# Chapter 4

# DAMAGE AND IMPACT OF EARTHQUAKE

## 4.1 Physical Damage and Human Impact

The earthquake struck the mountains of Central Luzon Island at the end of the rainy season. It had rained heavily on the days preceding the earthquake and the soils on the slopes were watersaturated and soft. As a consequence, the seismic activity triggered countless landslides throughout the mountain region.

Baguio, the city closest to the epicentre, became inaccessible, with all of the four major roads into the city cut by multiple slope failures. In the mountains of Nueva Vizcaya Province, towards the south-eastern end of the fault rupture, and particularly along the valley of Dalton Pass, an estimated 10% of slope coverage was immediately dislodged. Portions of some villages were swept away. Casualties were high, and in some cases it is still not known how many people were lost. Many people are still missing. Casualties also occurred in vehicles caught in the landslides. An unknown number of buses and "jeepneys" were buried, and others were carried down the mountainside.

Land instabilities continued to trigger landslides for several days. Three days after the earthquake heavy rains returned to central Luzon, causing more slope failures. As a result of the ensuing downpours, the soil coverage dislodged increased to 30%. Fewer casualties occurred during these subsequent days, but the number of people losing their homes increased dramatically. By the end of the rains, some 13,000 people were homeless in Nueva Vizcaya alone.

In Baguio City, 13 large reinforced concrete buildings collapsed. (Table 4.1-1) Despite the strong shaking experienced, the scale of the earthquake impact was not apparent immediately, since most of the timber-framed buildings and lower-rise concrete buildings in the city were undamaged. Unfortunately, the type of buildings that collapsed were mostly those that are occupied during working hours, such as schools, university buildings and commercial buildings. The only fortunate exception were the hotels, which do not have a high occupancy rate in the late afternoon.

The collapsed buildings were scattered throughout the city and it was almost 24 hours before the scale of the rescue resources needed became apparent. The local fire brigade, units from the Camp John Hay military base, and search and rescue teams from the nearby mining communities dealt with the collapsed buildings with the equipment they had available. The impassable roads into the city meant that additional equipment and heavy urban rescue machinery could not be moved in. As of December, routes through the mountains were still not capable of allowing heavy demolition machinery to be brought into the city.

**Table 4.1-1**
**Casualties in Collapsed Buildings, Baguio City, July 29, 1990**

| Building | Casualties | |
|---|---|---|
| | Dead | Alive |
| Hyatt Hotel | 27 | 9 |
| Hilltop Hotel | 4 | -- |
| Baguio Park Hotel | 14 | 9 |
| Export Processing Zone | 13 | 23 |
| Royal Inn | 7 | -- |
| Aurora Theater | 10 | 1 |
| University of Baguio | 99 | 86 |
| Pantranco | 2 | -- |
| Baguio Colleges | 3 | -- |
| Queen of Peace | 6 | 2 |
| Villanueva Apartel | 7 | -- |
| Lagman Building | 9 | 4 |
| Nevada Hotel | 25 | 12 |

Source: Advanced Command Post, Service Support Group, AFP, as of July 29, 1990.

Baguio airport suffered major ground settlement, and fissures in the runway prevented larger aircraft from landing. A helicopter air bridge was established, ferrying personnel, medical supplies and light equipment into the city.

The National Disaster Coordinating Council assumed command of the emergency. This was according to a disaster preparedness plan drawn up in 1978. Assessment of the effectiveness of the disaster emergency management is beyond the capability of this mission, but it is evident that the local control centre in Baguio was faced with an extraordinary situation of isolation and limited resources with which to deal with the immediate crisis.

International search and rescue units arrived to supplement the local teams after the third day. These included teams from Japan, USA, and the United Kingdom.

In Dagupan City there were no building collapses and damage from the vibrational energy of the earthquake was not as severe as the damage caused by liquefaction. Liquefaction was widespread and affected many of the commercial buildings in the central business district of the city. Thirteen people were killed in Dagupan city, some of the casualties were the outcome of movie goers stampeding out of a cinema, the rest were killed by falling debris in the streets.

## 4.2 Social Sector

### 4.2.1 Housing

The large majority of building stock in the affected area was not designed by engineers, but built by individual house owners, professional carpenters or building contractors. These non-engineered structures comprise nearly half the stock of residential buildings and much of the commercial low rise building stock.

Housing in the region is typically timber framed. The traditional form of house is a single storey, elevated off the ground on timber columns by a meter or more, and with a pitched roof with a large overhang and fairly slope of shallow 30 degrees or less. The distinctive Filipino roof style has a ventilating half gable appearing through the hipped roof. This characteristic design can be seen even in recent construction, where galvanized iron sheeting has replaced the traditional "nipa" palm thatching, and in the rarer reinforced concrete villas. The materials and styles of houses vary with age and location. The older, traditional and lower-cost houses use materials gathered locally, like unshaped timbers, bamboo and palm. "Sawali" walls, woven from flattened bamboo, form a light screen pervious to breezes, appropriate to the humid-tropical climate of the lowlands. These houses involve very little cash outlay to build, and traditionally are constructed by family and friends in a matter of hours. They represent the subsistence economy of villages and independent communities.

More numerous in the wealthier villages and in most urban residential areas are the cash-economy equivalent which uses purchased timber, factory-sawn, and is built by professional carpenters. Walls are built up in studwork and finished with external weather boarding or sheeting. Modern glazed windows have replaced the traditional open-lattice fenestration. Roofs are made from galvanized iron sheeting. A typical structure of around 50 square meters may cost 15-20,000 pesos (US$500-750) in materials, if the timber is purchased new. (A significant second-hand market exists for timber studs and boarding.) Structures of this type tend to be larger than traditional village homes, composed of several rooms and may be two storeys. This is accomplished by extending the stilts to a full storey height, to provide for storage or, when enclosed, to make a ground floor room. The ground floor structure is occasionally made from concrete block, which are typically manufactured by small local enterprises.

The more expensive houses are reinforced concrete framed structures of two or more storeys. These are built by local contractors, who also design the layout and use rule-of-thumb practices for construction details, assessment of reinforcement needs and other structural considerations. Frames are infilled with concrete block, and a timber roof covered with galvanized iron sheeting or larger profiled steel panels. These houses are thermally massive and often need to be air-conditioned. Concrete houses cost 5 to 10 times as much per square meter as timber houses.

In addition to the conventional types of housing there are the shanty shacks built by urban squatters from whatever is available. Sheeting is loosely tacked or wedged to tile the outside of the house, which is framed with any element that can be found. The shanty communities are usually found on the poorest sites, on steep slopes and marginal lands. Their siting on marginal land in the urban areas generally puts them at higher risk from site-related hazards, but in the two major cities affected by this earthquake, squatter settlements were not greatly affected by ground failures. In Baguio, the ravine sides on which most of the squatter settlements are located were spared serious failures. Fire caused by earthquakes overturning cookers or other sources of naked flame is a common hazard in closely packed shanty towns, but on this occasion no fire outbreaks were recorded.

Damage to timber housing was generally light. Losses did occur from ground failure in areas of major landslide or slope failure, but few houses suffered heavy damage from the vibrational effects of ground motion. No cases of a timber-framed building collapsing due to vibration were observed during the field study, even in areas where damage to masonry and other structures indicated that the intensities experienced had been high. Timber houses tend to be light, relatively well constructed, and ductile enough to survive ground shaking of high intensity without structural collapse. Older houses are noticeably more vulnerable, however, with timber becoming brittle and fixings deteriorating with age. In areas close to the epicentre, joints of older buildings can be seen to have failed, indicated by fallen beams or disconnected posts. Twisted or leaning buildings show that despite the failure of members and fixings, the structural frame and joints retain sufficient ductility to deform without collapse. The light structure of timber housing means that forces imposed on the structural system by even strong ground motion are relatively low. It is likely that higher forces are experienced from the wind loads of strong typhoons, which are experienced more frequently; it is probably true that a typhoon resistant house will also be earthquake-resistant. Exceptions to this occur when heavy loads are stored on upper floors, and the increasing trend towards using concrete block masonry in the wall construction. Both of these make the houses more vulnerable to earthquake damage. Non-engineered reinforced concrete houses proved more vulnerable to earthquake forces.

### 4.2.2 Educational Institutions and Other Public Buildings

Damage to buildings was found to be generally consistent with that of similar magnitude earthquakes in other parts of the world. The main types of damage were due to liquefaction of the soil in some towns such as Dagupan and Agoo, and damage or collapse due to severe ground shaking as in Baguio (30 - 40% g). Soil liquefaction caused loss of bearing capacity of foundations supporting buildings in Dagupan. Effects were similar to those observed in Niigata, Japan, during the 1964 earthquake. In both Niigata and Dagupan, many buildings underwent severe settlements as well as varying amount of tilting. Additional damage was often sustained as tilted buildings pressed against one another and caused cracking. It was noted that for many structures the settlement and tilting were the only damage. It may prove possible to correct this tilting by various techniques as was done in Niigata; however, the buildings are often of small size and the cost of correction need to be justified as compared to demolition and reconstruction.

Although a number of old buildings suffered damage and collapse due to ground-shaking effects, a surprising number of the newer and more modern-appearing buildings also collapsed. In fact, many older buildings withstood the earthquake with only minor damage. Many of the collapsed or severely damaged buildings failed in the columns, which is a very dangerous situation. A lack of concrete confinement and shear reinforcement at plastic hinge locations and/or inadequate anchorage of longitudinal bars contributed to this failure. Cracking was often observed to be the severest in areas of poor quality concrete. In most of the observed progressive failures of the buildings in pancake mode of failure are due to misconceptual earthquake resistant design with "only one line of defense" of rather brittle reinforced concrete frame structure with heavy floor structures and deep lintel beams. These buildings are usually designed considering only load carrying capacity without any consideration of deformability capacity or limitation of lateral displacements.

Of the public buildings affected by the earthquake, schools were the structures most often reported as damaged. In the National Capital Region alone, over 360 schools were reported as having suffered some damage. The majority of these received damage of a very limited nature; generally, minor cracking of plaster and hollow-block in-fill walls occurred. Twenty-four schools in the National Capital Region were reported as more severely damaged and condemned. Typically, these structures consist of reinforced concrete beams and columns with in-filled hollow block masonry walls. These buildings are relatively old and more probably designed and constructed based on the building codes which did not adequately consider earthquake forces.

For most of the damaged buildings inspected, in-filled masonry walls performed very poorly; these walls evidenced severe cracking and brittle failure. Poor construction and inadequate reinforcing contributed to the failures. Many of these walls are in a state of near-collapse and are still dangerous to occupants. The walls need to be adequately supported until they can be demolished.

Of the moderately damaged buildings investigated, some had more severe failures, but often only in isolated areas. A common type of failure occurred at beam to column connections. A lack of adequate concrete confinement and shear reinforcement at the top of columns contributed to these failures. Damage due to pounding was also often found at expansion joints in some of the schools. It appears that with adequate shoring, and other safety measures, these areas can be reconstructed.

In general, it appears that many of the school buildings in Manila reported as "condemned" can be brought back to their "pre-earthquake" condition. Such a reconstructed state is still a poor seismic risk. It is therefore recommended that these buildings be investigated for the possibility of additional seismic strengthening while being rehabilitated. The simple expedient of adding reinforced concrete shear walls in strategic locations to replace damaged masonry walls is one approach to increasing the survivability of these structures. This can only be done on a case/by/case basis after a condition survey and analysis of the existing building has been carried out. This analysis should also consider the interim conditions to which the building will be subjected during the construction of the proposed changes.

A number of public buildings that were severely damaged were in provincial areas. It was apparent that they had not been adequately reinforced for seismic loading. Construction was often shoddy as well. A recently constructed single storey building in Agoo was apparently so flexible that it caused hung ceilings and masonry walls to collapse, and windows to deform and break due to excessive swaying of the building. Structural failures occurred in the concrete beams and columns as well. Little consideration for the effects of seismic forces was apparent in the construction of this building.

**Based on the report of the Department of Public Works and Highways (DPWH)**, summary presentation of earthquake damaged school and public buildings is given in Table 4.2.2-1 and considered in respect to the total number of school buildings in the earthquake affected regions, provinces and major cities based on the data received from the regional offices of NEDA. The total number of damaged schools is estimated to 1,467 including Region IV-A and CAR. Most of these are primary and secondary schools. It appears that damage of school buildings is more or less uniformly distributed in CAR, Region I and III approaching 23-24% of the total number of existing public school buildings.

**Significantly higher damaging** effects are present in Baguio City (57.1%), Dagupan City (69.7%) and Cabanatuan (64.1%). In Baguio City, based on more detailed analysis of earthquake damage data presented in Tables 3.1-1, 62.5% of the total number of school buildings are out of use unless repair and strengthening of earthquake damaged buildings is provided, and about 11% of the total should be demolished. Considerable damage was also reported for the private colleges and universities. It should be recognized that a significant portion of the higher education facilities in Northern Luzon, more specifically in Baguio City, are privately funded institutions.

**More consistent summary presentation** of the earthquake effects to the school buildings is given in Table 4.2.2-2, based on the latest data obtained from the Department of Education, Culture and Sports, where damaged classrooms of public elementary and secondary schools and private schools are given separately for the CAR, Region I, II, and III. The total number of earthquake damaged classrooms of public elementary and secondary schools for all four regions is 6,137 or 7.7% of the total number of existing schools in the considered regions, and 2.1% of the total number in the Republic of the Philippines. With the additional similar effects to the private schools in the same four regions, the total number of earthquake damaged classrooms approaching 14.8% in respect to the existing one in the considered regions, or 3.7% in respect to the existing classrooms in the Republic of Philippines, which should be considered as very serious impact to the entire educational system.

**Other public buildings** like administrative buildings of the regional, city, municipality and local governmental buildings, police and fire stations, court buildings, libraries, etc., experienced significant damage. About 120 buildings are reported with observed damage (Table 4.2.2-1) dominantly in the CAR and Region I (87%). In Baguio City, for example, out of the considered 19 public buildings, 14 (78.7%) are out of use before repair and strengthening is provided. Considering that most of the public buildings (police and fire stations, etc.) are playing very important role in post-earthquake rescue operations it is of utmost importance that they should be upgraded in the repair and strengthening process to the level that they could resist future strongest earthquakes without structural damage. For this purpose, significant change in the design criteria and selection of more adequate earthquake resistant structural systems like shear wall structures should be implemented.

**Summarizing the effects** of the Luzon Earthquake of 16 July 1990 on educational facilities (schools, colleges and universities) and other public buildings, it is quite evident that they are extremely large approaching about 15-25% of the total stock of existing facilities in the CAR, Region I, II, and III and over 50% in the most affected areas (Baguio, Dagupan, Agoo). This is not acceptable from the safety and economic point of view. In addition, considering that most of these buildings are modern reinforced concrete constructions (NCR, Baguio, etc.) it is quite obvious that earthquake resistant design criteria and selection of more favorable structural types should be implemented in the reconstruction and development process of the earthquake affected regions and entire Republic of Philippines considering its frequent and highly intensive exposure to the earthquakes and other natural hazards.

4.2.3 Health (Hospitals, Clinics and Health Stations)

Damage to health buildings and other medical facilities as a direct effect of the Luzon Earthquake of 16 July 1990 was extensive one, reported from Cordillera Autonomous Region (CAR), Regions I, II, and III, and from National Capital Region (NCR). The most affected provinces were Benguet, Mountain Province, Ifugao, Kalinga-Apayao, La Union, Pangasinan, Nueva Vizcaya and Nueva Ecija.

Summary presentation of earthquake damage to the health facilities like hospitals, health centers, and barangay (commune) health stations is given for the five affected regions in Table 4.2.3-1, together with total number of considered health facilities based on the latest available data provided by the Department of Health (December 1990).

**Hospitals:** Total number of damaged hospitals is 86 making 4.8% of the total number in the Republic of Philippines, or only for CAR, Region I, II, and III 16.3% (69) are damaged in respect to the total number of 424 hospitals in these four regions. It is rather surprising that 17 hospitals experienced damage in NCR due to earthquake ground motions with peak ground acceleration estimated lower than 10% g (Fig. 2.12) at an epicentral distance of about 120 km. Although, this earthquake effects in NCR could be attributed to the high amplification of the earthquake ground motions and soft soil conditions at the sites of the hospital locations, for rather modern reinforced concrete constructions, it should not be expected to be damaged by moderate earthquake ground motions estimated at MM scale intensity of VII degrees (Fig. 2.10).

**Health Centers:** Total number of damaged health centers in the cities and municipal areas are 112 making 21.5% of the total existing number of health centers in the four most affected regions, or 5.4% of the total number in the country. Most of these health centers are constructed as reinforced concrete structures of low-rise buildings. Although, dominant damage is to the nonstructural elements, some of these buildings are severely damaged to be demolished or out of use (Baguio 66.7%, Table 3.1-1) until proper repair and strengthening is provided.

**Barangay Health Stations:** 310 barangay health stations are reported damaged making 11.6% of the existing health stations located in the four most affected regions (Table 4.2.3-1), or 3.4% of the total number of barangay health stations in the country. Most of these buildings are 1-2 storey timber houses with ground floor of concrete hollow blocks and with galvanized steel sheet roofs, representing relatively light structural systems. Major cause of damage and failure to these relatively small buildings could be attributed to the improper integration concrete block structure with r.c. elements and brittle behavior concrete block walls.

**Health Buildings:** In total, health buildings of hospitals, health centers, and barangay health centers suffered extensive damage making 13.5% of the total number of the health facilities in CAR, Region I, II, and III, or 3.9% of the total number of health facilities in the Republic of Philippines. the largest number of damaged health facilities is in Region I, 15.2% of total existing in the region, 17.3% of existing health centers and 15.8% of existing barangay health stations. The largest number of damaged hospitals is in Region III, making 12.4% of existing ones as well as health centers making 18% of the existing ones in this region.

**Damage to Medical Equipment:** Medical equipment damage was generally the result of its falling over due to induced earthquake ground motions as well as structural and non-structural elements partial failure of the health buildings. Damage to the medical equipment is estimated at a total P25 million in the provinces and P2.5 million in NCR, which makes about 12.2% of the estimated cost for reconstruction of all the damaged health buildings (World Bank Report, Technical Annex, 1990).

**Summarizing the effects** of the Luzon Earthquake of 16 July 1990 on health facilities, it is evident that they experienced an extensive damage mainly due to rather low implementation of consistent earthquake resistant design and proper quality of construction as well as implementation of favorable structural systems. Considering that health facilities are of the highest importance in the immediate post-earthquake conditions and rescue operations, it is necessary to reorganize the need for improvement of the earthquake resistant design criteria, improvement of existing structural systems and selection of more favorable structural systems to be implemented in the reconstruction and development process of the earthquake affected region and the entire country.

Table 4.2.2-1
**SUMMARY PRESENTATION OF SCHOOL AND PUBLIC BUILDINGS DAMAGED DUE TO LUZON EARTHQUAKE OF 16 JULY 1990 (Source DPWH, Republic of Philippines)**

| Region - Province City | School Buildings (SB) | | | Public Buildings (PB) |
|---|---|---|---|---|
| | Total No. of Schools | No. of Damaged | % Damaged of Total | |
| **1. CAR:** | **543** | **132** | **24.3%** | **31** |
| 1.1. Baguio City | 70 | 40* | 57.1 | 14* |
| 1.2. Abra | 296 | 50 | 16.9 | 9 |
| 1.3. Ifugas | 177 | 42 | 23.7 | 8 |
| **2. REGION I:** | **2,274** | **532** | **23.4%** | **72** |
| 2.1. Pangasinan | 1,231 | 351 | 28.5 | 50 |
| 2 2. La Union | 459 | 45 | 9.8 | 12 |
| 2.3. Dagupan | 33 | 23 | 69.7 | 9 |
| 2.4. Ilocos Sur | 486 | 86 | 17.7 | |
| 2.5. San Carlos | 65 | 27 | 41.5 | 1 |
| **3. REGION III:** | **1,420** | **348** | **24.5%** | **5** |
| 3.1. Cabanatuan | 53 | 34 | 64.1 | 5 |
| 3.2. Olongapo | 27 | 7 | 25.9 | |
| 3.3. Nueva Ecija | 687 | 101 | 14.7 | |
| 3.4. Bataan | 156 | 55 | 35.2 | |
| 3.5. San Jose | ? | 32 | | |
| 3.6. Pampanga | 497 | 119 | 23.9 | |
| **TOTAL CAR, REG. I & III:** | **4,237** | **1,012** | **23.9%** | **108** |
| **4. REGION IV-A:** | | **92** | | |
| 4.1. Pizal | | 38 | | |
| 4.2. Cavite | | 25 | | |
| 4.3. Lipato | | 7 | | |
| 4.4. Quezon | | 22 | | |
| **5. NCR** | | **363** | | **10** |
| **TOTAL 1-5:** | | **1,467** | | **118** |

* Considered private and governmental school buildings based on data from Mayor Office, Baguio City.

Table 4.2.2-2
SUMMARY PRESENTATION OF DAMAGED CLASSROOMS OF PUBLIC ELEMENTARY AND SECONDARY SCHOOLS AND PRIVATE SCHOOLS, DUE TO LUZON EARTHQUAKE OF 16 JULY 1990

| Region | Total No. | Damaged | % Damaged of Total | % Damaged of Total in Philippines |
|---|---|---|---|---|
| **NUMBER OF CLASSROOMS:** | | | | |
| 1. CAR | 5,565 | 1,338 | 20.4% | |
| 2. Region I | 27,453 | 3,852 | 14.0% | |
| 3. Region II | 21,419 | 726 | 3.4% | |
| 4. Region III | 25,610 | 221 | 0.9% | |
| Philippines: 285,050 | | | | |
| **Total 1-4:** | **80,047** | **6,137** | **7.7%** | **2.1%** |
| PRIVATE SCHOOLS: | | | | |
| 1. CAR | 156 | 9 | 5.8% | |
| 2. Region I | 332 | 57 | 17.2% | |
| 3. Region II | 194 | 6 | 3.1% | |
| 4. Region III | 450 | 9 | 2.0% | |
| Philippines: 5,051 | | | | |
| **Total 1-4:** | **1,132** | **81** | **7.1%** | **1.6%** |

Source: Department of Education, Culture and Sports, Republic of Philippines, December 1990.

## Table 4.2.3-1

### SUMMARY PRESENTATION OF HEALTH FACILITIES (HOSPITALS, HEALTH CENTERS AND BARANGAY HEALTH STATIONS) DAMAGED DUE TO LUZON EARTHQUAKE OF 16 JULY 1990

| Region | Hospitals | | | Health Centers | | | Barangay Health Stations | | | Total Health Facilities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total No. | No. of Damaged | % Damaged of Total | Total No. | No. of Damaged | % Damaged of Total | Total No. | No. of Damaged | % Damaged of Total | Total No. | No of Damaged | % Damaged of Total |
| 1 CAR | - | 27 | - | | 32 | - | - | 133 | - | | 192 | - |
| 2 Region I | 141 | 12 | 8.5% | 191 | 33 | 17.3% | 912 | 144 | 15 8% | 1,244 | 189 | 15.2% |
| 3 Region II | 106 | 8 | 7.5% | 124 | 10 | 8.1% | 553 | 4 | 0 7% | 783 | 22 | 2.8% |
| 4. Region III | 177 | 22 | 12.4% | 206 | 37 | 18.0% | 1,211 | 29 | 2.4% | 1,594 | 88 | 5.5% |
| 5. NCR | - | 17 | - | - | - | - | - | - | - | - | 17 | - |
| TOTAL (1-4)* | 424 | 69 | 16.3% | 521 | 112 | 21.5% | 2,676 | 310 | 11.6% | 3,621 | 491 | 13.5% |
| TOTAL (1-5)* | | 86 | | | 112 | | | 310 | | | 508 | |
| Philippines | 1,782 | | | 2,072 | | | 9,184 | | | 13,038 | | |
| % No. Damaged (1-5)/ Philippines | | 86 | 4.8% | | 112 | 5.4% | | 310 | 3.4% | | 508 | 3.9% |

Source: Department of Health, Republic of Philippines, December 1990
N.B * Health facilities of CAR are integrated in Regions I and II

### 4.3 Productive Sectors*

Economic losses caused by the earthquake far exceeded the cost of repairing the physical damage. The biggest impact of the earthquake came in the form of displaced labor and foregone revenues and opportunities. Labor displacement in industry, trade and tourism has been estimated at 8,556 in CAR, 11,345 in Region I, and 10,500 in Region II. While the displacement of labor was generally temporary, it is expected that a significant number of jobs will be lost as a result of reduced economic activities and consumer spending in the affected areas.

#### 4.3.1 Agriculture

The costs of physical damage reflect the resources needed, for example, to restore infrastructure, replace standing crops that were lost, and restock fishponds (see Table 4.3.1-1). The larger and more significant economic losses in agriculture include: (a) foregone income from crops destroyed by the earthquake; (b) foregone income from disruption in distribution flows of agricultural inputs and outputs due to infrastructure failure and associated transport problems; (c) foregone income of displaced labor; and (d) losses in production resulting from changes in land use and productivity. To date the government and has only estimated the economic losses based on foregone income from affected production activities.

In the rice subsector, foregone income was computed based on the value of production losses due to landslides and erosion in the four badly hit regions. They were valued at P5,000 per metric ton of estimated loss. In addition, there was an estimated 30 percent reduction in yield due to the non-availability of fertilizer and other inputs when the Dalton Pass road was closed cutting off supply to the Cagayan Valley. The earthquake coincided with the planting season when the fertilizers were critically needed. The earthquake also damaged several irrigation facilities, particularly in the Pantabangan area which services the provinces of Nueva Ecija, Pampanga and Tarlac, some of the most important rice producing areas of Luzon. This resulted in inadequate water supply which was estimated to have caused a decrease of some 12 percent in yield for about 58,000 hectares of rice lands. Based on damages reported by the end of August, income foregone in the rice subsector was estimated at P498 million (Table 4.3.1-2). Total production losses were estimated at 99,633 metric tons from 96,972 hectares of affected rice lands.

The losses in rice production and the disruption in transport of the rice that was produced substantially affected the supply in Metro Manila as well as in the other areas of Luzon. Prices would have risen dramatically if it were not for government price control measures. The effect on the income of farmers, particularly the small ones, due to disruption in supply of inputs and marketing of outputs has yet to be quantified.

Foregone income in the vegetable subsector stood at about P81 million based on an estimated gross production return of P20,000 per hectare (Table 4.3.1-3). Landslides hampered the marketing of harvested vegetables. As a result, retail prices of vegetables, particularly those coming from Ifugao and Benguet provinces, increased as much as 16 percent in Metro Manila immediately after the earthquake.

Fish farming is a major agricultural activity in Pangasinan Province and particularly in Dagupan City. Milk fish and other breeds are raised in shallow ponds of brackish water along the coast, contained by earth-bank dikes. Losses were caused by collapsing dikes and some liquefaction sand boils. Recent estimates by Region I Regional Development office put the recovery resources needed to compensate fishpond operators at some 386 million pesos. This is more than double the resources assessed for the recovery of crop and other agricultural losses in the region (160 million pesos) and is close to the amount needed to repair road infrastructure in Dagupan City (436 million pesos), and presumably reflects the importance assigned to the recovery of fish farming in the economy of the region. (Table 4.3.1-4)

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* N.B.: This section draws heavily on text and data of the Reconstruction and Development Program report of the National Economic Authority, November 1990, pp. 16-24.

Table 4.3.1-1

**DAMAGE TO PRIVATE SECTOR PRODUCTION: AGRICULTURE, FISHERIES, AND LIVESTOCK**

| Commodity | Region/Province | Area Damaged * (Has.) | Actual Loss (P) |
|---|---|---|---|
| RICE | CAR | | |
| | Abra | 277 | 1,382,850 |
| | Benguet | 465 | 2,325,000 |
| | Mt. Province | 36 | 178,000 |
| | Ifugao | 70 | 350,000 |
| | REGION I | | |
| | Ilocos Sur | 568 | 2,840,000 |
| | La Union | 1,495 | 7,475,000 |
| | Pangasinan | 5,468 | 27,342,100 |
| | REGION II | | |
| | Nueva Vizcaya | 225 | 1,125,000 |
| | REGION III | | |
| | Tarlac | 1,232 | 1,160,000 |
| | Nueva Ecija | 4,336 | 21,660,000 |
| | Subtotal | 14,172 | 70,857,950 |
| VEGETABLES | CAR | | |
| | Abra | 46 | 459,000 |
| | Mt. Province | 177 | 1,770,000 |
| | Benguet | 2,166 | 21,660,000 |
| | REGION I | | |
| | Ilocos Sur | 2 | 20,000 |
| | REGION II | | |
| | Nueva Vizcaya | 880 | 8,800,000 |
| | REGION III | | |
| | Nueva Ecija | 655 | 6,550,000 |
| | Subtotal | 3,926 | 39,259,000 |
| FISHERIES | | Area (Hectares) | |
| Fishpond | CAR | | |
| | Abra | 0.75 | 39,900 |
| | Benquet | 2.00 | 106,400 |
| | Ifugao | 2.50 | 133,000 |
| | Kalinga Apayao | 10.00 | 532,000 |
| | REGION I | | |
| | Pangasinan | 2,662 | 222,942,500 |
| | La Union | 408 | 34,186,750 |
| | REGION III | | |
| | Tarlac | 7 | 611,375 |
| | Pampanga | 10 | 866,813 |
| | Nueva Ecija | 18 | 1,507,500 |

| Commodity | Region/Province | Area Damaged * (Has.) | Actual Loss (P) |
|---|---|---|---|
| | | No. of Bancas | |
| Municipal Fisheries | REGION I | | |
| | Pangasinan | 46 | 195,200 |
| | La Union | 27 | 405,000 |
| | | Number of Facilities | |
| Fish Processing | REGION I | | |
| | Pangasinan | 29 | 374,750 |
| | Subtotal | | 261,901,188 |
| TOBACCO** | CAR | | |
| | Abra | 6 | 33,500 |
| | (No. of Facilities) | | |
| | REGION I | | |
| | La Union | 253 | 106,170,300 |
| | Pangasinan | | |
| | - facilities | 20 | 1,714,000 |
| | - area | 24 | 170,400 |
| | REGION III | | |
| | Tarlac | 1 | 10,000 |
| | Nueva Ecija | 21 | 210,000 |
| | Subtotal | 279 | 108,308,200 |
| | | Head | |
| LIVESTOCK | CAR | | |
| | Abra | 71 | 639,000 |
| | Benquet | 156 | 234,000 |
| | Mt. Province | 266 | 399,000 |
| | Kalinga Apayao | 657 | 639,700 |
| | REGION I | | |
| | Pangasinan | 8,017 | 36,873,600 |
| | La Union | 182 | 693,000 |
| | REGION III | | |
| | Nueva Ecija | 16 | 144,000 |
| | Subtotal | 9,365 | 39,622,300 |
| | GRAND TOTAL | | 519,948,638 |

* Damage on standing crop/production for one cropping season
** Damage to facilities such as trading centers, curing barns, redrying barns

Source: Department of Agriculture - Agriculture Information Management Staff

Table 4.3.1-2

**FOREGONE INCOME OPPORTUNITY LOSSES IN THE RICE SUB-SECTOR***

**(As of August 31, 1990)**

| REGION/PROVINCE | AREA DAMAGED (Has.) | PRODUCTION LOSS (M.T.) | FOREGONE INCOME (P) |
|---|---|---|---|
| CAR | | | |
| Abra | 277 | 805 | 4,025,000 |
| Benguet | 465 | 842 | 4,208,250 |
| Mt. Province | 36 | 81 | 404,060 |
| Ifugao | 70 | 230 | 1,148,000 |
| Subtotal | 848 | 1,958 | 9,785,310 |
| REGION I | | | |
| Ilocos Sur | 568 | 1,931 | 9,656,000 |
| La Union | 2,495 | 5,008 | 25,041,250 |
| Pangasinan | 5,468 | 17,608 | 88,041,562 |
| Subtotal | 7,531 | 24,547 | 122,738,812 |
| REGION II | | | |
| Nueva Vizcaya | 225 | 812 | 4,061,250 |
| Subtotal | 225 | 812 | 4,061,250 |
| REGION III | | | |
| Tarlac | 1,232 | 4,571 | 22,853,600 |
| Nueva Ecija | 4,336 | 18,645 | 93,224,000 |
| Subtotal | 5,568 | 23,216 | 116,077,600 |
| TOTAL | 14,172 | 50,533 | 252,662,972 |
| Cagayan Valley ** | 24,800 | 26,480 | 132,398,650 |
| Affected areas due to damaged irrigation systems*** | 58,000 | 22,620 | 113,100,000 |
| TOTAL | 82,800 | 49,100 | 245,498,650 |
| GRAND TOTAL | 96,972 | 99,633 | 498,161,622 |

* Covers one cropping season

** Probable reduction in yield of 30% due to non-availability of fertilizer

*** Decrease in yield of 12% due to inadequate water supply caused by damaged irrigation systems; covers two cropping seasons

Source: Department of Agriculture - Agriculture Information Management

Table 4.3.1-3

**FOREGONE INCOME IN THE VEGETABLE SUB-SECTOR**
**(As of August 31, 1990)**

| REGION/ PROVINCE | AREA DAMAGED (Has.) | FOREGONE INCOME LOSS (P) |
|---|---|---|
| CAR | | |
| Abra | 46 | 918,000 |
| Ifugao** | - | 2,195,000 |
| Mt. Province | 177 | 3,540,000 |
| Benguet | 2,166 | 43,320,000 |
| Benguet** | - | 220,400 |
| Subtotal | 2,389 | 50,193,400 |
| REGION I | | |
| Ilocos Sur | 2 | 40,000 |
| Subtotal | 2 | 40,000 |
| REGION II | | |
| Nueva Viscaya | 880 | 17,600,000 |
| Subtotal | 880 | 17,600,000 |
| REGION III | | |
| Nueva Ecija | 655 | 13,100,000 |
| Subtotal | 655 | 13,100,000 |
| T O T A L | 3,926 | 80,933,400 |

** unmarketed vegetables due to landslide

Source : Department of Agriculture-Agriculture Information Management Staff

Table 4.3.1-4

**FOREGONE INCOME IN THE FISHERIES SUB-SECTOR**

**(As of August 31, 1990)**

| SECTOR/REGION/ PROVINCE | AREA DAMAGED (Has.) | FOREGONE INCOME * (P) | TOTAL VALUE OF DAMAGES** (P) |
|---|---|---|---|
| FISHPONDS | | | |
| CAR | | | |
| Abra | 1 | 26,250 | 66,150 |
| Benguet | 2 | 70,000 | 176,400 |
| Ifugao | 3 | 87,500 | 220,500 |
| Kalinga-Apayao | 10 | 350,000 | 882,000 |
| Subtotal | 15.25 | 533,750 | 1,345,050 |
| REGION I | | | |
| Pangasinan | 2,662 | 124,226,667 | 347,169,167 |
| La Union | 408 | 19,049,333 | 53,236,083 |
| Subtotal | 3,070 | 143,276,000 | 400,405,250 |
| REGION III | | | |
| Tarlac | 7 | 340,667 | 952,042 |
| Pampanga | 10 | 483,000 | 1,349,813 |
| Nueva Ecija | 18 | 840,000 | 2,347,500 |
| Subtotal | 35 | 1,663,667 | 4,649,355 |
| TOTAL | 3,120 | 145,473,417 | 406,399,655 |
| MUNICIPAL FISHERIES | | | 974,950 |
| GRAND TOTAL | | | 407,374,605 |

* Income foregone from one cropping during reconstruction of damaged fishponds

** Foregone income plus actual losses

Source: Department of Agriculture - Agriculture Information Management Staff

4.3.2 Mining

It is estimated that the mining sector will to lose about P1.2 billion in 1990 from reduced production of gold, copper and silver. Gold output is expected to fall significantly due to the disruptions in the operations of the Benguet, Philex, and Lepanto companies. This drop is projected by the government to exceed 1,000 kilograms in 1990 for a total opportunity loss of about $12.99 million or P338 million (based on September 1990 world prices). In addition, many small-scale gold miners experienced a drop in production when they temporarily ceased activities due to damage to their operations and fear of aftershock induced landslides.

Copper production is expected to decline substantially. Philex had to stop work for more than a month, and Lepanto reduced production by 10 percent. Lepanto has been unable to transport its concentrate outputs to the port in San Fernando, La Union due to earthquake-damaged roads and bridges. Lepanto is also incurring extra transport expenses of about P5 million per month. Trucks that would normally link the mine with the port at San Fernando over a regular route of 160 km. must now detour over an alternate route of more than 1,000 km. As a result of all these factors, total copper production loss has been estimated at P834 million. However, if the roads from the mine site to the shipment point do not become passable by year-end, Lepanto will have to further reduce its production to 30 percent increasing the projected loss to P1.67 billion.

Silver production is mainly a by-product of gold and copper mining. Therefore, a proportional reduction in silver production will follow drops in the production of the other metals. It is estimated that the output for 1990 will drop by 2,500 kilograms valued at P10 million.

4.3.3 Manufacturing

In manufacturing, the gross value added is expected to drop significantly. The affected regions normally contribute about 11 percent to the country's manufacturing output. The damages sustained in the Baguio City Export Production Zone directly affected the operations of firms engaged in the manufacture of garments, bags, and metal fittings. The earthquake also caused a slowdown in production of industries, such as handicrafts and processed foods, which cater to tourists. Foregone revenues in manufacturing are expected to reach P250 million by year-end.

4.3.4 Construction

As a result of the massive rebuilding requirements in the affected regions, the construction sector has become a major focus of economic activity. Expansion, however, will depend on how well input suppliers can respond to the growth in demand. Local construction material producers are assured of ready markets, but many are having difficulty in providing adequate supply.

#### 4.3.5 Environment and Natural Resources

The earthquake has had a severe impact on the environment and natural resources. Although the shortage of data prevents a full quantitative assessment of ecological damages, it can be observed that the resulting soil erosion has caused severe siltation and sedimentation. This results in decreased agricultural productivity in the highland areas, and increased susceptibility of river systems to flooding in low lying areas.

Damage to watershed areas and forest plantations (e.g.: ISF-CARP, mangrove, timber stand improvement) may lead to further soil instabilities in the months to come.

### 4.4 Infrastructure Sector

The extent of earthquake damage to public infrastructure and facilities such as national, barangay (communal), and city roads and bridges; flood control, irrigation and water supply systems, ports, etc., was by far the largest one of all the sectors.Total resources allocated to reconstruction in this sector are P16.5 billion, equivalent to 48% of the P10 billion fund for reconstruction of the earthquake stricken region.

Some of the major arterial roads and bridges that were damaged are the San Jose - Sta. Fe section of the Maharlika Highway in Nueva Ecija, the Carmen Bridge in Pangasinan, the Baguio-Bontoc Road, and the access roads to Baguio City: Kennon Road, Marcos Highway and Naguilian Road (Fig. 4.4.1). Losses to other vital infrastructure include damages to national and communal irrigation systems, hydroelectric plants, about 218 km. of distribution lines, water supply systems, ports and other facilities.

#### 4.4.1 Roads and Bridges

**Roads:** Damaged locations of roads caused by 16 July earthquake are scattered in the entire affected area. Largest concentration of damages are observed in the following sections:

**Mountainous Areas:** Pan - Philippine Highway (San Jose - Dalton Pass Section), Nueva Ecija - Aurora Road, Laur - Gabaldon Road in the province of Nueva Ecija; Kennon Road and Baguio-Bontoc Road in the province of Benguet; Marcos Highway and Naguilian Road in the provinces of La Union and Benguet (Fig. 4.4.1).

**Along the Fault Rupture:** Laur - Gabaldon Road, Rizal - San Jose Road and Pan - Philippine Highway, all in the province of Nueva Ecija.

**Alluvial Deposits:** Roads in the flat areas of the province of Tarlac and Pangasinan.

Cracking of the pavement and settlement of shoulders were frequently evident. Areas associated with high levels of ground water, such as embankments near rivers and through swampy sections, were often most severely affected. Longitudinal cracking along road center lines was noted. This is probably due to lateral spreading of the embankment as the underlying soils lost strength, and also due to insufficient ties between the concrete pavement slabs.

Stability of embankments serving as bridge approaches was often affected, resulting in moderate to severe movements of the fills both horizontally and vertically. It should be noted that movements of a soil embankment can impose severe loading to the bridge structures and their foundations and even movements of 5 - 10 cm. of a heavy soil mass can damage piles at abutments.

Damage due to soil liquefaction and ground movements occurred extensively in the towns of Dagupan and Agoo as well as many river-side areas of Pangaisnan, Nueva Ecija and Tarlac. City streets as well as highways were severely damaged in some of these areas. Additional problems can be expected due to the settlement in these areas where the roads will now be exposed to possible flooding.

Massive landslides occurred in many areas in both cuts and fills. Literally millions of cubic meters of soil and rock were involved and the many photographs and videos taken of the roads affected cannot adequately portray the amounts of material that moved and the damage that was caused. Where slides have occurred, large amounts of unstable material remain on the slope posing a danger of further movements. Final, stable slopes have not been obtained in many areas and it will be necessary to further cut these slopes and to improve top-of-slope drainage.

Of additional concern is the vast amount of denudation of hillsides caused by the landslides and the resulting millions of cubic meters of material dumped into the rivers and streams. This material washed downstream thereby affecting the drainage patterns and ecological conditions of other provinces. This process of erosion and siltation is prolonged during the rainy season, and further damage is caused. The long term consequences of these events are severe and far-reaching. Areas where this type of failure occurred were in the mountainous sections of: Kennon Road, Marcos Highway, Naguilian Road, Dalton Pass of the Cagayan Valley Road and the Baguio-Bontoc Road.

There are a number of major highways that were damaged by the earthquake. These roads connect important cities and economic regions and are therefore of major interest. The areas of greatest concern are: i) those that connect Baguio City with other areas, particularly access from La Union and Pangasinan; ii) access to the Cagayan Valley from the Central Luzon Plain area; and iii) the intraprovince road network of Pangasinan which has important links to Nueva Ecija, La Union and the Cagayan Valley as well as to Metro Manila.

**Bridges**: One timber, two steel truss, and four concrete bridges collapsed out of 50 bridges reported to be damaged. Typical observed modes of damage on bridges are the following: damaged abutment protection, approach settlement; abutment damage, railing damage; pier settlement and inclination, and damage in shore.

Although the performance of a bridge is based on the interaction of all its components, it has been noticed in past earthquakes, and substantiated in the recent earthquake, that certain components are more vulnerable to damage than others: notably, the bearings, columns, piers, abutments and foundations. Major causes of bridge failure were observed to be due to movements at the pier foundations or abutments which were attributed to soil failure. Other damage resulted from lack of continuity in the superstructure, inadequate support length for girders or trusses and use of rocker type bearings.

Some of major bridges that collapsed partially or sustained heavy damage are presented by their location in Fig. 4.1.1 and described below:

**Carmen Bridge**: Pangasinan. The Carmen Bridge is 655 meters long and consists of thirteen 50 meter span steel trusses. Six spans collapsed or dropped from their supporting piers when the piers underwent severe horizontal and vertical movements caused by liquefaction. Evidence of large soil movements and ground fracturing abound on the nearby river banks.

**Calvo Bridge**: Carmen - Bayambang Road, Pangasinan. The Calvo Bridge is 160 meters long, consisting of four 40 meter span steel trusses supported on solid piers. One span dropped from its pier.

**Magsaysay Bridge**: Dagupan City. The Magsaysay Bridge is a reinforced concrete simply supported multi-span bridge which had four spans fall from their supports. The main cause of failure was again due to liquefaction and excessive backfill pressure at abutments.

**Sicsican Bridge**: Talavera, Nueva Ecija. This is a three-span simply supported steel truss bridge. The steel rocker bearing supporting one end of a truss collapsed due to excessive movement of its supporting pier, leaving dangerously little support length under the truss.

Table 4.4-1

PRINCIPAL MODES OF FAILURE AND DAMAGE ON ROADS WITH EXAMPLES OF PAVEMENT FAILURE AND DAMAGE OF BRIDGE ABUTMENT OBSERVED IN THE LUZON EARTHQUAKE OF 16 JULY 1990 (after International Engineering Consultants Association - Japan)

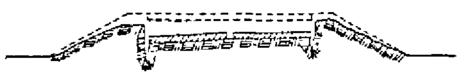
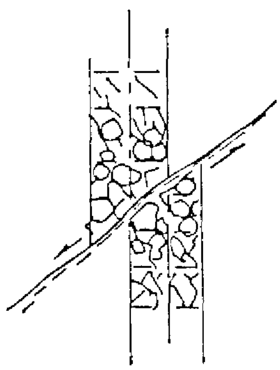
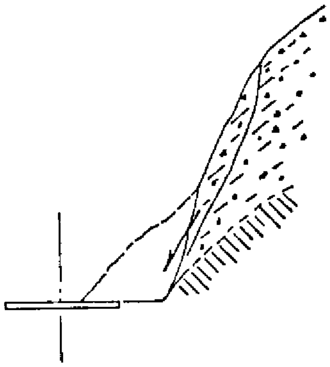
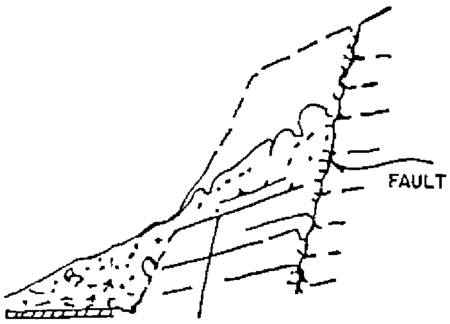
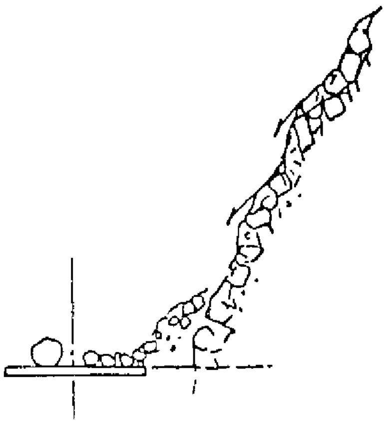
| Mode of Damage and Failure | Description |
|---|---|
| **PAVEMENT FAILURE AND DAMAGE**<br>**1. Settlement:**<br> | Intensive settlements caused by liquefaction on alluvial deposits, frequently formed in Dagupan City, Tarlac City and surrounding municipalities |
| **2. Side-movement:**<br> | Isolated, but deep settlement along the Philippine fault, maximum intensity of 1.0 m observed in Nueva Ecija. Most settlement on the fault rupture experienced side-movement. |
| **3. Trust-up:**<br> | Frequently occurred due to horizontal and vertical intensive vibrations lifting up rigid concrete pavement slab which cannot absorb induced deformations. |

Table 4.4-1 (Continued)

| Mode of Damage and Failure | Description |
|---|---|
| SLOPE FAILURE<br>**4. Surface slope failure:**<br> | Observed in mountainous areas.<br>Surface slope failure, or shallow-slope failure, often observed in the mountain regions with no vegetation. Excessive denudation of slope surface and ensuing erosion and weathering are potential cause of failure. |
| **5. Deep slope failure:**<br> | Deep slope failure observed along the structural weakness of slope such as faults bedding planes and border planes between firm bedrock and overlaying detritus of weathered rock or soil. |
| **6. Rock falls:**<br> | Large number of sections in mountainous areas experienced this type of failure (Kennon Road, Marcos Highway, etc.). Large quantity of stone and rock masses from unstable mountain slopes fell down in the road sections. |