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REPUBLIC OF THE PHILIPPINES  
AURORA INTEGRATED AREA DEVELOPMENT PROJECT

**WATERSHED PROTECTION & ENVIRONMENTAL/  
LAND USE PLANNING STUDY**

**OVERALL MAIN & FINAL REPORT**

**AUGUST 1990**

COWICONSULT-DARUDEC-TGCI / COMMISSION OF THE EUROPEAN COMMUNITIES

## I INTRODUCTION

- 1.01 During Phase I of the Aurora Integrated Area Development Project (AIADP), a watershed management study, with particular emphasis on watershed protection, environmental planning and land use planning, was carried out by a Technical Assistance Team provided by the European Commission (EC). The team comprised both foreign and local consultants. The study started in January 1989 and was completed in August 1990. On completion of the study almost 70 person-months of consultancy had been provided, equivalent to 1 person-month/ 4500 ha of land and 1 person-month/ 350 households in Aurora Province.
- 1.02 The broad objectives of the watershed study were outlined by the EC in their terms of reference (TOR) for prospective consultants and the scope of the study and proposed TOR were included in the proposal of COWIconsult (Appendix A). An inception report was prepared prior to the arrival of the Watershed Study Team Leader, and some adjustments were made to the TOR after his arrival.
- 1.03 One major consideration, affecting the overall output of the watershed study, has been the abolition of NACIAD, the original directing agency. The Watershed Study Team was to have received support from an Institutional Strengthening Component based at NACIAD in Manila. This component was decentralized to Aurora Province, and the main scope of institution building was widened to give general support to the provincial government and government line-agencies in Baler. As a result, the setting up of an Environmental Management Unit (EMU), originally to have been based at NACIAD in Manila for the purpose of guiding integrated area development projects with regard to environmental management, was deferred until a suitable alternative institution could be found to implement the EMU (see Chapter 19).

### Definitions of key terms and concepts

- 1.04 The Watershed Study has covered a wide range of disciplines including: hydrology, forestry, agriculture, sociology, economics, law, soil science, engineering geomorphology and geographical information systems. The integrating disciplines have been: watershed management, environmental planning and land use planning. Emphasis has been given to watershed protection and the establishment of watershed management project activities.
- 1.05 Watershed management is the management of the natural resources of a watershed primarily for the production and protection of water supplies and water-based resources, including the control of soil erosion, floods and the protection of aesthetic values associated with water. In addition, watershed management aims to achieve an optimal use of water, forest and land resources within individual watersheds by adopting management practices that are physically

sound, socially acceptable, economically viable and environmentally safe.

- 1.06 Environmental planning is a continuous process which involves decisions, or choices, about alternative ways of using available natural resources with the primary aim of achieving environmental safety.
- 1.07 Land use planning is a continuous process which involves decisions, or choices, about alternative ways of using available natural resources with the primary aim of achieving optimal, long-term, sustainable levels of production from the land.
- 1.08 It is evident from the above three definitions that watershed management is a combination of environmental planning and land use planning, since it aims to maintain or increase levels of natural resources whilst at the same time stabilizing or improving the state of the environment.
- 1.09 Watershed protection is a set of means by which individual watersheds may be preserved against resource depletion and environmental degradation. Protection may be achieved through physical means such as fences or armed guards, through technical means by improving the management of the watershed's resources, through social means by better education of the population or through economic means by providing alternative income sources.
- 1.10 Watershed management project is a set of related activities whose overall goals include better management of natural resources and elimination of environmental degradation in individual watersheds or watershed planning areas.

#### Aims and scope of the report

- 1.11 It is the aim of this Overall Main Report to provide the framework of a watershed management project plan for Aurora Province. The background to natural resources, the environment and the socio-economic setting have been described (Part A), natural resource and environmental issues and problems are considered, goals and objectives are set, short, medium, and long-term strategies are outlined, constraints are identified (Part B) and proposed individual project components are described along with organizational and financial requirements (Part C).
- 1.12 The scope of project activities is wide-ranging and falls into five broad sets of activities:
- a) technical field operations with project components such as implementation of watershed protection and rehabilitation, agroforestry and hill farm stabilization and community forest resource management.

b) integrated watershed development planning which includes the setting up of a Watershed Planning Unit to carry out physical, social and economic surveys, land use planning and physical planning of designated watershed planning areas;

c) environmental information, monitoring, evaluation and management activities carried out by an environmental management unit (EMU);

d) community development and education in order to improve community participation in watershed management, environmental management and sustaining natural resources;

e) further technical studies based on recommendations made by the Watershed Study Team in Phase I of the AIADP.

## II. ENVIRONMENT AND NATURAL RESOURCES

### Location and status

2.01 The Philippines consist of more than 7,000 islands arranged approximately in a 1700km north-south archipelago, the largest islands being Luzon in the north and Mindanao in the south. Aurora Province is located on the east coast of Luzon Island (Figure 2.1) between 15° 08'N and 16° 21'N and 121° 16'E and 122° 15'E. The province occupies a narrow strip of land on the coast isolated from neighbouring provinces by the Sierra Madre Mountain range. The total land area is about 311,000 ha although the precise area is unclear due to political boundary disputes with neighbouring provinces. Aurora is one of the least developed provinces in the Philippines.

2.02 The province is separated into 8 municipalities:

Baler	Casiguran
San Luis	Dinalongan
Dipaculao	Dilasag
Maria Aurora	Dingalan

The provincial capital is Baler, which is situated in the central part of the province, 230km north of Manila.

### Physiography and geology

2.03 Landforms Four main terrain units, landforms or land management units (LMU) may be identified within the province:

1. Coastal landscape
2. Alluvial landscape
3. Foothill slopes
4. Mountain slopes

2.04 The coastal landscape of recent mixed coarse and fine alluvial deposits, later reworked by marine processes, forms an almost level terrain of beaches, swamps and mangroves, rising to only a few metres above sea level. This unit occupies less than 2 per cent of the land area of the province.

2.05 The alluvial landscape, which is up to 50m thick in places, consists of mixed gravels, pebbles and boulders, sand, silt and clay. The unit is subject to varying degrees of flooding and occupies around 11 per cent of the province land area.

2.06 The foothill slopes were formed through volcanic uplift and subsequent tensional forces and compression. The processes of erosion, landsliding, tectonics, and deep dissection by river channels has considerably influenced the surface features of this

landform. The foothills range from 51 to 500m above sea level, and occupy up to 20 per cent of the province land area.

- 2.07 The mountain slopes of the Sierra Madre Range were formed as a result of violent uplift and tectonic movements with strong tensional forces and compression and volcanic activity. As for the foothills, erosion, landslides, tectonics and the dissection by rivers has considerably influenced the topography of the region. The mountains range from 501-1900 metres above sea level, and occupy around 68 per cent of the province land area.
- 2.08 Geology The stratigraphy and distribution of bedrock in the province is poorly understood (AIADP-WST, 1990i). The geology of Aurora was surveyed by the Bureau of Mines between December 1963 and July 1964. In 1975 the Japanese Government and the Bureau of Mines conducted a reconnaissance survey covering much of the province, but the results of this survey contrast with the findings of the earlier work. Rutland (1967) has contributed to the stratigraphic interpretation of the northern Sierra Madre. Based on the findings of these surveys the stratigraphy and distribution of reported rock types in each watershed has been summarised in a technical annex (AIADP-WST, 1990i).
- 2.09 A variety of rock types including sedimentary, volcanic, meta volcanic, igneous intrusives and metamorphics of mainly Jurassic and Eocene age are believed to be present in the province. The materials include Quaternary-Miocene alluvium, sandstones, conglomerates and mudstones, Oligocene greywackes and andesites, Eocene quartz-diorites and andesitic and basaltic tuff breccias, Cretaceous greywackes and Jurassic intrusives and meta volcanics. Little can be said of the influence of geology on environmental conditions given the conjectural nature of available information. Further work is necessary to establish the true distribution of bedrock in the province. Mineral resources known to exist in the province include: magnetite, chromite, copper, titanium, iron, sand, limestone, silica, shale and road aggregate.

#### Watersheds, hydrology and water resources

- 2.10 Watershed classification In the context used here a watershed is the area of a drainage basin and the water-divide separates adjacent watersheds. In Aurora Province watersheds have been classified into three main classes (Figure 2.2) and grouped into watershed planning areas (Figure 2.3):
- a) W-class or true watersheds (that is, areas from which the runoff drains to a single, common, outlet) the boundary of which can be delineated by following the water divide indicated by contours on the 1:50,000 maps of the province;
  - b) G-class or areas made up of slopes or of groups of watersheds which are either too small to be individually defined at 1:50,000

scale or too small to be of interest to the present study. The drainage divides surrounding such areas can be delineated from the contours, but the discharge boundary is not a single channel as in the case of a true watershed;

c) F-class or areas, generally in the form of outwash fans or other alluvial features, formed of material washed down from the mountains. At their heads the material in such fans can be very coarse, becoming progressively finer towards the sea. In these areas the natural drainage pattern and drainage divides are difficult to determine from the topographical maps and are in any case subject to change both natural due to the rivers changing their courses, or man-made due to the construction of irrigation and drainage works.

- 2.11 The watershed boundaries were interpreted from the contour lines on 1:50,000 topographic maps of the province, while the area of each watershed was determined by planimetry. From the basic list of 315 areas, 96 true watersheds and 70 watershed groups were identified (AIADP-WST, 1989a). The two largest watersheds are those of the Cabatangan/ Malupa River and the Diteki River. The former has a total drainage area in Aurora of 17900 ha and the latter an area of 13000 ha. Amro (7190 ha) and Calabgan (6150 ha) are the next largest watersheds. A total of 42 watersheds have an area of 2000 ha or more.
- 2.12 Surface water Six major rivers may be found in the province, namely the Aguang River in Baler, Calabgan River in Casiguran, Ditale and Dibutunan Rivers in Dipaculao and Ibuna and Sinanganan Rivers in Dingalan, all of which drain into the Pacific Ocean. Other rivers draining the province include the Dinalungan, Mabudo, Simbahan, Suklayin and Ibona, and Cataguman Creek. The majority of the lowland is subject to severe seasonal flooding due to river or stream overflow and runoff.
- 2.13 There is only limited information on river flow, base flows and peak flows in the province. Gauging stations existed for almost 20 years on the Cabatangan and Disalit rivers but these were abandoned in 1973 and 1976 respectively. Accurate base line hydrological information for the province has, therefore, yet to be determined.
- 2.14 Groundwater The majority of town or domestic water supplies are obtained from groundwater sources. In the mountain and foothill areas, groundwater issuing from springs is the main source of water, whilst artesian wells and boreholes in the lowlands provide water for domestic and irrigation purposes. The distribution of such wells in the province is not known.

## Climate

- 2.15 Climatic type The Philippines is located in the humid tropics climatic region which is characterised by monsoon rains with no winter, a short dry season and minimum temperatures above 18<sup>0</sup> C.

Aurora Province falls within the Coronas Type IV Climatic Classification which is characterised by an evenly distributed rainfall throughout the year.

2.16 Wind and tropical cyclones The normal wind speeds in the province are low, around 2 metres per second throughout the year at both Baler and Casiguran. At Baler, the prevailing wind direction is easterly, off the Pacific Ocean. During July and August, the southwest monsoon is established, and the prevailing winds are from the west. During the transition between the northeast and southwest monsoons in June, and again in September, the winds are south-westerly.

2.17 In Aurora Province, maximum recorded wind speeds of 180 and 270 km/hour have been measured in Baler and Casiguran, respectively. However, due to sub-optimal locations of weather stations, the actual gust speeds in more exposed locations will undoubtedly have exceeded these values.

2.18 The province is exposed to intense tropical cyclones which give rise to occasional very high windspeeds. Tropical cyclones are classified according to the maximum wind speeds found within the system as follows:

	m/s	Km/hr
Tropical depression	<17	<60
Tropical storm	>17 <31	>60 <110
Typhoon	>31	>110

A tropical cyclone can pass through each of these classes during its development. Some 54 per cent of all cyclones develop into typhoons.

2.19 During the period from 1948 to 1988, on average 19.8 cyclones per year crossed over or developed in the Philippines. The cyclone season is from June to December, with an average of one or more cyclones occurring during each of these months every year. No month is entirely free of the occurrence of tropical cyclones, and the average number of occurrences outside the main season ranges from 0.3 in February and March to 0.8 in May.

2.20 The number of cyclones affecting the province is confined to the main cyclone season, as the rare cyclones in the early months of the year pass well to the south. The mean number of cyclones per year is 3.4, 17 per cent of all cyclones which affect the Philippines. The main risk occurs over the six months from June to November, with an average of about 0.5 per year for each of these months, that is to say every other year. In May and December, the average drops to 0.2, or about once in five years.

- 2.21 Rainfall The annual rainfall totals at the various weather stations indicate that along the coast the mean annual rainfall is around 3300mm with a slight tendency for rainfall to increase northwards. Generally most stations reflect each other, with wet years and dry years occurring simultaneously at all stations. This reflects the uniform frequency of exposure to tropical cyclones, and to their associated heavy rainfall. Annual rainfall decreases with distance inland.
- 2.22 The monthly rainfall averages and extremes are quite variable. Maximum monthly rainfall at Baler ranges from 450-1200 mm while minimum monthly rainfall ranges from 30-90 mm. At both Baler and Casiguran one or more dry months occur sometime during the year, every nine years out of ten. Runs of 2 to 4 consecutive dry months also occur, mostly at the turn of the year at Baler, and a little later at Casiguran. These dry spells have a recurrence interval of one year in four on average.
- 2.23 The annual maximum daily rainfall at Baler and Casiguran is, in general, associated with tropical cyclones. The maximum fall at Baler was 675.6 mm on 12 December 1963, during the passage of typhoon Sisang which passed to the west of Luzon. However, the maximum recorded fall at Casiguran, 401 mm on 13th March 1971 does not appear to have been associated with a cyclone. The recurrence interval of daily rainfall events of 200mm or more is more or less even throughout the province at about 1 year in 2.
- 2.24 Temperature The mean annual temperature at sea level in the province is around 25.5<sup>0</sup> C. Temperatures reach a maximum of 33.4<sup>0</sup> C in June and a minimum of 22.9<sup>0</sup> C in January. The temperature lapse rate is close to 0.5<sup>0</sup> C per 100m, so that at the highest point in the province (1900m in the Mingan Mountains north of Dingalan) the mean annual temperature is around 17<sup>0</sup> C. The diurnal range in temperature is typically 8 or 9<sup>0</sup> which exceeds the fluctuation in the annual mean of 4<sup>0</sup> C, typical of tropical environments. Temperature data from Baler and Casiguran are presented in a technical annex (AIADP-WST, 1989a).
- 2.25 Relative humidity The relative humidity average is a constant 80-83 per cent throughout the year in Baler but higher in Casiguran with 86-89 per cent. There is little variation through the year.
- 2.26 Evaporation Annual evapotranspiration has been estimated using the modified Penman formula. The results indicate a potential evapotranspiration (PET) of 1,170mm at Baler and 1,069mm at Casiguran. The lowest and highest PET occur in December and May, respectively.
- 2.27 Sunshine There are no records of sunshine or net incoming short wave radiation for the province. However, the evaporation data are low for the latitude. This confirms a generally high level of cloud

cover (6 oktas on average), and a low radiation and sunshine level (average 5.9 hours per day).

- 2.28 Soil temperature Virtually all soils in lowland areas of Aurora may be considered to fall within the isohyperthermic temperature regime where temperatures at 50cm depth vary by less than 5<sup>0</sup> C throughout the year and have a mean annual temperature of 22<sup>0</sup> C or higher. In other parts of the province the annual range is likely to be greater and/or the average annual temperature is lower.

## Soils

- 2.29 The soils of Aurora were originally surveyed at a reconnaissance level in 1964 (mentioned in AIADP-BSWM, 1964). This report and its associated map have been strongly criticised for its lack of detail and inaccuracies (which may be partly due to inaccurate base maps) and therefore its inadequacy for use in development planning.
- 2.30 In 1989, the Bureau of Soil & Water Management (BSWM) undertook a more detailed survey of the province at a scale of approximately 1:50 000 (AIADP-BSWM, 1989a). It was intended that this survey should identify and classify soils, identify areas suitable for agricultural development, recommend suitable crops and assess fertilizer requirements. Unfortunately, this survey lacks the required pedological detail to be useful for detailed agricultural or forestry development planning.
- 2.31 Further investigations of soils were undertaken in five selected watersheds as part of a series of individual watershed studies (AIADP-BSWM, 1989c). The laboratory analysis of soils, sampled as part of this survey, had not been finalized at the time of writing of this report.
- 2.32 Soil classification and distribution The soils identified by the various surveys have been classified according to the Soil Taxonomy system (USDA, 1975). In the more recent surveys, the intensity of sampling has varied throughout the province, reflecting difficulty of access and the relative importance that the different areas have for agricultural development. In lowland areas for example, soils are classified to 'Family' level whereas in the uplands classification is only to 'Great Group' level.
- 2.33 The Soil Taxonomy system of soil classification depends on detailed chemical and physical analysis of soil properties and certain climatic variables, and requires relatively sophisticated analytical equipment. In remote areas, such as Aurora, reasonable precision can be achieved through the use of informed assumptions, and the selection of a small number of critical parameters, rather than comprehensive and sophisticated soil analysis.
- 2.34 The soils of Aurora are strongly controlled by the nature of the parent material which, in turn is controlled by local bedrock

geology. The scarcity of detailed geological information makes the precise identification of soils impossible without extensive field sampling.

- 2.35 The coastal landscape consists of soils developed in recent, mixed, coarse and fine, Quaternary alluvial sediments. They include poorly drained soils of the tidal flats, mangroves and beaches and also the slightly better drained soils of the alluvial plains and river terraces. High groundwater tables and frequency of flooding are the major limitations to the agricultural use of these soils.
- 2.36 In the hills and mountains weathering of the underlying rocks has produced red and grey clays, the precise characteristics of which depend on the nature of the parent material. On steep slopes, soil depth is occasionally a limiting factor for development purposes. Deeper soils are found on rounded hill and mountain crests, whereas sharp crests tend to be have shallow soils or rock outcrops.
- 2.37 The soil groups identified to date include Inceptisols and Entisols in low lying alluvial areas with Inceptisols, Alfisols and Ultisols in the foothills and mountains. Many of the divisions of these groups relate to the differences in geology and drainage status. More detailed information on the soils identified within the province is to be found in AIADP-BSWM (1989a).
- 2.38 Soil physical properties The physical characteristics of soils, that are most important for development planning, have been recorded for the major soil groups identified in the province. They include soil texture which can, together with information on land gradients and rainfall data, lead to an assessment of the soil erodibility and soil drainage status. Drainage status is important for assessing soil suitability for various crops and includes assessments of soil moisture retention and moisture availability. Soil depth is locally important on steeply sloping areas.
- 2.39 In lowland areas soil textures vary considerably from sandy and coarse-loamy in beach areas to fine-loamy or clayey in the palay growing areas. Extensive areas of boulder terraces are found along most rivers, representing boulders derived from upper mountainous watersheds. Drainage status is poor to imperfect.
- 2.40 In upland areas soil depth is variable but, on the whole, tends to be quite deep. The soils are generally well drained and are typically loamy or clayey.
- 2.41 Soil chemical properties A variety of soil chemical properties have been analysed with a view to defining soil nutrient status and potential fertilizer requirements (AIADP-BSWM, 1989a).
- 2.42 The relatively young age of soils in Aurora, developed on Quaternary alluvium in the plains and coastal zone and on a youthful topography

in upland areas, indicates that, despite an average annual rainfall in excess of 3 000 mm, nutrient levels are unlikely to pose a major limitation to the agricultural or forestry productivity of the land. The results of the existing chemical analysis tend to confirm this statement, with the exception of phosphorus content which is generally low in all soils throughout the province.

- 2.43 Low pH values are also reported around the province and this may reduce the availability of some plant nutrients, but is unlikely to present any major limitations unless it falls below pH 5.0.
- 2.44 Tropical soils generally are deficient in nitrogen and also organic matter, particularly if they have been cultivated for any length of time, and Aurora appears to be no exception.
- 2.45 Soils identified as Ultisols are of low base saturation which further tends to reduce the availability of nutrients to plants.
- 2.46 While soil nutrient levels generally are unlikely to give rise to any major limitations for crop production, almost all soils would benefit from applications of varying amounts of nitrogen, potassium and phosphorus fertilizer (see Table 3.2 in AIADP-WST 1990c).

#### Vegetation

- 2.47 The following sections describe natural and disturbed vegetation cover. Table 2.1 gives a summary of vegetation cover data for the 303 watersheds in Aurora. About 87% of the province has undisturbed or disturbed natural vegetation, the remaining 13% includes various agricultural land use types. Information on vegetation and land use in the province is available in AIADP-WST (1990d), AIADP-BSWM (1990b) and from NAMRIA which is currently conducting a new survey of vegetation and land use throughout the province.
- 2.48 Primary 'old growth' dipterocarp forest Dipterocarp forest which makes up about 73% of Aurora's vegetation cover has been exploited for generations, particularly for valuable Philippine Mahogany. As a result, much of this forest is now described as residual or secondary forest. Throughout Region IV, of which Aurora is a part, 8.6% of primary dipterocarp forest was lost between 1969 and 1988. Latest estimates suggest that less than 39 000 ha of primary forest remain in Aurora (discussed in AIADP-WST, 1990d). Figure 2.4 presents the percent cover of primary 'old growth' dipterocarp forest by watershed. It is quite clear that most watersheds no longer have any primary (undisturbed) dipterocarp forest. These areas are mainly in northern Aurora and are found in the central Sierra Madre where access has been limited.
- 2.49 Secondary 'residual' dipterocarp forest Residual forests represent those former primary forests which have been logged over at some time in the past. Figure 2.5 shows the percentage residual forest

cover for each watershed. The area is estimated to be about 135 500 ha much of which lies in existing timber licence areas and some of which is suitable for timber stand improvement, enrichment planting or reforestation.

- 2.50 Mossy forest Mossy forests occur mostly above 800m and usually contain stunted trees of low stature, normally of little importance for logging. The mossy forests are usually found in cloud or mist belt areas on mountain tops. About 54 500 ha of mossy forest are believed to occur in Aurora. Figure 2.6 shows the percentage mossy forest cover for 303 watershed areas in the province.
- 2.51 Mangrove forest The occurrence of mangrove forests in Aurora is limited to a small area of about 300 ha located in the north of the province (Figure 2.7).
- 2.52 Grassland and shrubland Grassland and shrubland represent only a small proportion of Aurora's vegetation; their occurrence by watershed is indicated in Figure 2.8. An estimated 29 000 ha (or 9% of the province) comprises grassland and shrubland. Many of these areas represent land deforested and degraded as a result of excessive logging or hill farming.
- 2.53 Non-forested wetland Apart from the small area of coastal mangroves, there are small areas of swamp grassland and reed that are confined almost entirely to the lowland alluvial areas and the coastal flats.

#### Wildlife

- 2.54 No scientific inventory of wildlife has taken place inside Aurora Province. Limited information is available from officials of the Aurora Memorial National Park (DENR, 1987 and AIADP-WST, 1990g).
- 2.55 The Philippine Eagle has been observed in northern Aurora and other adjacent parts of the Sierra Madre Mountains; this species is considered to be very scarce throughout the Philippines. Several other uncommon bird species have been noted: the Spotted Imperial Pigeon, the Serpent Eagle, Dollarbirds, and the Rufous Hornbill. A wide range of bird life is a distinctive feature of the Aurora dipterocarp forest.
- 2.56 The Philippine deer is vanishing from Aurora due to uncontrolled hunting for subsistence or sport purposes. Monitor lizards, common monkeys, wild pigs, flying lemurs, shrews and wild cats are present, but are under threat due to habitat loss.

#### Environmental hazards

##### Mass wasting and soil erosion

- 2.57 The Aurora Landslide Survey Inventory (ALSI) contains 673 records of landslides and 1167 records of soil erosion. These are

distributed unevenly in 265 out of 303 watersheds present within Aurora Province. All watersheds were surveyed except for 7 which lack aerial photographs or SPOT coverage (AIADP-WST, 1990i).

- 2.58 A wide range of landslide types may be found in the province, such as rotational slumps of rock and debris, translational failures known as mudslides, rockslides, debris slides, debris avalanches and debris flows, and rockfalls and topples. Soil erosion identified within Aurora Province was classified as sheet wash, rill erosion, gully erosion and river bank erosion.
- 2.59 The distribution of landslides and soil erosion (see Land Degradation Map in Appendix B and AIADP-WST, 1990i) is mostly concentrated in the foothills (52.1% of records) and mountains (33.5% of records). Considering that 68.3 per cent of Aurora Province is dominated by mountain slopes and 19.8 per cent by foothill slopes the greatest density of mass movement and soil erosion is concentrated in the foothills.
- 2.60 ALSI has identified a total area of 743 ha in Aurora Province directly affected by landsliding compared to 51,435 ha affected by soil creep and erosion. This gives a total degraded area of 52,178 ha or 16.8 per cent of the total area of Aurora Province.
- 2.61 The principal causes of landslides and soil erosion in Aurora are as follows:
- a) Natural: factors such as relief, rock type, weathering, which predispose a slope to failure and mass movement, and transient factors such as extreme climatic events and earthquakes which trigger landslides;
  - b) Man: where man's activities result in the destruction of vegetation and forest cover through logging and hill farming (kaingin) activity and the construction of roads (primarily logging roads on steep slopes).

The results indicate that the area of degradation caused by natural processes was 4967 ha (9.5%) compared to 34,179 ha (65.5%) due to the destruction of forest and 8,750 ha (16.8%) due to the construction of roads.

- 2.62 Figure 2.9 presents the distribution of landslide and soil erosion hazard in Aurora Province. The distribution shows that landslide and soil erosion hazard has the greatest impact in the municipalities of Dingalan, San Luis and Baler. This undoubtedly reflects the intensity of past and present deforestation in these areas. Further watersheds classified as high hazard may be found near Dipaculao, Dinalungan and in Dilasag. Watersheds classified as moderate hazard are located in Dingalan, San Luis, Maria Aurora, Dipaculao and Dinalungan. In the latter 3 municipalities there appears to be a strong association with the intensity of hill farming (slash and

burn) on the foothill slopes adjacent to the east coast of Aurora. Areas of low landslide and erosion hazard are dominated by the lowland, and inland watersheds in the mountains in the north and central areas of Aurora. The lowland, however, is subjected to severe flooding.

- 2.63 The worst manifestation of watershed degradation promoted by logging activities was observed in the Diteki watersheds. The area was heavily logged during the 1960s, which has led in recent years to a marked increase in the number of debris slides and debris avalanches clearly associated with logging roads and areas of cleared forest. Approximately 3.8 km north of Diteki Barangay a debris avalanche has caused significant sedimentation and enlargement of the Diteki River. There is evidence of a landslide dam, currently incised by the river, which poses a severe threat to downstream infrastructure. The site is still very active today and has so far deposited around 1.6 million cubic metres of debris into the Diteki River. The landslide dam is 15-20m in depth and extends down river for around 600m.
- 2.64 It is evident from observations in adjacent provinces, that unless the destruction of the forest by logging and hill farming activities is controlled, the extent and magnitude of landslides and soil erosion will increase causing irreparable depreciation of the land resources in Aurora.

#### Sedimentation

- 2.65 The impact of sediment in lowland areas is the most widespread consequence of natural and man-induced mass wasting of the foothill and mountain slopes. The deposition of sediment on the lowland with consequent channel enlargement, and stream bank erosion caused by migrating rivers, is very damaging to agriculture, roads and communities which have been developed on or adjacent to such alluvial landforms. The sediment which is produced contains both fine material, usually carried away in suspension, and which, in the absence of storage reservoirs or of surface water drinking water supplies, finds its way to the sea quite quickly and without causing major problems. The loss of fine material therefore represents a loss of soil resources within the watershed and relatively minor problems outside the watershed, although there is little hard evidence of the effect of sediment deposited into the coastal and marine environments.
- 2.66 The coarse material brought down by large landslides, including everything from sand up to large boulders, often delivered directly into the river, represents an altogether different problem. The capacity of a river to transport the coarse sediments is a function of depth and velocity, and significant movements of such materials are entirely confined to flood periods. Large inputs of coarse material can completely alter the channel geometry, often for long periods of time.

- 2.67 Abrupt flushes of sand and gravel, resulting from a landslide upstream, can be very damaging if they get into the irrigation canals. This happened in the Pingit watershed (AIADP-WST, 1989a). Once the sand and gravel is in the canals and fields it is beyond the capability of the farmers to remove the material, and land may go out of production indefinitely. This problem is exacerbated by the presence of permanent diversion works with no control over inflows to the main canal at times of flood.
- 2.68 Flooding Floods and flooding are of concern to a wide range of undertakings and have many different aspects. In Aurora, we are concerned almost exclusively with the magnitude and frequency of the peak flows, where the runoff from the watersheds is concentrated as it emerges from the mountains and passes through alluvial fans and plains to the sea.
- 2.69 There are many instances of reported flooding problems, often associated with problems of sediment deposition. Unfortunately, reports of flooding incidents are usually unspecific as to time and extent, so that verification and quantification of floods is often not possible. Certainly, there are instances of flooding in irrigation areas, and it is important to know the peak flows which can be expected to occur at the points where water is diverted for irrigation, and to make allowance for them.
- 2.70 Flooding can be caused simply by heavy rainfall in areas where the drainage cannot cope. The maximum daily fall is around 200mm or more every other year. Drainage design, particularly in urban areas, and where road construction may cut across natural drainage lines, needs to take these typical heavy falls into account. The incidence of storm surges at the entrance to the estuaries of large rivers has an important effect on flood levels in the lowland areas adjacent to the Pacific Ocean.
- 2.71 Not all flooding problems originate from inappropriate land use and land use practices to be found in the watersheds from which the flood waters originate. Inappropriate design or incomplete construction of irrigation schemes can lay schemes open to the uncontrolled entry of flood waters into the main canals. It is therefore important that schemes are designed to exclude flood flows, preferably by limiting the capacity of the main canal to the flow actually required, as well as by providing means of closing off the canal altogether during floods.
- 2.72 It is interesting to note that the traditional brush dams, constructed by the farmers themselves, have an inherent element of safety with regard to flood safety. During high flows they are washed out and cease to act as diversion weirs. This cannot happen with a concrete weir or dam.

## Typhoons and tropical storms

- 2.73 Intense tropical cyclones are the most impressive, and destructive, weather phenomenon of the tropical regions. The Philippines is located in a region which has the greatest frequency of tropical cyclones in the world.
- 2.74 The Aurora Province is exposed to intense tropical cyclones which give rise to occasional very high windspeeds, storm surges of wind-driven sea and consequent loss of life, damage and destruction. Historically, the greatest loss of life is caused by storm surges where a rise of several metres in sea level is not uncommon. The Casiguran area is particularly at risk because of the closed sound and bay between the San Ildefonso Peninsula and the mainland.
- 2.75 The main risk occurs over the six months from June to November. The frequency of tropical cyclones is relatively uniform throughout the province as reflected by annual rainfall trends. Heavy rainfall associated with tropical storms will undoubtedly promote mass wasting and flooding, contributing further to the hazards in the province.

## Earthquakes

- 2.76 Earthquakes and volcanic activity, both very prevalent in the Philippines, are the most perceptible evidences of on-going processes of structural development. Two structural divisions of the Philippines may be defined: the 'mobile (or Pacific earthquake) belt' and the 'stable region'. The mobile belt extends longitudinally through Luzon, the Visayas and Mindanao and is characterised by pronounced earthquake activity, active and recently inactive volcanoes (Figure 2.10). Earthquakes of magnitude 5 or above (Richter scale) are fairly common. Higher magnitudes of 5.3 to 6.9 have also occurred, particularly in east Mindanao and north Luzon, the latter having been known to experience magnitudes in excess of 7.0.
- 2.77 The worst earthquake to hit the Philippines in 22 years occurred recently on Monday 16th July 1990. The epicentre of the quake, measuring 7.7 on the Richter scale, occurred just north of Cabanatuan, 100km west-southwest of Aurora Province. Early reports indicated that the main Nueva-Ecija Road into the province was extensively blocked with landslide debris and would be impassable for some weeks. The impact of the quake in nearby provinces caused 900 fatalities, considerable damage to homes and structures and more than 3,000 people were injured. Water and electricity supplies were severed throughout the northern provinces of Luzon.
- 2.78 The earthquake undoubtedly triggered widespread landslide activity throughout Aurora and neighbouring provinces