, and residents no longer fear

Water treatment plant above the Centro Historico.

aftershocks. Most residences remain damaged, and virtually none of the collapsed buildings are being rebuilt. Shelters are still full, and many people are still living in small tent cities in plazas, parks, and playing fields. For many, the only improvement they have seen in their living condition is that the plastic, cardboard, or plywood tents they built themselves have now been replaced with canvas tents provided by international agencies. Health officials are concerned about a significant rise in respiratory ailments resulting from the large numbers of people living in crowded temporary quarters.

Residents of Quito have started planning and seeking assistance for reconstructing damaged or destroyed homes. Businesses are open, and the banks accept deposits and permit withdrawals. Most children are back in school, many in hastily constructed, temporary classrooms. Distribution centers are established to deliver food and supplies coming from abroad.

Tourism has ceased, adding to overall economic losses; foreigners watch Quito's earthquake recovery and make plans accordingly. Businesses have suffered considerable losses, and some will never recover. For the minority with insurance, their claims remain unaddressed as the extent of damage to many buildings has not yet been evaluated. For the time being, some business owners are given provisional payment until more accurate damage estimates can be determined and reinsurers can respond. Insurance companies are having problems converting their assets into cash, and some are likely to go bankrupt. Many businesses will receive insufficient reimbursement due to inadequate policies and lack of insurance company reserves and reinsurance.

Water service has been restored to most parts of Quito; the use of trucked water and water conservation are now a way of life in areas where it has not been restored. In areas where damage was particularly heavy, it will take two months or more to restore regular service.

The roads are clear of rubble, although in the Centro Historico some are blocked by wood poles used to support damaged buildings, especially churches. Collapsed overpasses have not been rebuilt, but the debris has been removed and alternate routes established. Temporary bridges are being built by the army.

Repairs to electrical substations in the north are still not complete, although substations in other parts of Quito have been repaired. Reduced system performance continues for several months due to transmission line damage in the western portion of Quito. Telephone service is still intermittent, and loss of convenient international communication severely disrupts national and international commerce.

School buildings.

Because of minimal repair capacity and the slow and difficult work of visually detecting sewer ruptures, officials estimate that the sewage system will not be fully operational for some five months. Funding for repairs is scarce since the system is uninsured. Collapse and blockage of major sewer tunnels cause extensive, long-term limitations in sewer use in parts of Quito. Contingency plans are established to clean sewage from streets and dig pits throughout the city, which will serve as interim dumps.

Officials start defining reconstruction plans for the city. Recovery assistance for individual citizens is insufficient, as most property owners do not have earthquake insurance. National agencies, such as the National Bank for Development and the Housing Ministry, do not have enough funds to help victims. Questions and complaints are raised as to how the available funds are being used.

Adobe buildings damaged in the March 1987 earthquake.

The preceding description illustrates some of the possible impacts on Quito from one particular earthquake in Quito. Other earthquakes, not evaluated in this study, will result in different consequences. This description is intended only for use in planning and preparedness programs and for raising awareness of the earthquake risk.

An earthquake could strike Quito in the future and produce effects such as those just described. As Quito is the seat of Ecuador's national government and the source of one-third of the gross national product, the effects would be felt across Ecuador. Municipal, regional, and national government functions would be disrupted. The city's commercial, banking, and insurance industries would take years to recover. Human casualties would be substantial.

There are steps, however, that Quito can take now to prepare for its next major earthquake—steps to reduce loss of life, damage to property, harm to the economy, disruption to government services, and damage to cultural heritage. Some of these steps are presented in the next section, "Managing Quito's Earthquake Risk."

Managing Quito's Earthquake Risk

In the third phase of the project, a group of international and Ecuadorian specialists from business and industry, city government, urban planning, emergency services, and infrastructure developed specific recommendations within their fields of expertise for managing earthquake risk in Quito. Their recommendations were based on the technical analysis of this project, their knowledge of Quito, and their experience with programs that have been successful in other earthquake-threatened cities. Their work was performed during a two-day workshop in July of 1993. The names of the participants are listed at the beginning of this report.

The recommendations are broad in scope. They include creating a Quito Earthquake Safety Advisory Board; addressing the vulnerability of buildings, infrastructure, and emergency response equipment and facilities; developing guidelines for safe construction; improving emergency planning and preparing disaster recovery plans; and furthering social and scientific research. Many recommendations are short-term and can be implemented within two to four years. Such measures include developing a

A view of Quito, looking northeast from Panecillo Hill.

comprehensive building code to help ensure that new facilities can withstand earthquake shaking; designing and practicing emergency response disaster contingency plans; and teaching the public about earthquake safety and emergency preparedness. Other recommendations are long-term, and may require decades to complete. These tend to be more expensive, and include strengthening existing buildings and infrastructure and improving emergency service facilities such as hospitals and the fire department.

The earthquake risk management recommendations, described in full in the report *The Quito, Ecuador, Earthquake Risk Management Project: A Compilation of Methods, Data, and Findings,* can be used as a starting point in designing an earthquake risk management program for Quito. Until such a program can be initiated, however, there are six projects that are of highest priority and deserve immediate attention. They are:

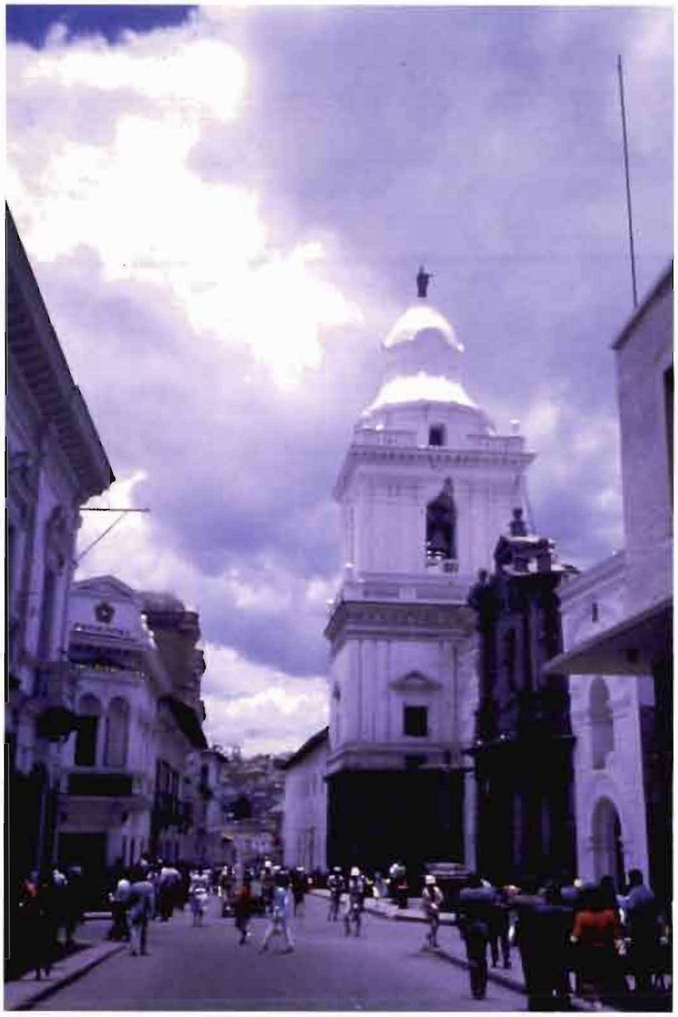
1. *Creating a Quito Earthquake Safety Advisory Board.* Implementation of earthquake risk management programs requires leadership, commitment, and ongoing oversight by government officials and community leaders. Efforts must be coordinated among government agencies at every level, schools, businesses, financial institutions, and other entities concerned with the city's future economic health and the welfare of its citizens. Such coordination and continuing progress toward earthquake safety goals require designation of primary responsibility and the formation of an oversight council or board.

   Under this project, the Office of the Mayor of Quito would appoint a special assistant to the mayor, who would report directly to the mayor and be responsible for the earthquake safety program. The special assistant would serve as the mayor's liaison to the Earthquake Safety Advisory Board and as its executive director. The mayor's office would define the purpose and authority of the board, criteria for selecting members, and bylaws to govern the board's activities. The mayor would issue a resolution creating the board and appointing its members to represent business, emergency services, government, and the scientific and engineering communities.

Taking Steps Toward Earthquake Preparedness

Recommendations for Improving Quito's Earthquake Safety

1. *Create a Quito Earthquake Safety Advisory Board.*
2. *Adopt and enforce an effective building code.*
3. *Support scientific research to further evaluate Quito's earthquake risk.*
4. *Develop a workplace earthquake preparedness program.*
5. *Improve emergency response equipment and facilities.*
6. *Establish a proper insurance tariff with underwriting guidelines.*



Centro Historico.

The Earthquake Safety Advisory Board would advise the mayor, local government agencies, and private industry on earthquake preparedness and risk management issues. It would also be responsible for setting mitigation priorities based on the earthquake threat; developing and administering an earthquake risk management program; monitoring and regularly updating the earthquake risk management program; advocating the incorporation of mitigation measures into the urban development process; and seeking local and international funding for mitigation projects.

2. *Adopting and enforcing an effective building code.* An effective building code helps to ensure that new facilities are designed and constructed to withstand earthquake shaking. Under this project, a committee of engineers and planners would design a building code for all structural types in Quito, facilitate the code's integration into design and construction, and regularly update the code. The code could also provide the basis for future retrofit of critical structures. Enforcement is achieved by establishing a committee to educate builders, planners, and engineers about the building code; determining an efficient method for enforcing it; and training inspectors to evaluate building design and construction.

3. *Supporting scientific research to further evaluate Quito's earthquake risk.* The Quito Earthquake Risk Management Project was restricted to the analysis of available data during an 18-month period. Hence, many assumptions were made in the development of the potential earthquakes and their effects. Further research is necessary to expand the soil profile data base to obtain a more detailed zonation of the city; map the depth and location of the bedrock to improve estimations of soil amplification; identify active faults and determine their geometries and mechanisms to better estimate potential magnitudes and locations of earthquakes; install instruments to measure epicenters, ground shaking, and response of buildings during earthquakes; develop improved procedures for estimating earthquake damage to structures in Ecuador; and develop a scenario for the greater Quito area and for other potential earthquakes. Such research will improve the technical base for a more accurate earthquake scenario, better methods of earthquake risk management, and improved earthquake codes and policies.

4. *Developing a workplace earthquake preparedness program.* Educating employees in earthquake risks and emergency preparedness, and the spread of this information to friends and family, would benefit individual businesses, employees, and the community at large. Under this project, ALERTA, Quito's private-sector disaster preparedness program, and various emergency service organizations would train business management to analyze the earthquake risks that they face, and to develop risk management plans for their institutions. Employees at every level would then be educated in preparing for and surviving an earthquake.

5. *Improving emergency response equipment and facilities.* Improved emergency response equipment and facilities are vital for quick, effective response to a major earthquake. Under this project, research teams would inventory available human and material resources, and, based on a disaster scenario, determine vulnerabilities and critical needs.

6. *Establishing a proper insurance tariff with underwriting guidelines.* A proper insurance tariff with underwriting guidelines considering earthquake hazards would encourage responsible, earthquake-resistant design and construction, and would make earthquake insurance available to residents of Quito. The insurance tariff and underwriting guidelines would be based on soil properties, estimated ground shaking intensities and subsequent geological hazards, damage distribution estimates, and structural design and construction. Rating discounts would then be available for structures with appropriate earthquake-resistant design and construction.

More detailed descriptions of these projects are included in the Appendices.

Practical steps can be taken now that would significantly reduce the physical, social, and economic consequences of earthquakes to Quito, as the preceding projects illustrate. However, managing earthquake risk is a process that requires time, sustained effort, and direction, all of which require that government officials, business leaders, and the public be convinced that earthquake safety is important relative to the other needs of the community. With direction, leadership, and the support of the community, Quito has the opportunity to prepare its citizens, buildings, and economy for the next major earthquake.

Tile roof and adobe cupola in the Centro Historico.

Conclusions

The Quito Earthquake Risk Management Project has led to several significant conclusions.

- ***Quito, which has a long history of earthquakes, will experience damaging earthquakes in the future.*** Some will be significantly stronger than the March 1987 earthquake, and will result in major damage to the city.

- ***Quito is unprepared for its next major earthquake, and becomes increasingly vulnerable with time.*** Significant loss of life, destruction of property, and harm to the economy will result unless government, business, and community leaders recognize and begin to address the earthquake threat by taking steps to manage earthquake risk.

- ***Steps toward reducing Quito's vulnerability to destructive earthquakes should be taken immediately.*** Quito has the opportunity to prepare its citizens, buildings, and economy for the next major earthquake, but significant progress toward reducing the physical, social, and economic consequences of earthquakes to Quito can only be achieved with the support of the community and from focused, sustained action by government, business, and community leaders.

- ***An Earthquake Safety Advisory Board should be established to develop, implement, monitor, and regularly update a comprehensive earthquake risk management program for Quito.*** The findings of the Quito Earthquake Risk Management Project provide a starting point for the work of this board.

Earthquakes will be a part of Quito's future, as surely as they have been a part of its past. While it is not known when the next major earthquake will occur, efforts put forth toward earthquake safety today will result in less damage and death in the future. This project is only a step toward Quito's earthquake risk management. The next step must be made by Quito's leaders and citizens.

Appendix A

Organization, Chronology, and Accomplishments

Organization

The participants of the project fell into one or more of four categories:

- An Ecuadorian-international Working Group (WG), consisting of specialists in geology, seismology, structural engineering, soils engineering, urban planning, and data management. All scientific, engineering, and planning work was performed by WG.

- The Technical Advisory Committee (TAC), consisting of international experts in the fields of structural engineering, soils engineering, geology, seismology, urban planning, emergency response, and data management. The TAC provided WG with technical recommendations on how earthquake risk assessments have been made in other cities, as well as advice on what mitigation actions may be useful in Quito. The TAC reviewed the project for technical accuracy and provided links with international science and engineering communities and professional organizations.

- The Social and Economic Advisory Committee (SEAC), consisting of international and Ecuadorian representatives from the banking and insurance industry, public health, utilities, construction, emergency response, and urban development. The SEAC contributed overall guidance and advice on long-term project planning, and provided links with international agencies and businesses concerned with managing earthquake risk. Project priorities were set by the Ecuadorian members of the SEAC.

- GeoHazards International coordinated the activities of WG, the TAC, and the SEAC.

The members of these groups are listed at the beginning of this report.

Technical advisors tour Quito, October 1992.

Chronology

DATE	*ACTIVITY*
July 25, 1992	International meeting of some members of WG, TAC, and SEAC at Tenth World Conference on Earthquake Engineering in Madrid to introduce project and receive initial advice
September 16-17, 1992	SEAC meets to establish project guidelines
October 1992	WG drafts work plan
October 26-27, 1992	TAC and WG review work plan, discuss data, and propose methodology
November 1992-April 1993	WG performs technical work; Ecuadorian soils engineer visits University of British Columbia, and University of British Columbia structural engineer visits Quito
January 11-15, 1993	Four Ecuadorian members of SEAC tour California government agencies and corporations having exemplary earthquake risk management programs
March 1993	ALERTA, a private-sector disaster preparedness council, is created following the model of Los Angeles' BICEPP
May 27-28, 1993	TAC, WG, and Ecuadorian members of SEAC meet to review progress
May-July 1993	WG refines hazard assessment and interviews operators of Quito's infrastructure to evaluate vulnerability
July 14-15, 1993	Members of WG, TAC, SEAC, and selected experts participate in workshop to describe Quito's earthquake vulnerability and draft recommended mitigation actions
July 15, 1993	ALERTA hears presentations by members of Los Angeles' BICEPP and California's Seismic Safety Commission
July-September 1993	WG writes first draft of final technical report and sends to TAC for review
October 10, 1993	TAC and WG meet to review draft of final report
November 1993	World Conference of Building Officials initiates project to translate and adopt U.S. building codes for Ecuador
January 1994	WG and GeoHazards International submit report to mayor of Quito
March 3, 1994	Mayor of Quito makes public presentation of the findings of the project

Accomplishments

The project accomplished the following in regard to its objectives:

Toward improving the understanding of Quito's earthquake hazard, the project resulted in:

- A comprehensive but preliminary estimation of the consequences of potential earthquakes on Quito.
- A survey of Quito's urban infrastructure, with emphasis on its vulnerability to earthquakes.
- The initiation of a review by Ecuadorian insurance companies of their exposure in the event of a damaging earthquake.

Toward raising the awareness of the earthquake risk within Ecuador and internationally, the project resulted in:

- The publication of three technical papers about Quito's risk management measures at international conferences in San Francisco, California; Wellington, New Zealand; and Montreal, Canada.
- Nine workshops in Quito, in which for the first time more than 100 Ecuadorian and international specialists, including the Mayor of Quito and other officials, conferred about Quito's earthquake history, hazard, and risk.

Emergency response working group of the Earthquake Risk Management Workshop, July 1993.

- An international tour, in which four Ecuadorian government officials and business leaders visited 12 California government agencies and businesses that are specialists in earthquake preparedness.

- The attendance of two representatives of the mayor's office at the Metropolis Conference, a meeting of officials from the world's largest cities, in Montreal, Canada.

Plenary meeting of the Earthquake Risk Management Workshop, July 1993.

- The attendance of three Ecuadorian scientists and engineers at the Tenth World Conference on Earthquake Engineering in Madrid, Spain, and at a NATO-US AID sponsored Advanced Research Workshop in Istanbul, Turkey.

- Two 1-week technical exchange visits, one by an Ecuadorian engineer to a Canadian University, and one by a Canadian engineer to the Escuela Politécnica Nacional in Quito.

- The publication and distribution of the products of this report to a broad audience.

And toward designing self-sustaining programs to manage Quito's earthquake risk, the project resulted in:

- A framework—reviewed by international technical, government, and business specialists—of a comprehensive, multi-year program to manage Quito's earthquake risk.

- ALERTA, a private-sector disaster preparedness council to foster earthquake risk management, following the model of Los Angeles' Business and Industry Council for Emergency Planning and Preparedness (BICEPP).

- The capability of the Escuela Politécnica Nacional and the Municipio de Quito to create new earthquake damage estimates for other earthquakes, and the ability to obtain new data on soils and structural response.

- The World Conference of Building Officials initiating a project to translate and adopt U.S. building codes for Ecuador.

Appendix B

Priority Earthquake Risk Management Projects

Establish an Earthquake Safety Advisory Board

Implementation of earthquake risk management programs requires leadership, commitment, and ongoing oversight by government officials and community leaders. Efforts must be coordinated among government agencies, schools, businesses, financial institutions, and other entities concerned with the city's future economic health and welfare of its citizens. Such coordination and continuing progress toward earthquake safety goals require designation of primary responsibility and the formation of an oversight council or board.

Under this project, the Office of the Mayor of Quito would appoint a special assistant to the mayor, who would report directly to the mayor and be responsible for the earthquake safety program. The special assistant would serve as the mayor's liaison to the Earthquake Safety Advisory Board and as its executive director. The mayor's office would define the purpose and authority of the board, criteria for selecting members, and bylaws to govern the board's activities. The mayor would issue a resolution creating the board and appointing its members to represent business, emergency services, government, and the scientific and engineering communities.

The Earthquake Safety Advisory Board would advise the mayor, local government agencies, and private industry on earthquake preparedness and risk management issues. It would also be responsible for setting mitigation priorities based on the earthquake threat; developing and administering an earthquake risk management program; monitoring and regularly updating the earthquake risk management program; advocating the incorporation of mitigation measures into the urban development process; and seeking local and international funding for mitigation projects.

Responsible Agencies:
- The Mayor of Quito
- The Office of the Mayor

Adopt and Enforce an Effective Building Code

An effective building code helps to ensure that new facilities are designed and constructed to withstand earthquake shaking. Under this project, a committee of engineers and planners would design a building code for all structural types in Quito, facilitate the code's integration into design and construction, and regularly update the code. Enforcement is achieved by establishing a committee to educate builders, planners, and engineers about the building code; determining an efficient method for enforcing it; and training inspectors to evaluate building design and construction.

Auxiliary Tasks:
- Adopt stricter building codes for the design and construction of emergency service and critical facilities buildings including hospitals, fire stations, police stations, Civil Defense buildings, public buildings, and emergency shelters.
- Establish standards for retrofit of critical structures.
- Publish and distribute guidelines for the design of self-built structures for use by individuals constructing their own dwellings.

- Organize training courses for professionals on seismic design and construction of new buildings. Adapt procedures already developed in other countries.
- Include in each building loan agreement a contract to ensure that borrowers abide by building codes.

Possible Resources:

Building codes from global cities preclude the need for Quito to develop an entirely new code. An existing model, such as the *Uniform Building Code* (UBC) of the United States, provides a comprehensive framework into which Quito can incorporate appropriate seismic parameters, structural types, methods of construction, and properties of building materials. Local and international organizations, such as Escuela Politécnica Nacional and other universities, Consejo Nacional de Desarrollo, Consejo Nacional de Universidades, the Structural Engineers Association of California, the Applied Technology Council of California, the Seismic Safety Commission of California, the International Conference of Building Officials, and the World Organization of Building Officials, may be valuable in helping to develop a code.

Responsible Agencies:

- Sociedad Ecuatoriana de Ingeniería Estructural
- Cámara de la Construcción de Quito
- Municipio de Quito
- Instituto Ecuatoriano de Normalización

Support Scientific Research to Improve Earthquake Scenarios

The hazard assessment of the Quito Earthquake Risk Management Project was based only on available data. As a consequence, several assumptions were made about depth to bedrock under Quito, attenuation relations, response of soils, and response of typical structures. Further research will improve earthquake hazard assessments, methods of earthquake risk management, and earthquake codes and policies. Specifically, the following studies will improve knowledge of Quito's earthquake risk:

1. ***Expand the soil profile data base.*** Increase the number and depth of soil profiles to obtain a more detailed soil zonation of the city.
2. ***Map the bedrock.*** Map the depth and location of the bedrock to improve estimations of soil amplification.
3. ***Map active faults.*** To better estimate potential magnitudes and locations of earthquakes and to assess seismic potential, identify active faults and determine their geometries and mechanisms.
4. ***Install instruments to locate earthquakes, measure ground shaking, and evaluate response of buildings during earthquakes.*** Install and maintain state-of-the-art seismometers around Quito to measure and locate earthquakes, and strong-motion accelerometers in various buildings and in various soil zones to increase knowledge of site effects and specific dynamic characteristics of representative structures.
5. ***Develop improved procedures for estimating earthquake damage to structures in Ecuador.*** Many methods used throughout the world for estimating earthquake damage are from the United States or Japan, and therefore they do not always account for specific characteristics of other regions. Damage matrices, used in such estimations, that are specific to Ecuador should be developed to improve future earthquake risk assessments.
6. ***Develop a scenario for the greater Quito area and for other potential earthquakes.*** Develop an earthquake scenario for greater Quito and for other potential earthquakes in order to incorporate seismic safety into future planning

and development of the city. Future scenarios should include improved methods of estimating earthquake casualties and deaths for the purpose of emergency service response planning.

Possible Resources:

Possible sources of funding for this project include international agencies such as the United Nations Department of Humanitarian Affairs, US and Canadian AID, Banco Interamericano de Desarrollo, JICA, and ORSTOM; and private organizations and foundations, banks, insurance companies, and the industrial sector. Resources include graduate students, visiting experts, and the international community.

Responsible Agencies:

- Instituto Geofísico of Escuela Politécnica Nacional and other schools of engineering and geology
- Professional societies and unions (such as SEIE)

Develop a Workplace Earthquake Preparedness Program

This project educates personnel in all sectors of industry about earthquake risks and emergency preparedness. This would result in the spread of information to friends and family as well, thereby benefiting not only individual businesses and employees but the community at large. Under this project, management would first be trained to analyze the earthquake risks they face and develop risk management plans for their institutions. The Superintendencia de Bancos y Seguros, the Cámara de Industria, and other relevant organizations would require management to submit education plans. Employees at every level would then be educated in preparing for and surviving an earthquake.

Auxiliary Tasks:

- Hold industry-wide meetings to determine methods of increasing risk awareness and to emphasize the opportunity of managing these risks through policy measures.

Possible Resources:

Courses on earthquake risk and emergency preparedness may be available through or developed by the Red Cross, the fire department, ALERTA, and the Office of Civil Defense. Useful references include BICEPP (Los Angeles' Business and Industry Council for Emergency Planning and Preparedness) and the California Seismic Safety Commission publications. Private industry is an important source of funding for this project.

Responsible Agencies:

- Management of respective institutions
- ALERTA
- Superintendencia de Bancos y Seguros, Ministerio de Industria, and other relevant organizations

Improve Emergency Response Equipment and Facilities

Improved emergency response equipment and facilities are vital for quick, effective response to a major earthquake. Under this project, research teams would inventory available human and material resources, and based on a disaster scenario, determine vulnerabilities and critical needs. Priority should be given to fire-fighting equipment, search and rescue equipment, and hospitals.

Auxiliary Tasks:

- Work with the fire department and Empresa Municipal de Agua Potable to regularly inspect and repair fire hydrants.
- Secure funds to purchase a crane for use in repairing and replacing damaged main sewage collectors.

- Provide institutions, private businesses, industries, and social and public services with basic emergency equipment, such as first aid kits and emergency food and water reserves.
- Improve training of search and rescue teams.

Responsible Agencies:

- Relevant emergency services organizations
- Municipio de Quito
- Direcciónes de Planeamiento de la Seguridad para el Desarrollo Nacional

Establish a Proper Insurance Tariff with Underwriting Guidelines

A proper insurance tariff with insurance underwriting guidelines considering earthquake hazards would encourage responsible, earthquake-resistant design and construction. Under this project, the Superintendencia de Bancos y Seguros, in collaboration with Asociación de Compañías de Seguros del Ecuador, Asociación Nacional de Agencias Colocadoras de Seguros del Ecuador, and international reinsurers, would establish fair rating guidelines, which would make earthquake insurance available to residents of Quito. The insurance tariff and underwriting guidelines would be based on soil properties, estimated ground shaking intensities and subsequent geological hazards, damage distribution estimates, and structural design and construction. Rating discounts would then be available for structures with appropriate earthquake-resistant design and construction. A proper insurance tariff and underwriting guidelines could also ensure that earthquake insurance is feasible for existing structures, especially residential buildings.

Auxiliary Tasks:

- Evaluate sufficiency of client earthquake coverage.
- Train insurance company staff to advise clients on earthquake risk management actions.
- Train insurance company staff to monitor clients' adherence to the building codes.

Possible Resources:

Sources of information for this project include the system of tariffs used in Mexico, and CRESTA, the international working group of insurance and reinsurance companies.

Responsible Agencies:

- Superintendencia de Bancos y Seguros
- Asociación de Compañías de Seguros del Ecuador
- Asociación Nacional de Agencias Colocadoras de Seguros del Ecuador
- Reinsurers
- Insurance companies, agents, and brokers

Appendix C

Acronyms and Translations

Acronyms

ACOSE	Asociación de Compañías de Seguros del Ecuador
ANACSE	Asociación Nacional de Agencias Colocadoras de Seguros del Ecuador
ATC	Applied Technology Council (USA)
BICEPP	Business and Industry Council for Emergency Planning and Preparedness (Los Angeles)
CAMECO	Cámara Ecuatoriana de la Construcción
CDMG	California Division of Mines and Geology
CENAPRED	Centro Nacional de Prevención de Desastres (Mexico City)
CODIGEM	Corporación de Desarrollo Geológico Minero y Metalúrgico (Quito)
CONADE	Consejo Nacional de Desarrollo (Ecuador)
EEQ	Empresa Eléctrica Quito
EMA	Empresa Municipal de Alcantarillado (Quito)
EMAP	Empresa Municipal de Agua Potable (Quito)
EMETEL	Empresa Estatal de Telecomunicaciones (Quito)
IASPEI	International Association of Seismology and Physics of the Earth's Interior
IDNDR	International Decade for Natural Disaster Reduction
IFC	International Finance Corporation (Washington, DC)
IFEA	Institut Français d'Etudes Andines (Quito)
INECEL	Instituto Ecuatoriano de Electrificación
JICA	Japan International Cooperation Agency
NATO	North Atlantic Treaty Organization
OLADE	Organización Latinoamericana de Energía
ORSTOM	Institut Français de Recherche Scientifique pour le Developpement en Cooperation (France)
SEAC	Social and Economic Advisory Committee
SEIE	Sociedad Ecuatoriana de Ingeniería Estructural
TAC	Technical Advisory Committee
UNDRO	United Nations Disaster Relief Organization (Geneva)
UNESCO	United Nations Educational, Scientific, and Cultural Organization (Paris)
US AID	United States Agency for International Development
VPI	Virginia Polytechnic Institute
WG	Working Group

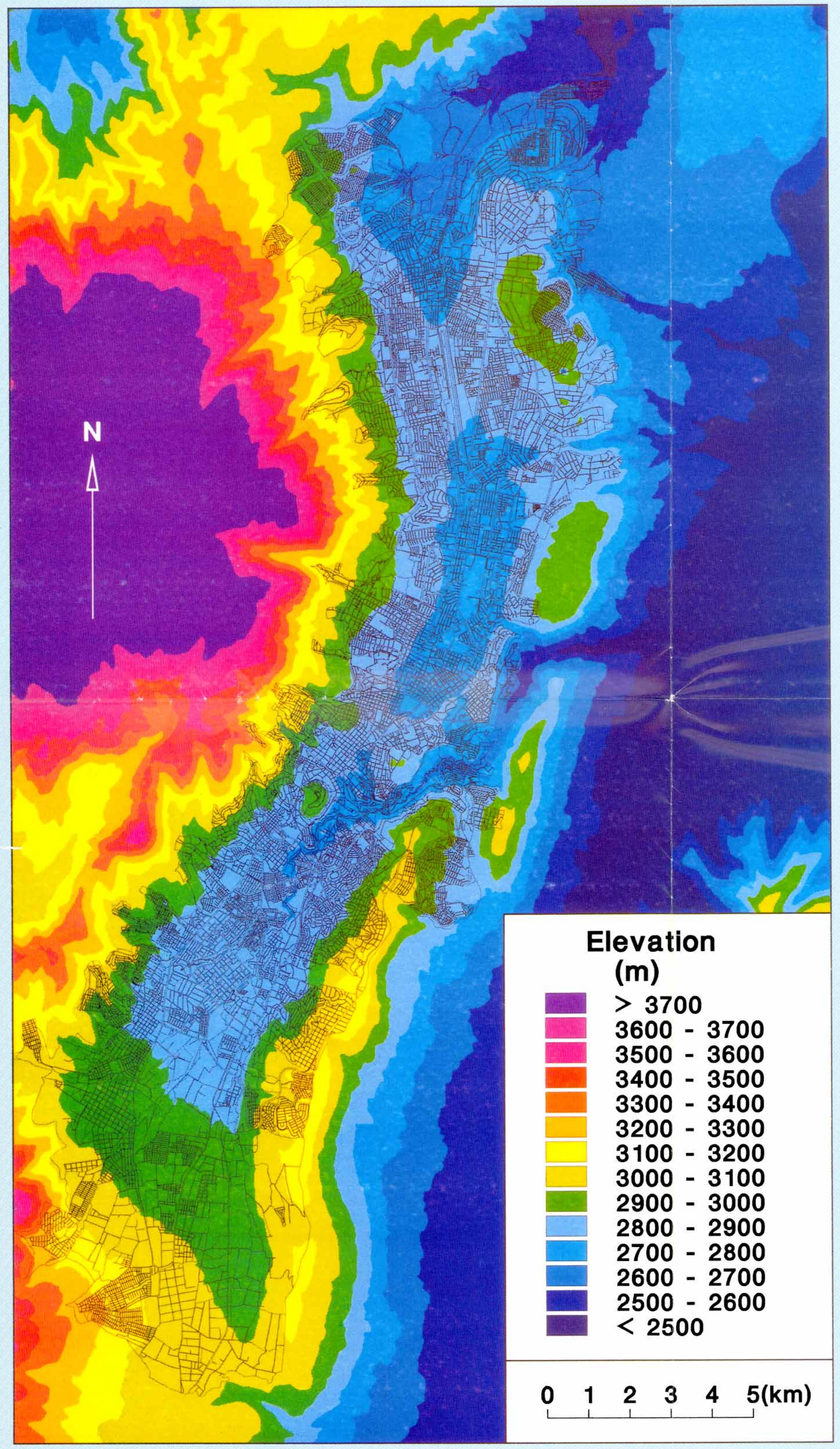
Translations

Asociación de Bancos Privados del Ecuador	Association of Private Banks of Ecuador
Asociación de Compañías de Seguros del Ecuador	Association of Insurance Companies of Ecuador
Asociación Ecuatoriana de Radiodifusión	Ecuadorian Association of Broadcasting
Asociación Nacional de Agencias Colocadoras de Seguros del Ecuador	National Association of Insurance Brokers of Ecuador
Banco Interamericano de Desarrollo	Interamerican Development Bank
Cámara de Industria	Chamber of Industry
Cámara de Industriales de Pichincha	Chamber of Industrialists of Pichincha
Cámara de la Construcción de Quito	Chamber of Construction, Quito
Cámara Ecuatoriana de la Construcción	Ecuadorian Chamber of Construction
Centro Nacional de Prevención de Desastres	National Center for Disaster Prevention
Compañeros de las Américas	Partners of the Americas
Consejo Nacional de Desarrollo	National Development Council
Consejo Nacional de Universidades	National Council of Universities
Corporación de Desarrollo Geológico Minero y Metalúrgico	Development Corporation of Geology, Mines and Metallurgy
Cuerpo de Bomberos de Quito	Quito Fire Brigade
Defensa Civil	Civil Defense
Dirección de Aviación Civil, Aeropuerto	Administration of Civil Aviation, Airport
Dirección de Fiscalización Ilustre Municipio de Quito	Municipal Administration of the Treasury, Quito
Dirección de Planificación	Planning Department
Direcciones de Planeamiento de la Seguridad para el Desarrollo Nacional	Offices of Security Planning for National Development
Dirección Nacional de Tránsito	National Administration of Transit
Empresa Eléctrica Quito	Quito Electrical Company
Empresa Estatal de Telecomunicaciones	State Telecommunications Company
Empresa Municipal de Agua Potable	Municipal Drinking Water Company
Empresa Municipal de Alcantarillado	Municipal Sewer Company
Escuela Politécnica Nacional	National Polytechnic School
Fondo de Salvamento	Salvation Fund
Fundación Rescate	Rescue Foundation
Ilustre Municipio de Quito	Illustrious Municipality of Quito
Instituto de Capacitación Municipal	Municipal Institute of Training
Instituto Ecuatoriano de Electrificación	Ecuadorian Institute of Electricity
Instituto Ecuatoriano de Normalización	Ecuadorian Institute of Standardization
Instituto Geofísico	Geophysical Institute
Ministerio de Industria	Ministry of Industry
Ministerio de Salud Pública	Ministry of Public Health
Organización Latinoamericana de Energía	Latin American Energy Organization
Sociedad Ecuatoriana de Ingeniería Estructural	Ecuadorian Structural Engineering Association
Superintendencia de Bancos y Seguros	Superintendence of Banks and Insurance
Unidad de Transporte Ilustre Municipio de Quito	Municipal Transportation Unit of Quito
Universidad Católica de Quito	Catholic University of Quito

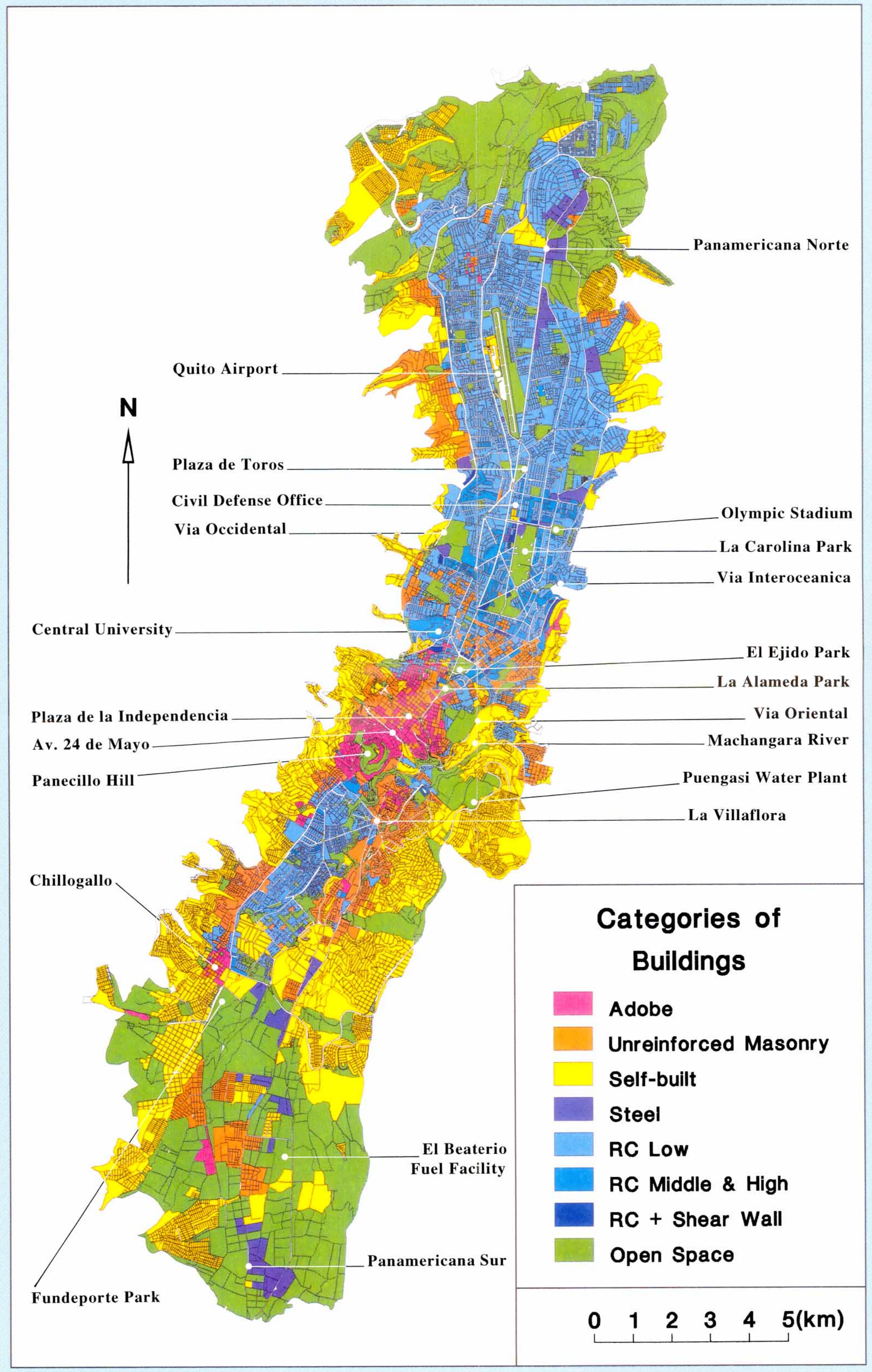
Back cover photo:
SPOT Satellite image ©CNES 1994

Selected Maps from the Quito, Ecuador Earthquake Risk Management Project

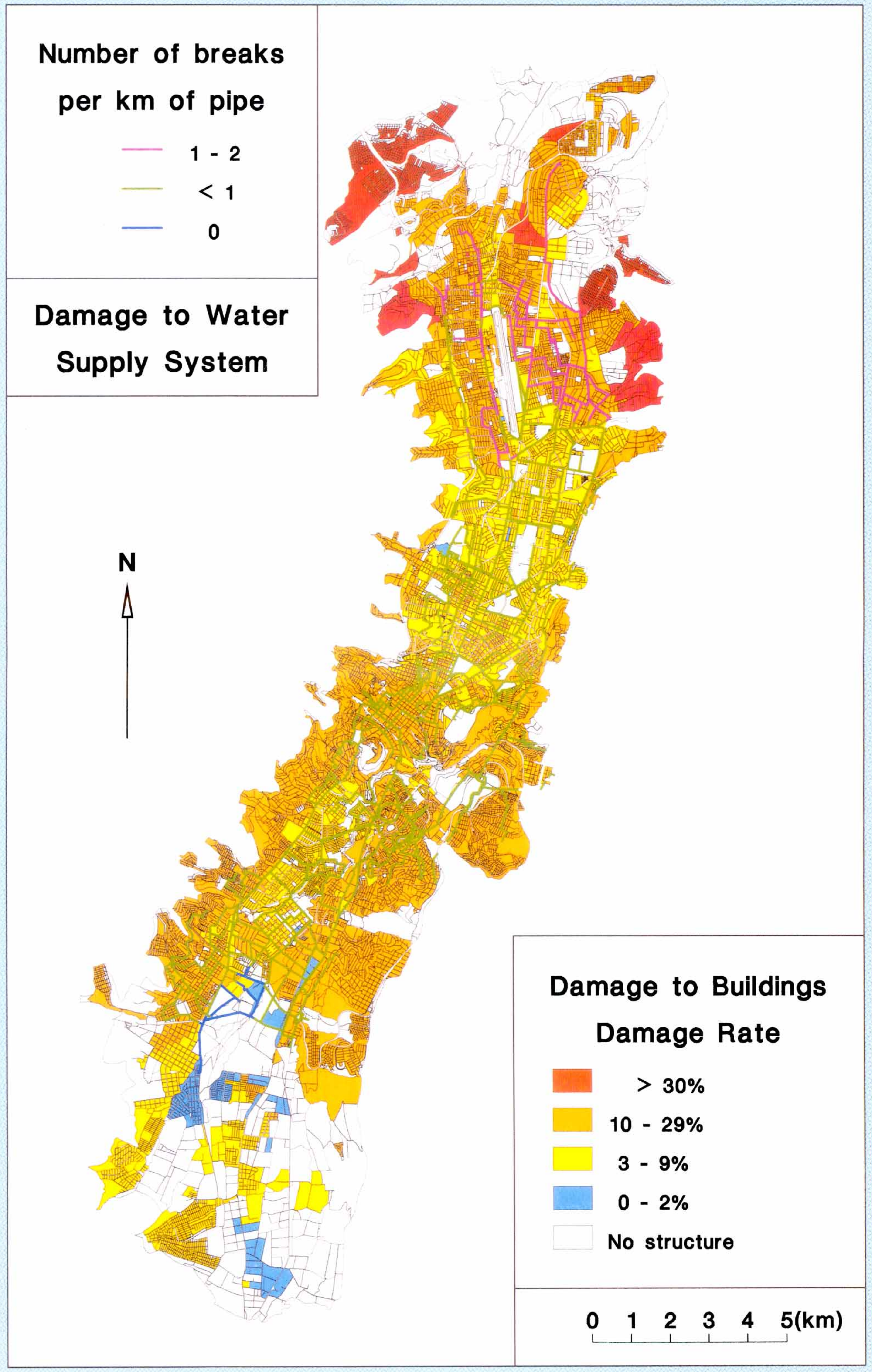
Escuela Politecnica Nacional GeoHazards International Ilustre Municipio de Quito ORSTOM Quito OYO Corporation



Topography of the Quito Area

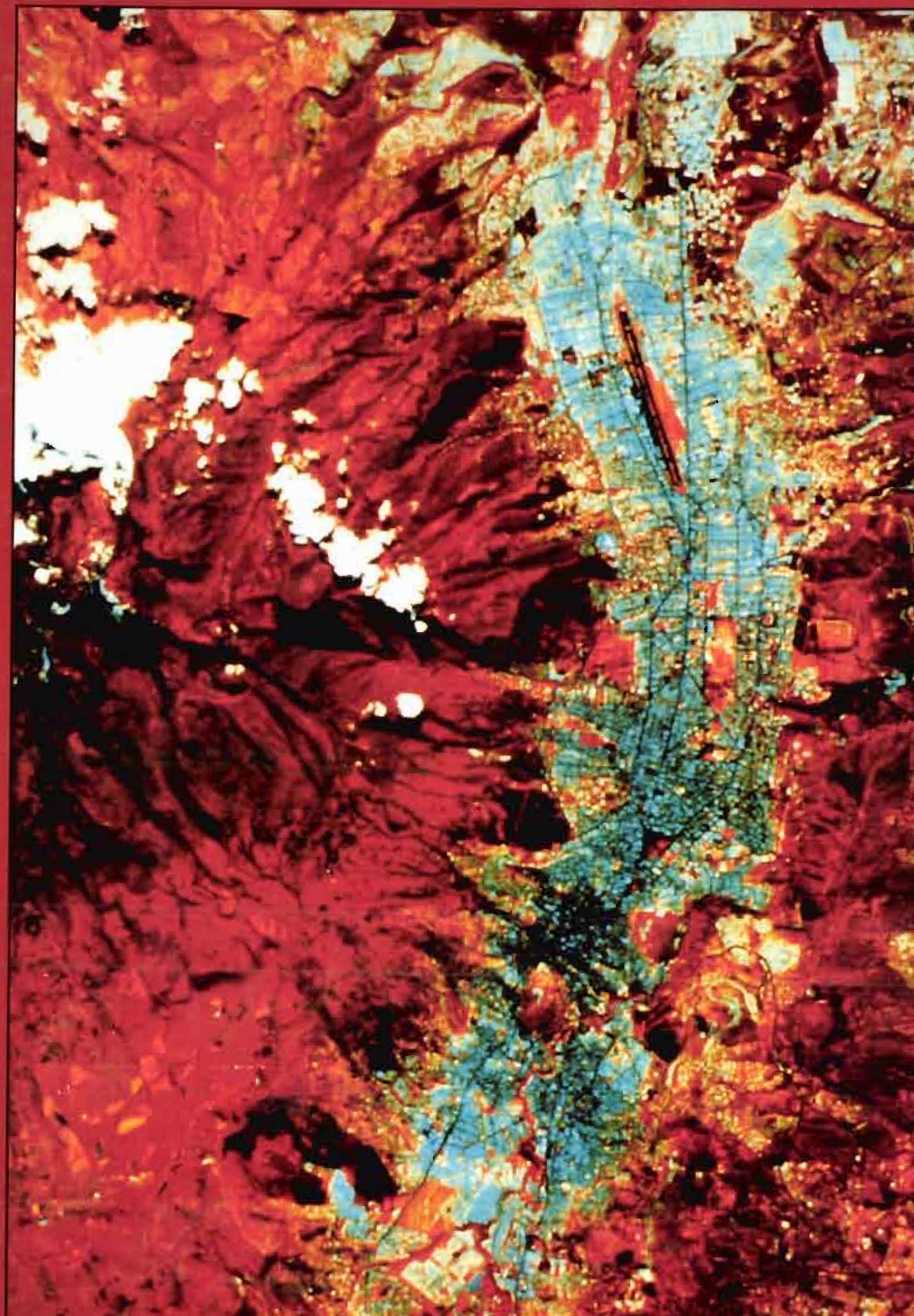


Distribution of Buildings Categories
Selected Landmarks



Damage Resulting from the Potential Local Earthquake

Infrared satellite image of Quito. Built areas appear blue, vegetation appears red.



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