A Comprehensive Study on the Applicability of Japanese Dam Technologies to the Alarming Condition of Angat Dam in Bulacan, Philippines

AMEERHA P. ORTEGA
ADRC Visiting Researcher
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ADRC Visiting Researcher
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ABSTRACT

A review of the present status of Angat Dam, Bulacan, Philippines in the effectiveness of disaster preparedness of the different stakeholders in relation to the warning from the experts that the West Valley Fault which runs through the central Metro Manila area is potentially active, and a splay sits 200 meters east of the Angat dam. Expert predicts of clear and present danger of dam breach when a magnitude of 7.2 on the Richter scale earthquakes strike triggering activity in Marikina West Valley Fault Line.

Adapting Japanese Dam Technologies is being considered to address the occurring problem of country's largest hydropower dam.

INTRODUCTION

Angat dam is one of the country's largest dams. This dam supplies potable water and energy to Metro Manila and nearby areas. The Angat River Basin is situated on the southeastern part of Central Luzon, originating on the slopes of the Sierra Madre Mountains. It has a catchment area of 781 km^2 and estimated annual run-off of 873 MCM collecting from the main tributaries of Matulid and Maputi rivers. The watershed area is bounded by Umiray River in the northeast, the Kanan River in the southeast, and the Marikina River in the south. The river defines a huge semi-elliptical curve of about 12 kilometers long near Sitio Bitbit in Norzagaray, Bulacan Province. At a few kilometers downstream, the river emerges from the mountain, flowing in a westerly course across the lowland plains of Bulacan before emptying its water into Manila Bay.

The Angat Lake created by the dam is the main potable water supply source of the Metro Manila Area. However this water when in over abundance, due to very heavy rainfall, is also the cause of widespread flooding, deaths, and accompanying misery affecting not only the provinces of Bulacan and Pampanga but also the Metro Manila Area. This happens every time the dam water reaches its maximum height and the spilled water races down through the gullies and streams to the east of the dam and this rampaging water joins the water of the Marikina river system multiplying the floodwater volume of the Marikina River system thereby causing rapid increase in the volume of floodwater in the Marikina Valley. This happens every time very heavy rains overfill the Angat water reservoir.

This study determined the capabilities/preparedness of the different stakeholders in relation with the problems of Angat Dam. Specifically, it sought answers to the level of preparedness of the different stakeholders in relation with the problems of Angat Dam along the phases of disaster management such as a) prevention, b) mitigation, c) response, and d) recovery and rehabilitation. This study is also concern with the policies that can be formulated to enhance the disaster management preparedness of the different stakeholders' tasks to ensure security, peace and order in Angat Dam and its environment.

The objectives of this study are: 1). to qualify the socio-economic impacts resulting from the extreme events; 2). to determine possible schemes that would minimize the impacts of extreme events downstream as a result of hydro-meteorological extremes that often plague the region; and 3). to identify local adaptation strategies that will minimize damage to the people, and properties in the basin as well as to the recipients of the water downstream of the basin.

Among the expected results of this study are as follows: a) a closer relationship between Japan-Philippines and ADRC member countries in solving disaster problems particularly in dam break, flooding, and typhoon; b) affected areas of Angat Dam in the Philippines will find a way to correct the threat of the ageing dam to Bulacan, and Metro Manila residents; and c) to make a documentation on disaster related to dam-breach (i.e. flooding, typhoon, earthquake.

SCOPE AND DELIMITATION OF THE STUDY

This study dealt with the capabilities/preparedness of the different stakeholders in relation with the problems of Angat Dam. It emphasizes on the disaster management program particularly on the prevention, mitigation, response, and recovery and rehabilitation.

Similarly taken into consideration in this paper is the goal of the study summarizes as follows: 1) to shed light on the various forms of danger caused by dam failure; 2) to learn on the practices being used by Japan in monitoring and addressing problems caused by dam failure, and 3) to evolved strategies designed to eradicate or minimize occurrences of calamities be it natural or man-made, when solution is at hand and only requires implementation of such.

Stake holders includes, but not limited to, the province of Bulacan, the province of Rizal, the Metro Manila areas, the Angat Dam Management, the National Power Corporation (NAPOCOR), National Irrigation Authority (NIA), the Metropolitan

Waterworks and Sewerage System (MWSS), the National Government (DILG, DOH, DSWD, NEDA, the Congress of the Philippines, the different agencies in Japan (ADRC, JICA, etc.), the DRRMC (National, Regional, Provincial, Municipal,) . The vision, mission and goals taken were only along that which is responsive to disaster management. Resources meanwhile covered the manpower, transportation facilities, communication facilities, infrastructure support system and equipments. Also covered are the referred linkages with the government and private agencies.

SIGNIFICANCE OF THE RESEARCH

Dam safety is a huge global concern. Dams built some 50 years ago are highly prone to dam bursts particularly in countries that lack adequate monitoring. As dams get old, they become increasingly more expensive to maintain. Most alarming, dams have not been built to allow for the erratic hydrological patterns that climate change is bringing. Extreme storms and increasingly severe floods can trigger earthquake as a result of the weight of the reservoir and earthquake increase the probability of dam failure and the risk of downstream flooding. The research will have a tremendous implication to the following:

Environmental Impacts of Dams

The environmental consequences of large dams are numerous and varied, and includes direct impacts to the biological, chemical and physical properties of rivers and riparian (or "stream-side") environments. The dam wall itself blocks fish migrations, which in some cases and with some species completely separate spawning habitats from rearing habitats. The dam also traps sediments, which are critical for maintaining physical processes and habitats downstream of the dam (include the maintenance of productive deltas, barrier islands, fertile floodplains and coastal wetlands).

Economic Impacts of Dams

Large dams have long been promoted as providing "cheap" hydropower and water supply. Today, we know better. The costs and poor performance of large dams were in the past largely concealed by the public agencies that built and operated the projects. Dams consistently cost more and take longer to build than projected. In general, the larger a hydro project is, the larger its construction cost overrun in percentage terms. The true risks and costs of dams are being forced into the open due to increasing public scrutiny and attempts to attract private investors to existing and new projects.

Human Impacts of Dams

Large dams have forced some 40-80 million people from their lands in the past six decades, according to the World Commission on Dams. Indigenous, tribal, and peasant communities have been particularly hard hit. These legions of dam refugees have, in the great majority of cases, been economically, culturally and psychologically devastated. Those displaced by reservoirs are only the most visible victims of large dams. Millions more have lost land and homes to the canals, irrigation schemes, roads, power lines and industrial developments that accompany dams. Many more have lost access to clean water, food sources and other natural resources in the dammed area. Millions have suffered from the diseases that dams and large irrigation projects in the tropics bring. And those living downstream of dams have suffered from the hydrological changes dams bring to rivers and ecosystems; an estimated 400-800 million people--roughly 10% of humanity--fall into this category of dam-affected people.

RELATED STUDY AND LITERATURE (CASE STUDIES/EXPERIENCES)

Despite the presence of voluminous data and information around the world concerning dam breach, the researcher believes that history of disaster and calamities of Japan and Philippines is still the best source of preventive measures. For that reason, the Japanese experience shall be the first to be discussed.

Japan's Record of Dam / Dike Failure and Flooding

The 1923 Great Kantō Earthquake

On 1 September 1923 about 11:58:44 a.m. JST, a magnitude 7.9 earthquake with its focus deep beneath Izu Ōshima Island in the Sagami Bay struck the Kantō Plain of Honshu (本州 literally "Main Island") Island. Varied accounts indicate the duration of the earthquake was between four (4) and 10 minutes and recorded 57 aftershocks.

The earthquake affected Chubu and Kanto Region in the Honshu Island. It devastated Tokyo, Chiba, Kanagawa especially the port city of Yokohama and Kamakura City where a Great Buddha statue weighing 84,000 kgs moved almost 2 feet, and caused widespread damaged throughout the Kantō Region. It also affected Shizuoka Prefecture in Chubu Region.

Estimated casualties totaled about 142,800 deaths, including about 40,000 who went missing and were presumed dead. Embankments along several rivers broke due to the earthquake. Many large fires broke out and some developed into firestorms that swept across cities. An estimated 6,400 people were killed and 381,000 houses were destroyed by the fire alone.


Fire in Marunouchi

Photo credit: en.wikipedia.org

A strong typhoon struck Tokyo Bay at about the same time as the earthquake. Winds from the typhoon caused fires off the coast of Noto Peninsula in Ishikawa Prefecture to spread rapidly. Many homes were buried or swept away by landslides in the mountainous and hilly coastal areas in western Kanagawa Prefecture, killing about 800 people. A collapsing mountainside in the village of Nebukawa, west of Odawara, pushed the entire village and a passenger train carrying over 100 passengers, along with the railway station, into the sea.

Destruction in Yokohama

Photo credit: en.wikipedia.org

A tsunami with waves up to 10 m (33 ft) high struck the coast of Sagami Bay (Kanagawa Prefecture), Bōsō Peninsula (Chiba Prefecture), Izu Islands, and the east coast of Izu Peninsula (Tokyo Prefecture) within minutes. The tsunami killed many, including about 100 people along Yui-ga-hama Beach in Kamakura and an estimated 50 people on the Enoshima causeway. Over 570,000 homes were destroyed, leaving an estimated 1.9 million homeless. The damage is estimated to have exceeded US$1 billion (or about $14 billion today).

The 1947 Typhoon Kathleen

September of 1947, Typhoon Kathleen with maximum sustained winds of 185km/h (115mph) struck the Kanto Region and produced a record-breaking amount of rainfall of 166.8 mm (Sept 13-15) and the maximum hourly rainfall was 34.7 mm/hr.

It affected six (6) prefectures in Kanto Region namely Toko, Chiba, Saitama, Gunma, Ibaraki, and Tochigi Prefecture. The typhoon caused several dike failures such as the massive dike failure along the Tone River which resulted in an inundated area 3km wide and affected 300,000 people and the resultant flow also affected Tokyo Metropolitan Area. The total affected area is estimated to be at around 440

Areas inundated by Typhoon Kathleen (September 1947)

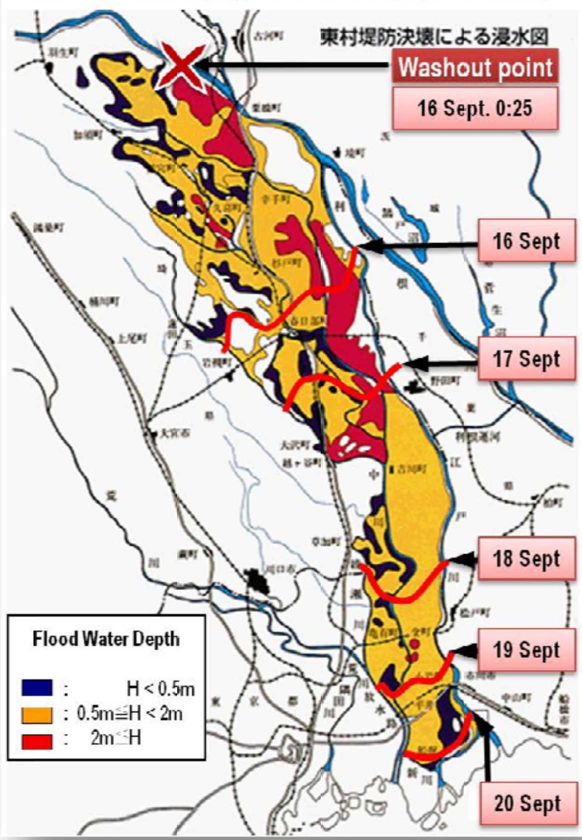
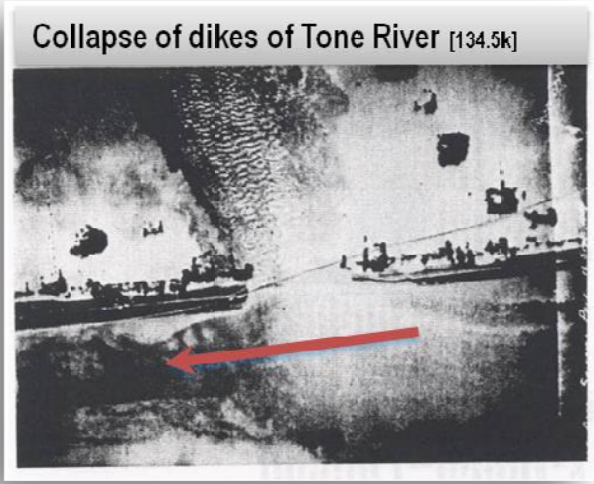


Photo credit: JWA Presentation dated 4 Feb 2015 km2 in which 600,000 people were affected and about 150,000 houses damaged. The typhoon claimed 1,100 lives and economic loss is estimated at about 100B Yen.

Photo credit: JWA Presentation dated 4 Feb 2015



The 1958 Typhoon Kanogawa

On 20 September 1958, Typhoon Kanogawa (with international name of Typhoon Ida) formed in the West Pacific near Guam moving west at 185 km/h (115 mph). The typhoon struck Japan in southeastern Honshu on 26 Sept with winds of 190 km/h (120mph), crossed the Eastern portion of the country and emerged from Fukushima Prefecture into the Pacific Ocean. Typhoon Kanogawa became extra tropical on 27 Sept, moved through Sapporo before dissipating on 28 September.

Typhoon Kanogawa produced heavy rainfall that reached 748.6 mm (29.47 in) on Mount Amagi on the Izu Peninsula. In the capital city of Tokyo, the storm dropped almost 430 mm (17 inch) of rainfall. Across the country, the rains caused flooding along the Kano, Merugo, and Arakawa rivers; the flooding of the Kano River destroyed to villages along the Izu Peninsula. The heavy rainfall caused dike failure and flooding on both sides of the main stream and several tributaries. The rains resulted in at least 1,900 landslides, including 786 in the Tokyo area. There was a storm tide of 1.1 m (3.6 ft) in Chiba, which flooded 120,000 acres of rice fields. Along the coast, there were 32 ships that were missing or sunk, and another 20 were damaged.

Across the country, more than 520,000 homes were flooded, 17,743 damaged houses, more than 244 road or rail bridges were destroyed, 12,000 people left homeless, 1,138 injured people and 1,269 died in the typhoon. Overall damaged was estimated at around 20.6B Yen.

The 1978 Izu-Oshima-Kinkai Earthquake

On 14 January 1978, a destructive earthquake of 7.0 Magnitude occurred at Southeastern area of Izu Peninsula. The epicenter of the main shock was located about 15km off the east coast of the peninsula, midway between the peninsula and Oshima Island. The main shock was followed by a series of aftershocks lasting for a week with their epicenters moving gradually in a westerly direction. The largest aftershock was a pair of shakings that took place at 7:30 a.m. and 7:36 a.m. on January 15, 1978 with their epicenters located approximately in the middle of the Izu Peninsula but most of the shocks are presumed to have had a focal depth of about 10 km.

The earthquake caused 25 fatalities, 211 injured people, 96 collapsed houses, damaged 9 railways and 4 road tunnels. Local tsunami was observed at Izu-Oshima (35 cm) and at Tateyama (12cm).

Two (2) dams retaining tailings from Mochikoshi gold mine failed, leading to a release of a large volume of tailings. One of the dams, No.1 dike, collapsed almost simultaneously with the shaking of the main shock, but another dam, No.2 dike, failed about 24 hours later at a time when there was no shaking. The failure of the No.1 dike is known to have been triggered by the liquefaction which developed in the tailings deposit in the impoundment pond.

The 2011 Great East Japan Earthquake

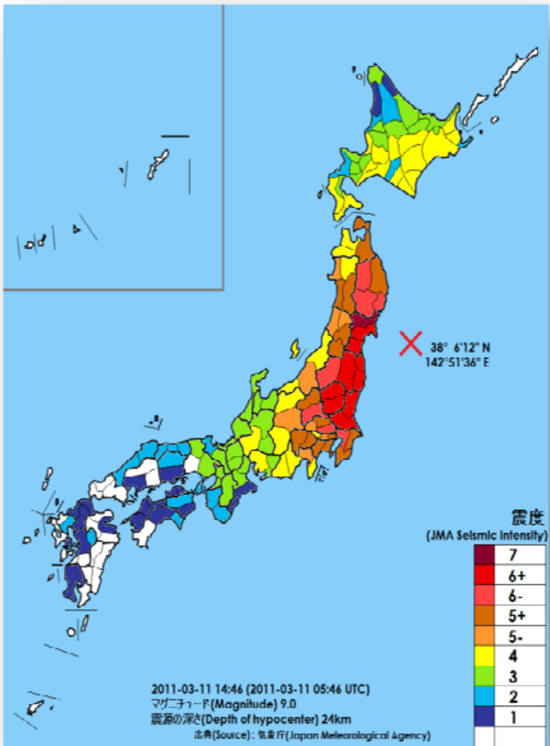


Photo credit: en.wikipedia.org

The 2011 earthquake of the pacific coast of Tōhoku, also known as the Great East Japan Earthquake, the 2011 Tohoku earthquake and 3.11 earthquake, was a magnitude 9.0 that occurred at 14:46 JST on 11 March 2011 lasting about six (6) minutes, with epicenter approximately 70 kilometers (43 mi) east of Oshika Peninsula of Tōhoku. It was the most powerful earthquake ever recorded in Japan. The earthquake triggered powerful tsunami waves that reached heights of up to 40.5 meters (133 ft) in Miyako in Tōhoku's Iwate Prefecture, and inundated a total area of approximately 561 km2 in Japan.

The main shock was preceded by number of large aftershocks, and several of which is over 7.0 Magnitude. A magnitude 7.4 Mw at 15:08 (JST), 7.9 Mw at 15:15 and a 7.7 Mw quake at

15:26 all occurred on 11 March. A month later, a major aftershock struck offshore on 7 April with a magnitude of 7.4 Mw. Four days later on 11 April, another magnitude 7.1 Mw aftershock struck Fukushima, on 7 December 2012 a large aftershock of magnitude 7.3 Mw caused a minor tsunami, and again on 26 October 2013 small tsunami waves were recorded after a 7.1 Mw aftershock. As of 16 Mar 2012 aftershocks continued, totaling 1887 events over magnitude 4.0. As of 6 December 2013 there have been a total of 776 aftershocks of 5.0M or greater, 112 of 6.0M or greater, and 8 over 7.0 M as reported by the Japan Meteorological Agency (JMA).

The earthquake took the lives of 15,889 persons, 6,152 were injured and 2,601 went missing across 20 prefectures. Of the total confirmed deaths, 14,308 were drowned, 677 were crushed to death and 145 perished from burns. Also, 19 foreigners died in the earthquake; two (2) from US, Canadian Missionary, Chinese, Korean, Taiwanese, Pakistan and a Filipino.

The earthquake and tsunami totally collapsed a 127,290 building, 272,788 half collapsed and 474,989 buildings were partially damaged, 300 hospitals were damaged, and 11 were completely destroyed. An estimated 230,000 automobiles and trucks were damaged or destroyed in the disaster. All of Japan's ports were briefly shut down after the earthquake and 15 ports were located in the disaster area. A total of 319 fishing ports were damaged.

Japan's transport network suffered severe disruptions. Many sections of Tōhoku Expressway were damaged. All railways were suspended in Tokyo with an estimated 20,000 people stranded at major stations across the city, also 20,000 stranded visitors spent the night of 11 – 12 March inside the Tokyo Disneyland. JR East train lines suffered damaged in the worst hit areas, 23 stations on seven (7) lines were washed away, with damaged of loss of track in 680 locations and the 30-km radius around the Fukushima Daiichi nuclear plant. The Tōhoku Shinkansen bullet train was worst hit, with JR East estimating 1,100 sections of the line varying from collapsed station roofs to bent power pylons, will need repairs. A tsunami flooded Sendai Airport, while Narita and Haneda airport briefly suspended operations. Cellular and landline phone service suffered major disruptions in the affected area.

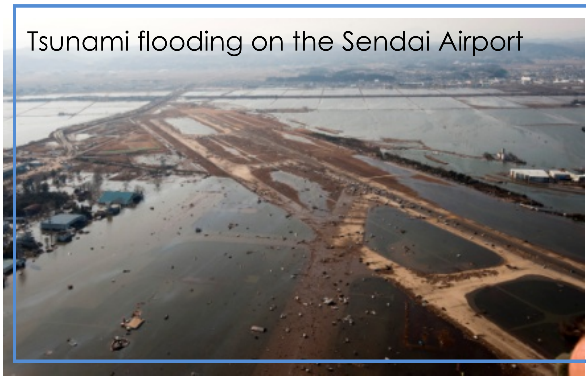

Tsunami flooding on the Sendai Airport

Photo credit: en.wikipedia.org


Train washed away uphill from Onagawa Station runway

Japanese authorities inspected over 400 dams following the earthquake, according to the reports, almost all of these dams withstood minor to severe ground shaking and retained their reservoir with generally minor to moderate damage except Fujinuma Dam.

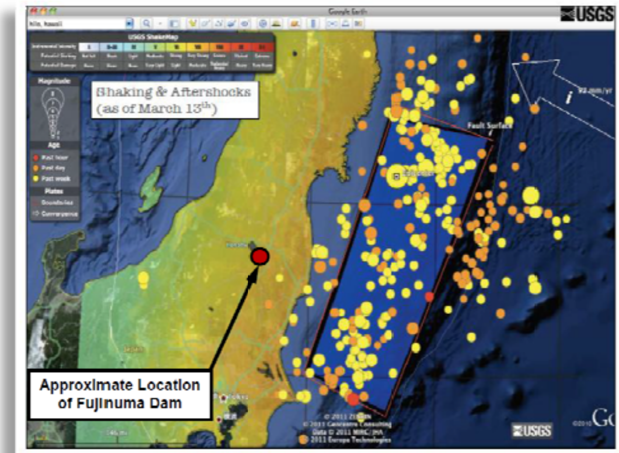


Figure 1: Approximate Location of Fujinuma Dam in Southern Fukushima Prefecture Shown on USGS Shake Map for March 11, 2011 Tohoku Offshore Earthquake, (adapted from USGS, March 13, 2011)

The Fujinuma Dam was located approximately 80 kilometer from the fault rupture and directly opposite the approximate middle of the 600-kilometer fault rupture zone. According to the report, the dam was nearly full when the earthquake occurred. The dam crest reportedly was overtopped approximately 20-25 minutes after the earthquake with a large discharge developing later. The resulting breach flow travelled down a narrow canyon down to the village of Naganuma that causes flooding and washing away five away five houses while damaging others, disabling a bridge and blocked roads with debris. Seven (7) loss lives and one (1) went missing. Reportedly, some locals attempted to repair the leaks in the dam before it completely failed.

Fujinuma-ike is an irrigation reservoir situated on the right branch of upper Sunoko River and it taps water from the main stream of Sunoko River by head race. There exists an auxiliary embankment dam on the right abutment saddle. The construction of Fujinuma dam, auxiliary dam and head race were started in April 1937, suspended during the World War II and completed in October 1949. Fujinuma dam is an earth fill dam with the height of 18.5 meter and the crest length of 133.2 meter, while the auxiliary dam is of earth embankment type with the height of 10.5 meter and the crest length of 72.5 meter. From 1977 to 1979, the spillway and surface protection work of Fujinuma Dam were repaired and from 1984 to 1992, countermeasures against the leakage by grouting as well as upgrading of intakes were conducted. The agricultural water taken from Fujinuma dam irrigates the land of 837 ha and the dam is managed and operated by Ebanagawa Irrigation District.

Philippines' Record of Dam Failure

Marinduque Mining and Industrial Corp., Sipalay Negros Occidental

- 1982 Nov 8: dam failure due to slippage of foundation on clay soil, 28 million metric tons of tailings released resulting in a widespread inundation of agricultural land up to 1.5m high and the siltation of Tao-Angan River

Lepanto Consolidated Mining Corporation, Mankayan, Benguet

- 1986 Oct 17: collapsed of tailings pond 3 due to wakened dam embankment caused by additional loading caused the siltation of the Abra River which affected nine (9) municipalities

Manila Mining Corp (MMC) in Placer, Surigao Del Norte

- 1987 July 9: dam failure causing fish kills
- 1995 Sept 2: dam foundation failure at tailing pond 5 of Placer copper-gold project killing 5 people and coastal pollution
- 1999 Apr 26: 700,000 tonnes of cyanide tailings spill from damaged concrete pipe in tailings pond due to excessive rains caused 40 houses to be buried and 40 hectares of land affected including 20 hectares of agricultural land

PHILEX Mining Corp

- 1992 Jan: In Tuba, Benguet, collapsed of wall of tailings pond due to "weakened dam structure caused by 1990 earthquake" 80 million metric tons of tailings released

Itogon-Suyoc Mines Inc , Mankayan, Benguet

- 1993 June: overtopping at the dam of the Itogon-Suyoc gold and mines occurred during a typhoon when the dam penstock and diversion tunnel were blocked caused the siltation of adjoining river

MARCOPPER Mining/Placer Dome, Marinduque

- 1993: the Maguila-guila siltation dam collapsed due to the pressure from heavy siltation at the dam wall and caused the Mogpog River to be flooded resulting to death of 2 children, livestock killed, agricultural land contamination, downstream communities and Mogpog Town flooded
- 1996 Mar 24: old drainage tunnel burst, releasing over 3 million m3 of tailing from storage pit into 2 major river systems, over 1,200 residents evacuated, 18km of river filled with tailings

Canatuan Gold Mines

- 2007 April 6 & July 11: In Canatuan Gold Mines in Siocon, Zamboanga Del Norte heavy rains washed out the clay soil and destructed the concrete wall of the sulphide dam which resulted to contamination of water, where cyanide and mercury is detectable, flows to the Canatuan River down to Siocon River and towards the sea.

Angat Dam In Focus

MALOLOS CITY— The experts commissioned to test the structural integrity of Angat Dam have recommended its immediate rehabilitation after finding that the 44-year-old structure and its dike in Norzagaray, Bulacan, sit on a fault line and could flood 30 cities and towns if damaged in an earthquake.

Official name	Angat Dam
Location	Barangay San Lorenzo, Norzagaray, Bulacan, Philippines
Construction began	November 1961
Opening date	October 16, 1967
Construction cost	Php 315.344 Million
Operator(s)	National Power Corporation
Dam and spillways	
Impounds	Angat River
Length	568 meters
Height	131 meters
Width (base)	550 meters
Reservoir	
Creates	Angat Reservoir
Total capacity	850 million cubic meters
Power station	
Turbines	10 Vertical shaft, Francis turbine (Includes turbines from the main powerhouse and the auxiliary powerhouse)
Installed capacity	256,000 kW

The recommendation was revealed by officials of the Metropolitan Waterworks and Sewerage System led by Administrator Gerardo Esquivel, during a meeting with provincial officials led by Gov. Wilhelmino Sy-Alvarado at the provincial capitol here.

John Grimston, Tonkin and Taylor International, the group commissioned to study the dam's structural integrity, said a series of fault lines were identified in the foundation of the main dike and up to 15 kilometers upstream.

The experts said an earthquake on the Western Marikina Valley Fault could trigger movement on the fault lines beneath the dam and its dikes. If those were damaged, they warned, the flood wave would affect not only areas near the Angat River but extend both upstream and downstream into the floodplain of the Pampanga River.

That would flood 30 cities and towns in Bulacan, Pampanga and Metro Manila, they said.

The flood waters in some areas of Norzagaray, Bustos and Baliuag could reach as high as 30 meters during the initial break of the dam, the experts' report says. They could reach as high as 10 meters in Pulilan and Plaridel and all the way to Calumpit and Malolos City. Areas of Pampanga and Metro Manila could experience floods of three to five meters, they said.

"Considering the safety of the Angat Dam and Dyke is indeed a national security concern which needs to be addressed immediately. There is a need to undertake remediation work at the earliest possible time,".

Myth about Angat Dam and Bustos Dam

Bustos Dam also known as Angat Afterbay Regulator Dam (AARD) is a small irrigation dam at Bustos, Bulacan is often mistaken by the locals as Angat Dam since it is located close to the nearby town of Angat. It is important to correct such wrong notion to avoid further misconception to the issue.

The project is located at Barangay Tibagan, Bustos, Bulacan, served by the Angat River. The main dam is about 18 meters above sea level. Among the 2.5-meter high, six-span dam's main features are easily deflectable and inflatable rubber body, resistance to sedimentation, economical and having auto-deflation system.

History

Built in 1926, 50 kilometers upstream from the Bustos Dam as a fixed type river weir without gates, AARD is the longest rubber dam in Asia at 79 meters and the second largest in the world serving nearby cities: Real, Quezon, Rodriguez (Montalban), Rizal, Antipolo City, Rizal.

In 1967, steel sector gates were installed on top of the regulator dam for the purpose of generating irrigation water, power supply and domestic water supply.

Rehabilitation

With its construction, the Bustos Dam's height was increased by 2.5 meters and later renamed Angat Afterbay Regulator Dam, increasing the service area of the Angat-Maasim Rivers Irrigation System (AMRIS), which operates the AARD from 25,000 hectares in 1927 to 31,485 hectares in 20 towns in Bulacan and Pampanga benefitting 20,562 farmers.

The series of typhoons from 1968 to the early part of 1980 was damaging to the dam whose Bay 1 sector gate finally gave way in September 1990 after typhoon "Iriang" carried away the structure 250 meters downstream from its original post. The agency has undertaken temporary rehab works in the dam using their own budget and through funding assistance from the World Bank.

The present dam was rehabilitated by Kurimoto, LTD., Osaka, Japan, manufacturing date, as of May, 1997. It has Washed Out, Intake, Sluice and Roller Gates sets. It's clear spans are 4.6% 1.53 meters. Its gate (opening) heights are 4.5 and 1.0 meters. The weights of the leaves are 5.4 and 1.0 tons. The operating speed is 0.3 m./ min.

Historical Marker

In 2001, The Japan International Cooperation Agency (JICA) has approved a P500-million grant-in aid to the government for the repair and improvement of the Angat Afterbay Regulatory Dam (AARD) in Bustos, Bulacan.

By the 3rd Quarter of 2014, The National Irrigation Administration (NIA) is bidding out the P1-billion contract for the rehabilitation of the Bustos rubber dam in Bulacan.

DATA ANALYSIS

To give a clearer view of the researcher's topic and to avoid questionable acts and deeds that may result to infringement of property right and copyright law, the researcher summarizes the following case studies:

A. The Vaiont (Vajont) landslide of 1963

The Vajont reservoir disaster is a classic example of the consequences of the failure of engineers and geologists to understand the nature of the problem that they were trying to deal with. During the filling of the reservoir a block of approximately 270 million cubic metres detached from one wall and slid into the lake at velocities of up to 30 m/sec (approx. 110 km/h). As a result a wave over topped the dam by 250 m and swept onto the valley below, with the loss of about 2500 lives. Remarkably the dam remained unbroken by the flood.

Since the catastrophic failure, a huge range of work has been undertaken on the causes of the failure. Initially the was a large amount of speculation about the location of the sliding surface, but more recent studies have confirmed that it was located in thin (5 - 15 cm) clay layers in the limestone. It is claimed by some that as such it represents a reactivation of an old landslide (Hendron and Patten, 1985; Pasuto and Soldati, 1991), whilst others claim that it was a first-time movement (Skempton, 1966; Petley, 1996). It is likely that increasing the level of the reservoir drove up pore pressures in the clay layers, reducing the effective normal strength and hence the shear resistance. Resistance to movement was created by the chair-like form of the shear surface. Dropping the level of the reservoir induced hydraulic pressures that increased the stresses as water in the jointed limestone tried to drain. It has been estimated that the total thrust from this effect was 2 - 4 million tonnes (!?) (Muller, 1964). Failure occurred in a brittle manner, inducing catastrophic loss of strength. The speed of movement is probably the result of frictional heating of the pore water in the clay layers (Voight and Faust, 1982, 1992).

B. Dam Break Analysis for Polavaram Project

Drastic changes in geographical surface characteristics and meteorological characteristics lead to flash flood, whose magnitude if exceeds the capacity of spillways causes overtopping of embankment dams, resulting in the dam failure. When a dam fails, a large quantity of storage water is released to downstream, producing a flood wave which is capable of creating disastrous damage to the downstream people and property. Pre-determination of flood wave characteristics along the downstream river reach is very much essential in mitigating such disasters. The Prediction of characteristics of dam-breach flood wave formation and the downstream propagation for all the existing and the future major dams located in the earthquake prone areas and regions of heavy rainfall is very much essential. Accordingly the down-stream developments can be controlled, the possible extent of inundation of downstream zone can be predicted and the emergency action plan can be formulated to mitigate the disaster. The present study aims to predict the characteristics of the flood wave like peak flood stage, peak flood discharge and their times of occurrence at different locations downstream in the river due to dam-breach, for a hypothetical dam-breach pattern for a rock-fill dam on the Godavari River. The effect of variation of duration of breach of dam on the outflow hydrographs is also studied. The National Weather Service Dam Break Flood Forecasting (DAMBRK) model has been used for the study and the results are discussed in terms of outflow hydrographs.

C. TED Case Studies - Three Gorges Dam

The Three Gorges is the general name for the Qutang, Wuxia, and Xiling gorges. The Three Gorges area begins at Baidicheng in Fengjie County, Sichuan Province, and ends at Nanjinguan in Yichang County, Hubei province, a distance of 193 kilometers. The Three Gorges area, well known for its precipitous terrain and numerous scenic spots, has been listed as the best of the top 40 scenic spots in China.

Since no specific measures have been implemented, China is eager to import international parts and equipment for the dam construction. The China Yangtze Three Gorges Project Development Corporation, which is responsible for overseeing the entire project, announced that some stages of construction would be opened to bids from international companies. The government has also approved importing key technologies, materials, and spare parts needed to build the twenty-six 680,000 kilowatt turbo generators and the 50,000 volt high tension transmission lines. Joint ventures for the dam itself are also possible. These parts and equipment are expensive and therefore, the amount of trade should be significant.

Technical assistance from abroad, such as the United States and Japan, constitute international service flows. For example, the U.S. Department of Interiors Bureau of Reclamation and the Army Corps of Engineers are helping with technical assistance on design and construction.

D. Dam Breach Modeling – An overview of Analysis Methods

The paper presents an overview of today's typically used methods for predicting dam breach outflow hydrographs, with discussion of the advantages and disadvantages of different approaches for specific applications. The methods presented range from simpler well established methods to more complex approaches now under development.

The two primary tasks in the analysis of a potential dam failure are the prediction of the reservoir outflow hydrograph and the routing of that hydrograph through the downstream valley to determine dam failure consequences. When populations at risk are located close to a dam, it is important to accurately predict the breach outflow hydrograph and its timing relative to events in the failure process that could trigger the start of evacuation efforts. This paper provides an overview of the methods used to predict breach outflow hydrographs, ranging from simple methods appropriate for appraisal-level estimates to more complex methods for analysis of individual cases. The progression of technology development is followed from methods that predict peak outflow directly to those that predict breach development directly and model the hydraulics analytically, and finally to methods that model erosion processes, breach development and hydraulics in great detail.

E. Teton dam failure (June 12, 1975)

Case Studies of dam breach geography and hydraulics

Dams provide many benefits to society; however, floods resulting from dam failures have produced some of the most devastating disasters of the last two centuries (Wahl, 1998). Therefore, earth-dam failure has become a subject of increasing concern among dam engineers, federal, state, and local officials, and society at large.

Despite the existence of ample documentation, the prevailing mechanisms for earth-dam failure are still not clearly understood. Studies have shown that earth-dam failures can be due to many causes. Generally, these are classified into: (1) hydrologic, and (2) geotechnical. Failure usually results in the eventual development of a breach compromising a certain length of embankment. The breach width has been documented in a large number of cases. Dam-breach studies have shown that the shape and time evolution of the breach determine to a large extent the characteristics of the outflow hydrograph (Ponce, 1982).

The objective of the paper is to develop a dimensionless relationship between geometric and hydraulic parameters governing earth-dam breach failures.

F. Prediction of Embankment Dam Breach Parameters

A Literature Review and Needs Assessment

This peer-reviewed report examines the role, importance, and methods for predicting embankment dam breach parameters needed for analysis of potential dam-failure floods. Special emphasis is given to dam breach analysis within the context of the risk assessment process used by the Bureau of Reclamation (Reclamation). Current methods for predicting embankment dam breach parameters and numerically modeling dam breach events are reviewed, and the needs and opportunities for developing improved technologies are discussed. Recent technical advances that could contribute to improvements in dam breach simulation are identified. In addition to this literature review, Reclamation and the Agricultural Research Service (ARS) cosponsored an international workshop on dam breach processes February 10-11, 1998, attended by about 35 leading professionals working in this field. The workshop provided an opportunity to review and discuss the state-of-the art, ongoing research, and future needs for dam breach analysis tools. Key findings from this literature review and the workshop include:

- There is presently both a need and opportunity to achieve significant improvements in technology used to analyze embankment dam breach processes. The potential benefits to be achieved from this effort may significantly aid risk assessment studies, in which thresholds of dam failure, probabilities of failure, and consequences of failure are all of prime importance.
- When population centers are located close to dams, accurate prediction of breach parameters is crucial to development of effective emergency action plans, design of early warning systems, and characterization of threats to lives and property.
- Warning time is the most important parameter affecting potential loss of life due to dam failure.
- The primary benefits of improved prediction of breach initiation and formation times will accrue to the population within a few kilometers of the structure, but this is also the region which historically has the greatest risk for loss of life.
- The distinction between breach *initiation time* and breach *formation time* has not been clearly made in the literature or the available case study data; this impacts the ability to accurately predict warning time.
- Although breach initiation time is critical to the determination of loss of life, there is little guidance in the literature for its prediction. Numerical dam breach models have the potential to predict breach initiation times, but are not widely used and are not based on observed breach erosion mechanisms.
- Breach parameter prediction equations based on analyses of dam failure case studies have significant uncertainty, breach formation time is especially difficult to predict

G. Dam-break Problems

Solutions and Case Studies

A dam is an engineering structure constructed across a valley or natural depression to create a water storage reservoir. Such reservoirs are required for three main purposes: (1) provision of a dependable water supply for domestic and/or irrigation use; (2) flood mitigation and (3) generation of electric power.

In providing water supply, the reservoir storage is filled during the periods of above average stream-flow. For flood mitigation, the storage reservoir is kept nearly empty during drought and periods of low rainfall, so that when rainstorms occur, the storage volume available in the reservoir provides a buffer against severe flooding events. For power generation, the storage reservoir provides a head of water upstream of the dam and the potential energy of this water is converted first to kinetic and then to electrical energy. A large dam has two essential requirements. First, it must be reasonably watertight. Second, the dam must be stable. Movements and deformations of the dam and its foundations cannot be eliminated, but they must be predicted and allowed for in the design. Because of these requirements, the location and design of dams are undoubtedly influenced to some extent by structural and/or geological features. It therefore follows that geological factors, and the proximity of construction materials are elements of overriding importance in determining the type of dam constructed at a given site. Once a site has been selected for a dam, consideration has to be given to deciding which type of dam is most suited to the site. Anyway, at any site, several types of dam should be considered. In general, three factors control this final decision: (1) the topography of the dam site and reservoir area; (2) the strength and variability of the foundations and (3) the availability and suitability of construction materials.

These factors are largely controlled by the geological structure and history of the site, and an informed decision requires a great deal of geological data analysis, particularly for the second and third factors, presented in a manner that planners and engineers can use in design calculation and procedures. When designing a large dam, the engineers have to abide by two main goals: (1) the dam must be stable and (2) the structure must be constructed as economically as possible. The two objectives are against each other: ensuring stability by over-design increases the costs, while cost-cutting methods could lead to unsafe structures. On a worldwide scale, it is clear that the objective of constructing stable dams is not always achieved. During the 1900–1965 period, for example, about 1% of the 9000 large dams in service throughout the world have failed, and another 2% have suffered serious accidents.

A comparison was made between disasters (both Japan and Philippines experiences) and it was decided that the information are useful to this research for the following reasons: 1) that Japan is more vulnerable to earthquake than the Philippines; 2) that dams in Japan withstand even the most powerful earthquake with tolerable damage to life and property; and 3) that the Japanese technologies (particularly in dam technologies) is way above compare to the most advanced country in the world. A detailed and more comprehensive discussion on the said subject follows:

A Review of Japanese Dam Technologies

Due to geographical location of Japan, unintentionally, gained mastery of hazards and almost perfectly developed technology to rule over harsh environment. But this, of course, did not happen overnight. It took many years of painful endeavor and sacrifices before it attained a world class technology.

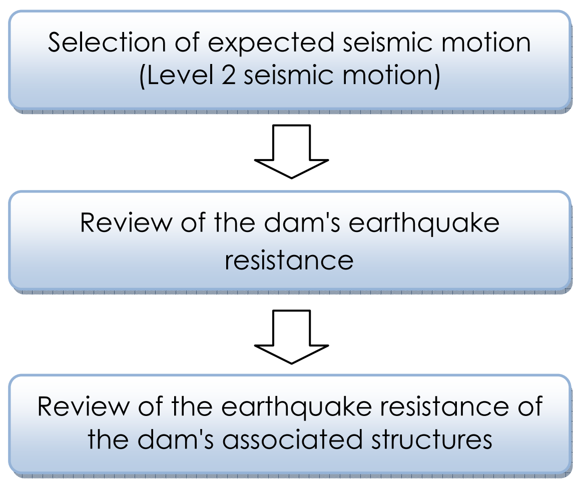
Japanese supremacy in dam technology could be summarized as follows:

Japanese believed in the philosophy that dams are very useful in hydroelectric power generation, water resource development, flood control, and other areas. Furthermore, they believed that dams must continue to function and must not break down. Japanese advanced technologies offers a construction of sound dams, even using less-than-ideal materials on less-than-ideal foundations, within a short period of time and with low cost. They will have excellent qualities such as high strength, high durability, and resistance to earthquakes, which will also yield very low life-cycle cost.

1. **High Durability and Earthquake-resistance of Dams can Reduce Life Cycle Cost (LCC)**
    a. Japanese dams have endured major earthquakes owing to Japanese dam technologies
    b. High durability of dams together with speedy construction can reduce LCC
    c. Reduce LCC through Total Quality Management (TQM)

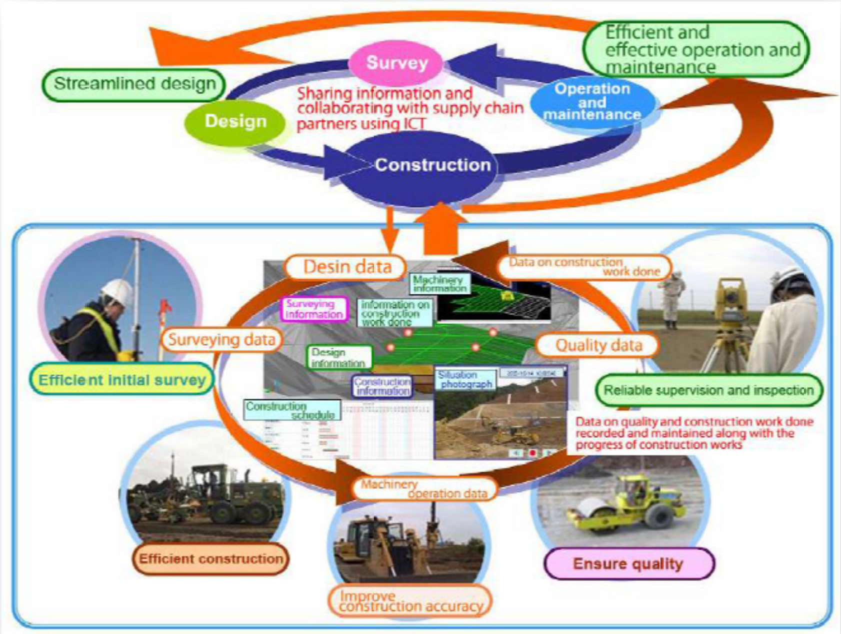
Japanese dams have endured major earthquakes owing to Japanese dam technologies The history of modern dam construction in Japan began in 1887 when an earth dam to collect water for water supply was built. Japan's first concrete dam to supply water was completed in 1900. The older of the two (the earth dam) was damaged by massive flooding in 1982. The concrete dam was damaged by the Great Hanshin (Kobe) Earthquake in 1995, which measured 7.3 on the Richter scale. Both dams are still in service, even though they suffered minor damages under frequent occurrence of major natural disasters.

From Dam Technologies of Japan



"Procedures in testing to verify earthquake resistance"

"Smart" construction utilizing information and communication technologies (ICT) can make the work process more efficient and accurate. By using ICT, data can be shared and made traceable so it can be used to ensure quality. This is an example of the Total Quality Management (TQM) effort in dam construction to ensure uniform dam quality, make dams more durable and thereby reduce their life cycle cost.



From Dam Technologies of Japan

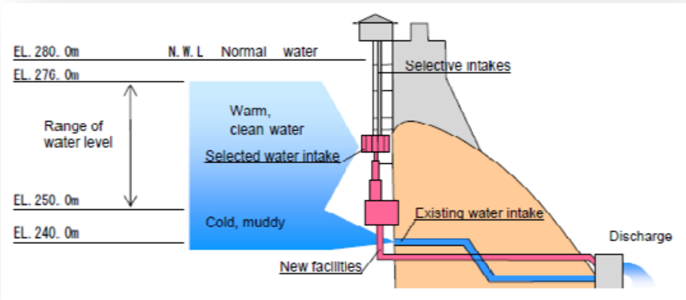
For a dam to function over a period of time it should be constantly repaired and maintained. The cost required for dam maintenance, repairs and renewed is low at the beginning, but equipment should be renewed after about 10 years.

2. **Upgrading Technologies to Effectively Use Existing Dams (Reduce Costs, Construction Periods, Environmental Impacts)**
    d. Increasing reservoir volume under operation
    e. Construction to enable more effective use of reservoir water under operation (Improving operation, Increasing discharge capacity)
    f. Restoring dam function Control sediment)

One way of improving dam function is increasing reservoir volume under operation. The height of the dam can be raised under operation, to increase reservoir volume. To do this, the safety of the existing dam is assessed, ways to unify the old dam with the new construction are examined, and the stability of the foundation and the newly constructed dam extension is examined. Even old dams can be made higher following detailed and careful assessment.

From Dam Technologies of Japan

Using Japan's upgrading technologies, we can drill the dam body and build a water intake in the existing dam under operation, and thus increase the water supply and discharge capacity. The selective intake facility can be built at any depth in the dam to take water at the temperature required for use. The water is warmer and clearer near the surface, while water near the bottom is colder and muddier.



From Dam Technologies of Japan

Japan has technologies to restore dam performance and make dams last longer under operation. Sediment bypass tunnel is a technique used to prevent sediment flowing into the dam reservoir by bypassing it into a tunnel leading downstream from the dam. Using this technique, reservoir volume reduction resulting from sediment accumulation is minimized, allowing the dam to be used longer.

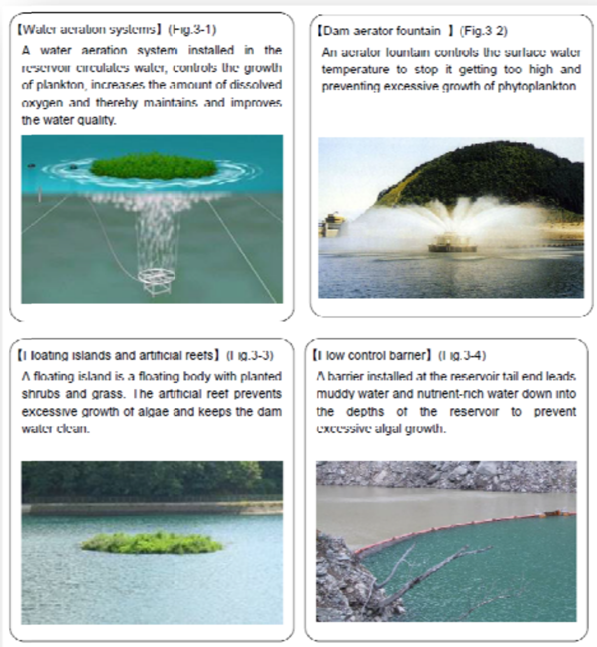
A non-powered siphon is used to suck and remove the sediment that has accumulated at the bottom of the reservoir. The siphon's intake works by itself and sucks sediment at a rate depending on the sediment density in the discharge pipe.

3. Environmentally Friendly Technologies to Conserve the Environment and Ecosystem

g. Conserving water quality in the reservoir
h. Conserving the ecosystem
i. Monitoring for the water quality and environment during construction

Japan is working hard to keep reservoir water clean and to protect the environment. Issues caused by river water remaining in the dam reservoir include variation of the water temperature and the amount of organic substances in the water, eutrophication and persistent muddy water.

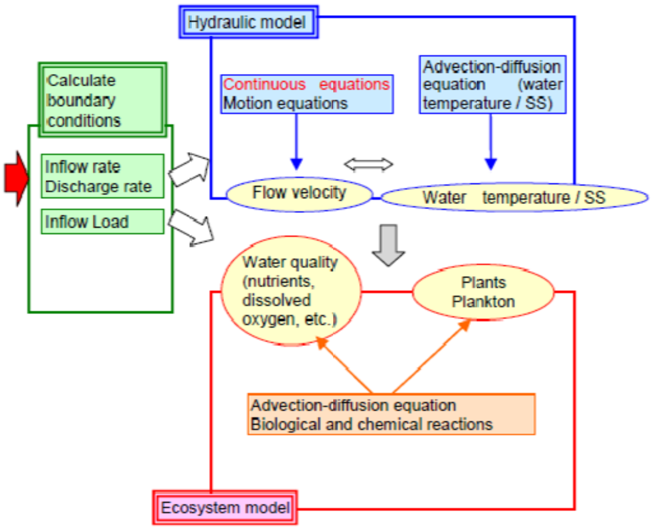
While newly constructed dams create a new environment, they also affect the habitats and nesting grounds of birds of prey. Dams submerge the habitats of rare plants, and prevent fish going upstream and downstream. Japan has techniques to minimize the effects of dam construction on ecosystems.



From Dam Technologies of Japan

In the planning phase of a dam construction projects, we conduct surveys on items listed in Table 1 and conduct qualitative forecasting and assessment. If a significant impact on the environment is likely, we examine methods to protect the environment and assess the impact of the activities that will be taken.

Environmental factors	
Atmospheric environment	Air quality (dust)
	Noise
	Vibration
Water environment	Water turbidity due to sediment,water temperature, eutrophication, dissolved oxygen levels, hydrogen ion concentration (pH)
Animals	Important species and habitats need to be monitored
Plants	Important communities and species
Ecosystems	Ecosystems that characterize the local region
Scenic views	Important scenic viewing points and landscape resources
Waste, etc	By-products associated with construction



From Dam Technologies of Japan

In Japan, when discharging the muddy water that has been generated during the course of aggregate production, concrete placement and other construction work, the water should first meet a water-quality standard in order to protect the river environment. Muddy water is treated at facilities at dam construction sites (quarry sites, aggregate sites, dam sites) using poly-aluminum chloride (PAC), polymer coagulant, carbon dioxide and other chemicals.

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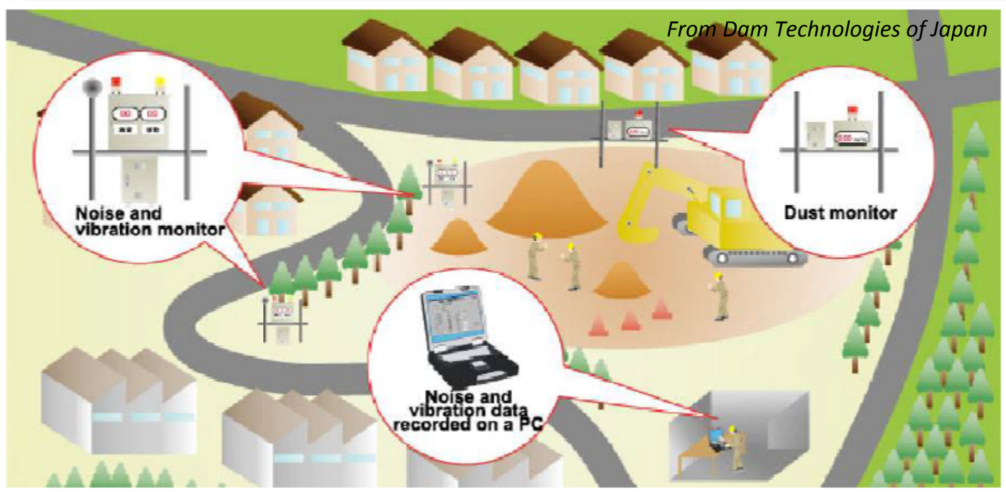
Dam construction, using large machinery and carrying a massive amount of sand, soil and rocks, can be a source of noise, vibration and dust. To protect the local community and natural environment, levels are measured and necessary measures are taken.



A closer look to the advantages Japanese dam technologies could offer is insurmountable; it is the best, most efficient, secured, and defendable dam technology in the world today.

Activities of Stakeholders in Angat Dam

Manila Bulletin – Sat, Dec 14, 2013

DAM BREAK DRILL — More than 12,000 students, health workers, and government employees walk along the MacArthur Highway going to the evacuation site at the Bulacan Sports Complex in Sta. Isabel, Malolos City as part of the Angat Dam Break Drill yesterday morning.

Malolos City, Bulacan — Fearless Bulakenyos cheered as they resolved the "doomsday scenario" posed by a possible Angat Dam break in the event of a 7.2-magnitude earthquake like the one that struck Bohol last October.

More than 12,000 students and residents in all of Bulacan rose from bed at dawn yesterday to gather in front of the Centro Scholar University (CEU) and other specified venues where Angat Dam Break Drills were set.

In times of chaos and devastation wrought by a powerful earthquake that could trigger the "destruction" of the 45-year-old Angat Dam, preparedness, good management and strong leadership can make a big difference in saving as many lives as possible.

This was the assessment of Office of Civil Defense 3 Regional Director Josefina Timoteo on the Angat Dam Break Drill conducted by the Provincial Government of Bulacan early yesterday morning.

The drill was made after Gov. Wilhelmino M. Sy-Alvarado ordered the review and upgrading of Emergency Action Plans of the provincial government, including various schools in this historic capital city, as part of the adaptation program on the "clear and present danger" being poised by the destructive effects of global warming and climate change.

Earlier, Philippine Institute of Volcanology and Seismology (PHIVOLCS) Director Renato U. Solidum assessed that Angat Dam is susceptible to a break once Bulacan is hit by an earthquake with a magnitude of 7.2. In a matter of hours, the whole of Bulacan will be inundated.

Timoteo said the drill conducted by the Provincial Government and the Provincial Disaster Risk Reduction and Management Office (PDRRMO), is "99.9 perfect."

Aging Angat Dam poses grave threat to Bulacan, Metro Manila residents

Tuesday, 05 April 2011 23:31 Ramon Efren R. Lazaro / Correspondent

CITY OF MALOLOS—Half of Bulacan could be wiped out if the aging Angat Dam is not rehabilitated within seven years.

This was the assessment of Bulacan Gov. Wilhelmino Sy Alvarado as he was informed by dam experts that the life expectancy of Angat Dam is only for 50 years and it is now 43 years old. However, the life span of the dam can be extended for another 50 years if it is rehabilitated before the end of its expected life span.

Alvarado also noted it is time that the dam structure be assessed of its structural capability to withstand water pressure in its reservoir because of its age.

The governor also quoted a statement by Metropolitan Waterworks Sewerage System (MWSS) that because of its age and the presence of the Marikina West Valley Fault Line in the vicinity of the dam "making our water supply source at risk," a new water source is needed to help mitigate the loss of water supply from other sources in case of major disasters such as natural calamities (referring for the construction of the Laiban Dam in Rizal province).

He said that Dr. Kaare Hoeg of the Norwegian Technical Institute previously noted that Angat Dam may be able to withstand intensity 7.5 earthquake.

Alvarado added if the aging dam gives way to the stress from the water pressure from its water reservoir or if a big earthquake strikes, the main water source for Metro Manila will be destroyed, leaving it with no potable water to sustain its residents.

However, these situations will not only imperil the main water source for Metro Manila, Alvarado told the Business Mirror, but also could wipe out half of Bulacan province and an estimated 2 million of its residents killed by rampaging water and flood.

Alvarado said the MWSS and other concerned agencies should not prioritize the construction of Laiban Dam but should give importance for the rehabilitation of Angat Dam.

The governor said the Laiban Dam project is capable of providing Metro Manila with 1,900 million liters per day (MLD) of water compared with the 4,019 MLD of water that Angat Dam currently provides.

“Common sense dictates that we should first give priority to the rehabilitation of the water source that provides the majority of the water needs for Metro Manila because of its perceived vulnerability due to its age and the catastrophic damage it can bring when tragedy strikes, rather than prioritize a project that is to provide only an augmentation supply of water,” Alvarado noted.

Because of these, Alvarado said he recently met with officials of the MWSS, the National Power Corp. (Napocor) and other concerned government agencies and recommended that a technical working group be created to assess the structural capability of the aging Angat Dam and for eventual rehabilitation.

In an interview on Friday, Froilan Tampinco, president of Napocor, admitted that a technical working group is set to undertake assessment on the structural soundness of Angat Dam and its finding to be submitted to President Aquino.

Tampinco said dam experts, local or foreign, will be tapped to make an expert study on Angat Dam and added that to give credibility to its findings, these experts will not be tapped from concerned government agencies that will be sponsoring the study.

Tampinco also admitted that water seapages at the dike of Angat Dam but these are only natural because of the materials used in its construction.

However, Tampinco would not confirm nor deny if there were any cracks in the dam’s structure because of its age and added that is why they are to conduct the study to assess the structural soundness of the dam and what actions need to be taken on its findings.

Angat Dam before it bursts

FROM THE STANDS by Domini M. Torrevillas (The Philippine Star) updated May 13, 2014 - 12:00am

The alarm bells are ringing. We’re being told not to waste water as our source of the commodity is near bankruptcy, ie., running dry. This may sound melodramatic, but the danger of Angat Dam’s water level probably going to drop to zero level cannot be ignored.

Media reporters tell us that according to data from the Philippine Atmospheric, Geophysical and Astronomical Services Administration, the water level at the Angat Dam had reached the critical level of 180 meters due to lack of rainfall. Brief rain showers have not helped raise the water level. Cloud seeding over the dam’s watershed has not started as the Napocor. is still trying to secure a clearance from the

Civil Aviation Authority of the Philippines to do so – why it's taking the CAAP time to give the clearance is beyond comprehension.

Angat Dam's critical water level is a big issue, but there is yet a bigger issue — if the dam's rehabilitation is not made, the dam could burst when a big earthquake takes place. When that happens, whatever water remains inside the dam could drown people, houses and rice fields around the dam. Already, some local residents, by flight of their imagination perhaps, report seeing cracks on the walls of the facility.

Our attention was drawn to Angat Dam by lawyer Jesus I. Santos, whose primary advocacy during the last 36 years has been the preservation of the Angat Dam watershed since he appeared as counsel for the victims of the October 26, 1978 tragedy where many Bulakeños perished as a result of the sudden release of water from the dam.

For years, Jess said, "Often than not, I was alone in calling the attention of the government to the importance of the watershed." Recently, light broke through when he learned that Rep. Linabelle Ruth Villarica had been elected to chair the committee investigating the condition of the watershed. Villarica (a second termer from the 4th District, Bulacan) is president of the Central Luzon bloc in the House which consists of 23 members (coming from Pampanga, Tarlac, Bataan, Bulacan, Nueva Ecija and Zambales). It came naturally that Angat Dam would be her, and the bloc's major concern.

Subsequently, the bloc filed House Resolution 846 directing the committee on public works and highways to immediately conduct an investigation in aid of legislation to look into the status of the Angat Dam Rehabilitation Project, also called Angat Dam and Dike Strengthening Project, with the end of expediting its implementation to ensure the safety and reliability of the Angat dam and dike from geological and hydro-meteorological hazards.

The resolution came on the heels of the warning from the PHIVOLCS that the West Valley Fault which runs through the central Metro Manila area is potentially active, and that a splay or local fault runs 200 meters east of the Angat dam and dike, and any movement of the West Valley fault may affect the local fault.

A Safety Study was conducted; this recommended the strengthening of the dam and dike, and construction of a spillway to accommodate the updated Probable Main Flood (PMF) of 12,000 cubic meters.

Accordingly, government agencies signed a memorandum of agreement on Oct. 21, 2011 to identify, prioritize and implement a program for the safety and integrity of the Angat Dam in the event of an earthquake. The result was the creation of ADDSP, which was approved on Sept. 4, 2012, by the National Economic and Development Authority (NEDA) with a budget of P1.826m for its implementation.

The resolution was prepared based on an aid memoire by Engr. Jose D. Dorado Jr., ADDSP project manager. It is pending with the committee on rules, which has yet to schedule a meeting to formally refer it to the committee on public works and highways. According to Villarica, the resolution was carefully crafted to refer it to only one committee, the committee on public works and highways, and not to the joint committees on environment, energy, local government and public works, for speedy action.

To date, the project has not been implemented, according to Villarica, "perhaps due to the unpredictable nature of natural calamities."

But there is a bigger issue than unpredictable natural calamities.

It's not only the government that is responsible for the slow-foot implementation of ADDSP. Let's look at Angat Dam's history. Located in Norzagaray, Bulacan, the dam and dike were constructed by the Napocor in the early 1960s as a multi-purpose facility for domestic water supply, irrigation, power and flood control.

As stated above, PHIVOLCS announced the potential danger of the West Valley Fault affecting the dam, government agencies signed a MOA to identify, prioritize and implement a program and project that will ensure the safety and reliability of the dam from geological and hydro-meteorological hazards. Immediately after the MOA signing, the Safety Study was undertaken – thus the creation of ADDSP.

The project, according to an aide memoire from the Metropolitan Waterworks and Sewerage System, will be implemented under a Design-Build Scheme, and is a flagship component of Metro Manila's Water Security Legacy that ensures the long-term sustainability of its water supply.

Here now comes a twist of fate. On Oct. 9, 2012, the Supreme Court approved the sale of the 218-megawatt hydroelectric power plant (HEEP) of the Angat Dam to a company that is owned and controlled by the Korean government. The decision said the bidding of the facility was transparent and objective, and the award of operation of the dam's hydropower facility to Korea Water Resources Development Corp. (K-Water) was valid and legal.

The Court said the National Power Corporation should "retain full supervision and control over the extraction and diversion of waters from the Angat River," while K-Water can use the water in the Angat dam for hydropower generation and acquire generation assets.

The hydropower facility, said the Court, was sold pursuant to the privatization provision mandated under the Electric Power Industry Reform Act or the EPIRA law.

According to the MWSS aide memoire, "in light of the Supreme Court decision confirming the sale of the AHEP to K-Water as valid and legal, discussion is still ongoing between MWSS and K-Water being the new AHEPP owner, regarding the implementation of the Project. Under the terms of the bid, K-Water is obligated to undertake mandatory rehabilitation of Angat Dam."

It is therefore clear: K-Water is in charge of the rehabilitation of the dam. So far, no physical manifestations of physical rehabilitation works at the site are evident. K-Water must do something now, to prevent the possibility of the dike cracking, and the dam breaking loose when an earthquake of severe magnitude takes place.

Then we can continue praying for the rain to fall.

And Jess Santos can pursue his study of the deforestation of the Angat watershed, leading to the poor water supply from the denuded forest land.

CONCLUSIONS:

This study aimed at understanding the alarming condition of Angat Dam, Philippines. Based on the study conducted, the main findings can be summarized as follows:

1. ***Rehabilitate Angat dam ASAP***; - if the dam's rehabilitation is not made, the dam could burst when a big earthquake takes place. When that happens, whatever water remains inside the dam could drown people, houses and rice fields around the dam.

2. ***Activities concerning DRRM must be given to DRRMC R-3 as lead agency;*** concerned government agencies and recommended that a technical working group be created to assess the structural capability of the aging Angat Dam and develop policies that will ensure safety and order within the area;

3. **Enhance capability/preparedness of all sector not only government entities;** There's no national dam safety law yet in the Philippines. 'There are many stakeholders in dam operations in the Philippines, but there is no single office that monitors the dams because there is no law on dam safety;'

4. **Conduct periodic dam-break-drill,** at least twice a year. Institute a wider information dissemination campaign. there is truth to the saying POWER IN INFORMATION, you now have in your hands a *life-saving* revelation to somebody who needs to hear it.

5. **This study must have a follow-up study** – Safety is everybody's concern, we should join hands in promoting peace, stability, and prosperity in Angat dam.: and last but not the least,

6. **Adopt Japanese dam technologies in Angat dam, Philippines**

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APPENDICES

List of Major Dam Failures

Dam/Incident	Year	Location	Fatalities	Details

Marib Dam	575	Sheba, Yemen		Unknown causes, possibly neglect. The consequent failure of the irrigation system provoked the migration of up to 50,000 people from Yemen.
Puentes Dam	1802	Lorca, Spain	608	1,800 houses and 40,000 trees destroyed.
Bilberry reservoir	1852	Holme Valley, United Kingdom	81	Failed due to heavy rain.
Dale Dike Reservoir	1864	South Yorkshire, United Kingdom	244	Defective construction, small leak in wall grew until dam failed. More than 600 houses were damaged or destroyed.
Mill River Dam	1874	Williamsburg, United States	139	Lax regulations and cost cutting lead to an insufficient design, which fell apart when the reservoir was full. 600 million gallons of water were released, wiping out 4 towns and making national headlines. This dam breaks lead to increased regulation of dam construction.
South Fork Dam	1889	Johnstown, United States	2,209	Blamed locally on poor maintenance by owners; court deemed it an "Act of God". Followed exceptionally heavy rainfall. Caused Johnstown flood. 1,600 homes were destroyed.
Walnut Grove Dam	1890	Wickenburg, United States	100	Heavy snow and rain following public calls by the dam's chief engineer to strengthen the earthen structure.
Gohna Lake dam	1894	Garhwal, India	1	Failure of a landslide dam. Authorities had been able to evacuate the valley.
McDonald Dam	1900	Texas, United States	8	Extreme current caused failure.
Hauser Dam	1908	Helena, United States	0	Heavy flooding coupled with poor foundation quality. Workers managed to warn people downstream.
Austin Dam	1911	Austin, United States	78	Poor design, use of dynamite to remedy structural problems. Destroyed paper mill and much of the town of Austin.
Desná Dam	1916	Desná, Austria-Hungary (now Czech Republic)	62	Construction flaws caused the dam failure.
Lake Toxaway Dam	1916	Transylvania County, USA	0	Heavy rains caused the dam to give way. Dam was later rebuilt in the 1960s
Sweetwater Dam	1916	San Diego County, USA	0	Over-topped from flooding.
Lower Otay Dam	1916	San Diego County, USA	14	Over-topped from flooding.

Tigra Dam	1917	Gwalior, India	1,000	Failed due to water infiltrating through foundation. Possibly more fatalities.
Gleno Dam	1923	Province of Bergamo, Italy	356	Poor construction and design.
Llyn Eigiau dam and Coedty reservoir	1925	Dolgarrog, United Kingdom	17	The outflow from Llyn Eigiau destroyed Coedty reservoir. Contractor blamed cost-cutting in construction but 25" of rain had fallen in preceding 5 days.
St. Francis Dam	1928	Santa Clarita, United States	600	Geological instability of canyon wall that could not have been detected with available technology of the time.
Secondary Dam of Sella Zerbino	1935	Molare, Italy	111	Geological unstable base combined with flood.
Nant-y-Gro dam	1942	Elan Valley, United Kingdom	0	Destroyed during preparation for Operation Chastise in WW II.
Edersee Dam	1943	Ruhr, Germany	70	Destroyed by bombing during Operation Chastise in World War II. Widespread destruction.
Möhne Dam	1943	Ruhr, Germany	1,579	Destroyed by bombing during Operation Chastise in World War II. 11 factories were destroyed, 114 seriously damaged.
Tangiwai disaster	1953	Whangaehu River, New Zealand	151	Failure of Mount Ruapehu's crater lake.
Vega de Tera	1959	Ribadelago, Spain	144	According to dam workers testimonies, the grounds had serious structural deficiencies due to poor construction. On the night of January 9, a 150 meters long portion of the contention wall collapsed letting out nearly 8 million cubic meters of stored water.
Malpasset dam	1959	Côte d'Azur, France	423	Geological fault possibly enhanced by explosives work during construction; initial geo-study was not thorough. Two villages were destroyed.
Kurenivka mudslide	1961	Kiev, Ukraine	1,500	Caused by heavy rains with up to 2,000 fatalities.
Panshet Dam	1961	Pune, India	1,000	Dam wall burst due to pressure of accumulated rain water.
Baldwin Hills Reservoir	1963	Los Angeles, United States	5	Subsidence caused by over-exploitation of local oil field. 277 homes destroyed.
Spaulding Pond Dam (Mohegan Park)	1963	Norwich, United States	6	More than $6 million estimated damages.

Vajont Dam	1963	Monte Toc, Italy	2,000	Strictly not a dam failure, since the dam structure did not collapse and is still standing. Filling the reservoir caused geological failure in valley wall, leading to 110 km/h landslide into the lake; water escaped in a seiche over the top of dam. Valley had been incorrectly assessed stable. Several villages completely wiped out.
Swift Dam	1964	Montana, USA	28	Caused by heavy rains.
Mina Plakalnitsa	1966	Vratsa, Bulgaria	107	A tailings dam at Plakalnitsa copper mine near the city of Vratsa failed. A total 450,000 cu m of mud and water inundated Vratsa and the nearby village of Zgorigrad, which suffered widespread damage. The official death toll is 107, but the unofficial estimate is around 500 killed.
Sempor Dam	1967	Central Java Province, Indonesia	2,000	Flash floods over-topped the dam during construction.
Certej dam failure	1971	Certej Mine, Romania	89	A tailings dam built too tall collapsed, flooding Certeju de Sus with toxic tailings.
Buffalo Creek Flood	1972	West Virginia, United States	125	Unstable loose constructed dam created by local coal mining company, collapsed in heavy rain. 1,121 injured, 507 houses destroyed, over 4,000 left homeless.
Canyon Lake Dam	1972	South Dakota, United States	238	Flooding, dam outlets clogged with debris. 3,057 injuries, over 1,335 homes and 5,000 automobiles destroyed.
Banqiao andS himantan Dams	1975	Zhumadian, China	171,000	Extreme rainfall, beyond the planned design capability of the dam, dumped on China by Typhoon Nina. 11 million people lost their homes. Worst dam failure.
Teton Dam	1976	Idaho, United States	11	Water leakage through earthen wall, leading to dam failure. 13,000 head of cattle died.
Laurel Run Dam	1977	Johnstown, United States	40	Heavy rainfall and flooding that over-topped the dam. Six other dams failed the same day, killing five people.
Kelly Barnes Dam	1977	Georgia,United States	39	Unknown, possibly design error as dam was raised several times by owners to improve power generation.
Machchu-2 Dam	1979	Morbi, India	5,000	Heavy rain and flooding beyond spillway capacity. Old estimates were 1,800-25,000 but a recent book by Sandersara & Wooten reduces the bracket to 5,000-10,000.

Wadi Qattara Dam	1979	Benghazi, Libya	0	Flooding beyond discharge and storage capacity damaged the main dam and destroyed the secondary dam in the scheme.
Lawn Lake Dam	1982	Rocky Mountain National Park, United States	3	Outlet pipe erosion; dam under-maintained due to location.
Tous Dam	1982	Valencia, Spain	25	Heavy flooding coupled with poor quality of the dam wall, lack of qualified staff and negligence of a warning of heavy rain in the area. On the next day, newspapers reported possibly 40 fatalities and 25 disappeared but in the coming days the count went down to 8 or 9. One year later, LaVanguardia spoke of 25.
Val di Stava dam	1985	Tesero, Italy	268	Poor maintenance and low margin for error in design; outlet pipes failed leading to pressure on dam.
Upriver Dam	1986	Washington State, United States	0	Lightning struck power system, turbines shut down. Water rose behind dam while trying to restart. Backup power systems failed, could not raise spillway gates in time. Dam overtopped (rebuilt).
Kantale Dam	1986	Kantale, Sri Lanka	180	Poor maintenance, leakage, and consequent failure. Destroyed over 1600 houses and 2000 acres of paddy fields.
Peruća Dam detonation	1993	Split-Dalmatia County, Croatia	0	Not strictly a dam failure as there was a detonation of pre-positioned explosives by retreating Serb Forces.
Merriespruit tailings dam	1994	Free State, South Africa	17	Dam failed after a heavy thunderstorm. The dam was in an unacceptable condition prior to failure. Widespread devastation and environmental damage.
Saguenay Flood	1996	Quebec, Canada	10	Problems started after two weeks of constant rain, which severely engorged soils, rivers and reservoirs. Post-flood enquiries discovered that the network of dikes and dams protecting the city was poorly maintained.
Meadow Pond Dam	1996	New Hampshire, United States	1	Design and construction deficiencies resulted in failure in heavy icing conditions.
Opuha Dam	1997	Canterbury, New Zealand	0	Heavy rain during construction caused failure, dam was later completed.
Doñana disaster	1998	Andalusia, Spain	0	Over-steepened dam failed by sliding on weak clay foundation, releasing 4–5

				million cubic metres of acidic mine tailings into the River Agrio, a tributary of the River Guadiamar, which is the main water source for the Doñana National Park, a UNESCO World Heritage Site.
Shihgang Dam	1999	Taiwan	0	Caused by damage sustained during the 921 earthquake.
Martin County coal slurry spill	2000	Martin County, United States	0	Failure of a coal slurry impoundment. The water supply for over 27,000 residents was contaminated. The spill was 30 times larger than the Exxon Valdez oil spill and one of the worst environmental disasters ever in the southeastern United States
Vodní nádrž Soběnov	2002	Soběnov, Czech Republic	0	Extreme rainfall during the 2002 European floods.
Zeyzoun Dam	2002	Zeyzoun, Syria	22	2,000 individuals displaced and over 10,000 directly affected.
Ringdijk Groot-Mijdrecht (nl)	2003	Wilnis, Netherlands	0	Peat dam became lighter than water during droughts and floated away. Around 1,500 residents had to be evacuated.
Hope Mills Dam	2003	North Carolina, United States	0	Caused by heavy rains. 1,600 people evacuated.
Silver Lake Dam	2003	Michigan, United States	0	Heavy rains caused earthen dam and bank to wash away. 1,800 people evacuated.
Big Bay Dam	2004	Mississippi, United States	0	A small hole in the dam grew and eventually led to failure. 104 buildings damaged or destroyed.
Camará Dam	2004	Paraiba, Brazil	3	Poor maintenance. 3000 people homeless. A second failure happened 11 days after.
Shakidor Dam	2005	Pasni, Pakistan	70	Sudden and extreme flooding caused by abnormally severe rain.
Taum Sauk reservoir	2005	Lesterville, United States	0	Computer/operator error; gauges intended to mark dam full were not respected; dam continued to fill. Minor leakages had also weakened the wall through piping. The dam of the lower reservoir withstood the onslaught of the flood.
Campos Novos Dam	2006	Campos Novos, Brazil	0	Tunnel collapse.
Gusau Dam	2006	Gusau, Nigeria	40	Heavy flooding. Approximately 500 homes were destroyed, displacing 1,000 people.

Ka Loko Dam	2006	Kauai, United States	7	Heavy rain and flooding. Several possible specific factors to include poor maintenance, lack of inspection and illegal modifications.
Lake Delton	2008	Lake Delton, United States	0	Failure due to June 2008 Midwest floods.
Koshi Barrage	2008	Koshi Zone, Nepal	250	Heavy rain. The flood affected over 2.3 million people in the northern part of Bihar.
Kingston Fossil Plant coal fly ash slurry spill	2008	Roane County, United States	0	Failure of a fly ash slurry pond.
Algodões Dam	2009	Piaui, Brazil	7	Heavy rain. 80 people injured, 2000 homeless.
Sayano–Shushenskaya Dam	2009	Sayanogorsk, Russia	75	Collapses when turbine 2 broke apart violently, flooding the turbine hall and causing the ceiling to collapse.
Situ GintungDam	2009	Tangerang, Indonesia	98	Poor maintenance and heavy monsoon rain.
Kyzyl-Agash Dam	2010	Qyzylaghash, Kazakhstan	43	Heavy rain and snowmelt. 300 people were injured and over 1000 evacuated from the village.
Hope Mills Dam	2010	North Carolina, United States	0	Sinkhole caused dam failure. Second failure of the dam, will be replaced.
Testalinda Dam	2010	Oliver, Canada	0	Heavy Rain, low maintenance. Destroyed at least 5 homes. Buried Highway 97.
Delhi Dam	2010	Iowa, United States	0	Heavy rain, flooding. Around 8,000 people had to be evacuated.
Niedow Dam	2010	Lower Silesian Voivodeship, Poland	1	Heavy rain, over-topped from flooding.
Ajka alumina plant accident	2010	Ajka, Hungary	10	Failure of concrete impound wall on alumina plant tailings dam. One million cubic meters of red mudcontaminated a large area, within days the mud had reached the Danube.
Kenmare Resourcestailings dam	2010	Topuito, Mozambique	1	Failure of tailings dams at titanium mine. 300 homes had been rebuilt.
Fujinuma Dam	2011	Sukagawa,Japan	8	Failed after 2011 Tōhoku earthquake. 7 dead and 1 unknown. Japanese authority says dam failure caused by earthquake which has death toll is not reported world-wide since 1930.
Campos dos Goytacazes dam	2012	Campos dos Goytacazes,Brazil	0	Failed after a period of flooding. 4000 people displaced.

Ivanovo Dam	2012	Biser, Bulgaria	8	Failed after a period of heavy snowmelt. A crack in the dam went un-repaired for years. Eight people killed and several communities flooded.
Köprü Dam	2012	Adana Province,Turkey	10	A gate in the diversion tunnel broke after a period of heavy rain during the reservoir's first filing. The accident killed ten workers.
Tokwe Mukorsi Dam	2014	Masvingo Province,Zimbabwe	0	Downstream slope failure on a 90.3 m (296 ft) tall embankment dam, possibly as the reservoir was being filled. Residents evacuated upstream.

PRESIDENTIAL DECREE NO. 1067

December 31, 1976

THE WATER CODE OF THE PHILIPPINES

A DECREE INSTITUTING A WATER CODE, THEREBY REVISING AND CONSOLIDATING THE LAWS GOVERNING THE OWNERSHIP, APPROPRIATION, UTILIZATION, EXPLOITATION, DEVELOPMENT, CONSERVATION AND PROTECTION OF WATER RESOURCES.

WHEREAS, Article XIV, Section 8 of the New Constitution of the Philippines provides, inter alia, that all waters of the Philippines belong to the State;

WHEREAS, existing water legislations are piecemeal inadequate to cope with increasing scarcity of water and changing patterns of water use;

WHEREAS, there is a need for a Water Code based on rational concepts of integrated and multi-purpose management of water resources and sufficiently flexible toadequately meet future developments:

WHEREAS, water is vital national development and it has become increasingly necessary for government to intervene actively in improving the management of water resources;

NOW, THEREFORE, I, FERDINAND, E. MARCOS, President of the Philippines, by virtue of the powers in me vested by the Constitution, do hereby orders and decree the enactment of the water Code of the Philippines of 1776, as follows:

CHAPTER I
DECLARATION OF OBJECTIVES AND PRINCIPLES

Article 1. This Code shall be known as "The Water Code of the Philippines."

Article 2. The objectives of this Code are:

a. To establish the basic principles and framework relating to the appropriation, control and conservation of water resources to achieve the optimum development and rational utilization of these resources;

b. To define the extent of the rights and obligation of water users and owners including the protection and regulation of such rights;

c. To adopt a basic law governing the ownership, appropriation, utilization, exploitation, development, conservation and protection of water resources and rights to land related thereto; and

d. To identify the administrative agencies which will enforce this Code.

Article 3. The underlying principles of this code are:

a. All waters belong to the State.

b. All waters that belong to the state can not be the subject to acquisitive prescription.

c. The State may allow the use or development of waters by administration concession.

d. The utilization, exploitation, development, conservation and protection of water resources shall be subject to the control and regulation of the government through the National Water Resources Council, hereinafter referred to as the Council.

e. Preference in the use and development of waters shall consider current usages and be responsive to the changing needs of the country.

Article 4. Waters, as used in this Code, refers to water under the grounds, water above the ground, water in the atmosphere and the waters of the sea within the territorial jurisdiction of the Philippines.

CHAPTER II
OWNERSHIP OF WATERS

Article 5. The following belong to the state:

a. Rivers and their natural beds;

b. Continuous or intermittent waters of springs and brooks running in their natural beds and the beds themselves;

c. Natural lakes and lagoons;

d. All other categories of surface waters such as water flowing over lands, water form rainfall whether natural or artificial, and water from agriculture runoff, seepage and drainage;

e. Atmospheric water;

f. subterranean or ground water; and

g. Seawater

Article 6. The following waters found on private lands also belong to the States:

a. Continuous or intermittent waters rising on such lands;

b. Lakes and lagoons naturally waters rising on such lands;

c. Rain water and falling on such lands;

d. Subterranean or ground waters; and,

e. Waters in swamps and marshes.

The owner of the land where the water is found may use the same for domestic purposes without securing a permit, provided that such use shall have be registered, when required by the Council. The Council, however, may regulate such use when there is wastage, or in times of emergency.

Article 7. Subject to the provisions of this Code, any person who captures or collects water by means of cisterns, tanks, or pools shall have exclusive control over such water and the right to dispose of the same.

Article 8. Water legally appropriated shall be subject to the control of the appropriator from the moment it reaches the appropriator's canal or aqueduct leading to the place where the water will be used or stored and, thereafter, so long as it is being beneficially used for the purposes for which it was appropriated.

CHAPTER III
APPROPRIATION OF WATERS

Article 9. Waters may be appropriated and used in accordance with the provisions of this Code.

Appropriation of water, as used in this Code, is the acquisition of rights over the use of waters or the taking or diverting of waters from a natural source in the manner and for any purpose allowed by law.

Article 10. Water may be appropriated for the following purposes:

a. Domestic;

b. Municipal;

c. Irrigation;

d. Power generation;

e. Fisheries;

f. Livestock raising;

g. Industrial;

h. Recreational; and

i. Other purposes;

Use of water for domestic purposes is the utilization of water for drinking, washing, bathing, cooking or other household needs, home gardens, and watering or lawns or domestic animals.

Use of water for municipal purposes is the utilization of water for supplying the water requirements of the community.

Use of water for irrigation is the utilization of water for producing agricultural crops.

Use of water for power generation is the utilization of water for producing electrical or mechanical power.

Use of water for power fisheries is the utilization of water for the propagation and culture of fish as a commercial enterprise

Use of water for livestock raising is the utilization of water for large herds or flocks of animals raised as a commercial enterprise.

Use of water for industrial purposes is the utilization of water in factories, industrial plants and mines, including the use of water as an ingredient of a finished product.

Use of water for recreational purposes is the utilization of water for swimming pools, bath houses, boating, water skiing, golf courses and other similar facilities in resorts and other places of recreation.

Article 11. The state, for reasons of public policy, may declare waters not previously appropriated, in whole or in part, exempt from appropriation for any or all purposes and, thereupon, such waters may not be appropriated for those purposes.

Article 12. Waters appropriated for a particular purpose may be applied for another purpose only upon prior approval of the Council and on condition that the new use does not unduly prejudice the rights of other permittees, or require an increase in the volume of water.

Article 13. Except as otherwise herein provided, no person, including government instrumentalities or government-owned or controlled corporations, shall appropriate water without a water right, which shall be evidenced by a document known as a water permit.

Water rights is the privilege granted by the government to appropriate and use water.

Article 14. Subject to the provisions of this Code concerning the control, protection, conservation, and regulation of the appropriation and use of waters, any person may appropriate or use natural bodies of water without securing a water permit for any of the following.

a. Appropriation of water by means of hand carried receptacles; and

b. Bathing or washing, watering or dipping of domestic or farm animals, and navigation of watercrafts or transportation of logs and other objects by flotation.

Article 15. Only citizens of the Philippines, of legal age, as well as juridical persons, who are duly qualified by law to exploit and develop water resources, may apply for water permits.

Article 16. Any person who desires to obtain a water permit shall file an application with the Council who shall make known said application to the public for any protests.

In determining whether to grant or deny an application, the Council shall considerthe following: protests filed, if any; prior permits granted; the availability of water; the water supply need for beneficial use; possible adverse effects; land-use economics; and other relevant factors.

Upon approval of an application, a water permit shall be issued and recorded.

Article 17. The right to the use of water is deemed acquired as of the date of filing of the application for a water permit in case of approved permits, or as of the date of actual use in a case where no permit is required.

Article 18. All water permits granted shall be subject to conditions of beneficial use, adequate standards of design and construction, and such other terms and conditions as may be imposed by the Council.

Such permits shall specify the maximum amount of water which may be diverted or withdrawn, the maximum rate diversion or withdrawal, the time or times during the year when water may be diverted or withdrawn, the points or points of diversion or location of wells, the place of use, the purpose for which water may be used and such other requirements the Council deems desirable.

Article 19. Water rights may be lent or transferred in whole or in part to another person with prior approval of the Council, after due notice and hearing.

Article 20. The measure and limit of appropriation of water shall be beneficial use.

Beneficial use of water is the utilization of water in the right amount during the period that the water is needed for producing the benefits for which the water is appropriated.

Article 21. Standards of beneficial use shall be prescribed by the council for the appropriator of water for different purposes and conditions, and the use of waters which are appropriated shall be measured and controlled in accordance therewith.

Excepting those for domestic use, every appropriator of water shall maintain water control and measuring devices, and keep records or water withdrawal. When required by the council, all appropriators of water shall furnish information on water use.

Article 22. Between two or more appropriation of water from the same sources of supply, priority in time of appropriation shall give the better right, except that in times of emergency, the use of water for domestic and municipal purposes shall have a better fight over all other uses; Provided, That where water shortage is recurrent and the appropriator for municipal use has a lower priority in time of appropriation, them it shall be his duty to find an alternative source of supply in accordance with conditions prescribed by the Council.

Article 23. Priorities may be altered on grounds of greater beneficial use, multi-purpose use, and other similar grounds after due notice and hearing, subject to payment of compensation is proper cases.

Article 24. A water right shall be exercised in such a manner that rights of third persons or of other appropriators are not prejudiced thereby.

Article 25. A holder of a water permit may demand the establishment of easements necessary for the construction and maintenance of the works and facilities needed for the beneficial use of the waters to be appropriated subject to the requirements of just compensation and to the following conditions:

a. That he is the owner, lessee, mortgage or one having real right over the land upon which he purposes to use water; and

b. That the proposed easement is the most convenient and the least onerous to the servient estate.

Easement relating to the appropriation and use of waters may be modified be agreement of the contracting parties provided the same is not contrary to law or prejudicial to third persons.

Article 26. Where water shortage is recurrent, the use of the water pursuant to a permit may, in the interest of equitable distribution of benefits among legal appropriators, be reduced after due notice and hearing.

Article 27. Water users shall bear the diminution of any water supply due to natural causes or force majeure.

Article 28. Water permits shall continue to be valid as long as water is beneficially used; however, it maybe suspended on the grounds of non-compliance with approved plans and specifications or schedules of water distribution; use of water for a purpose other than that for which it was granted;

non-payment of water charges, wastage; failure to keep records of water diversion, when required; and violation of any term or condition of any permit or of rules and regulations promulgated by the Council.

Temporary permits may be issued for the appropriation and use of water for short periods under special circumstances.

Article 29. Water permits may be revoked after due notice and hearing on grounds of non-use; gross violation of the conditions imposed in the permit; unauthorized sale of water; willful failure or refusal to comply with rules and regulations or any lawful order; pollution, public nuisance or acts detrimental to public health and safety; when the appropriator is found to be disqualified under the law to exploit and develop natural resources of the Philippines; when, in the case of irrigation, the land is converted to non-agricultural purposes; and other similar grounds.

Article 30. All water permits are subject to modification or cancellation by the Council, after due notice and hearing, in favor of a project of greater beneficial use or for multi-purpose development, and a water permittee who suffers thereby shall be duly compensated by the entity or person in whose favor the cancellation was made.

CHAPTER IV
UTILIZATION OF WATERS

Article 31. Preference in the development of water resources shall consider security of the State, multiple use, beneficial effects, adverse effects and cost of development.

Article 32. The utilization of subterranean or ground water shall be coordinated with that of surface waters such as rivers, streams, springs and lakes, so that a superior right in one is not adversely affected by an inferior right in the other.

For this purpose, the Council shall promulgate rules and regulations and declare the existence of control areas for the coordinated development, protection, and utilization of subterranean or ground water and surface waters.

Control area is an area of land where subterranean or ground water and surface water are so interrelated that withdrawal and use in one similarly affects the other. The boundary of a control area may be altered from time to time, as circumstances warrant.

Article 33. Water contained in open canals, aqueducts or reservoirs of private persons may be used by any person for domestic purpose or for watering plants as long as the water withdrawn by manual methods without checking the stream or damaging the canal, aqueduct or reservoir; Provided, That this right may be restricted by the owner should it result in loss or injury to him.

Article 34. A water permittee or appropriator may use any watercourse to convey water to another point in the watercourse for the purpose stated in a permit and such water may be diverted or recaptured at that point by said permittee in the same amount less allowance for normal losses in transit

Article 35. Works for the storage, diversion, distribution and utilization of water resources shall contain adequate provision for the prevention and control of diseases that may be induced or spread by such works when required by the Council.

Article 36. When the reuse of waste water is feasible, it shall limited as much as possible to such uses other than direction human consumption. No person or agency shall distribute such water for public consumption until it is demonstrated that such consumption will not adversely affect the health and safety of the public.

Article 37. In the construction and operation of hydraulic works, due consideration shall be given to the preservation of scenic places and historical relics and in addition to the provisions of existing laws, no works that would required the destruction or removal of such places or relics shall be undertaken without showing that the destruction or removal is necessary and unavoidable.

Article 38. Authority for the construction of dams, bridges and other structures across of which may interfere with the flow of navigable or floatable waterways shall first be secured from the Department of Public Works, Transportation and Communications.

Article 39. Except in cases of emergency to save life or property, the construction or repair of the following works shall be undertaken only after the plans and specifications therefore, as may be required by the Council, are approved by the proper government agency; dams for the diversion or storage of water; structures for the use of water power; installations for the utilization of subterranean or ground water and other structures for utilization of water resources.

Article 40. No excavation for the purpose of emission of a hot spring or for the enlargement of the existing opening thereof shall be made without prior permit.

Any person or agency who intends to develop a hot spring for human consumption must first obtain a permit from the Department of Health.

Article 41. No person shall develop a stream, lake, or spring for recreational purposes without first securing a permit from the council.

Article 42. Unless otherwise ordered by the President of the Philippines and only in times of national calamity or emergency, no person shall induce or restrain rainfall by any method such as cloud seeding without a permit from the proper government agency.

Article 43. No person shall raise or lower the water level of a river, stream, lake, lagoon or marsh nor drain the same without a permit.

Article 44. Drainage systems shall be so constructed that their outlets are rivers, lakes, the sea, natural bodies of water, such other water course as any be approved by the proper government agency.

Article 45. When a drainage channel is constructed by a number of persons for their common benefit, cost of construction and maintenance of the channel be borne by each in proportion to the benefits derived.

Article 46. When artificial means are employed to drain water from higher to lower land, the owner of the higher land shall select the routes and methods of drainage that will cause the minimum damage to the lower lands, subject to the requirements of just compensation.

Article 47. When the use, conveyance or storage of water results in damage to another, the person responsible for the damage shall pay compensation.

Article 48. When a water resources project interferes with the access of landowner to a portion of his property or with the conveyance of irrigation or drainage water, the person or agency constructing the project shall bear the cost of construction and maintenance of the bridges, flumes and other structures necessary for maintaining access, irrigation, or drainage in addition to paying compensation for land and incidental damages.

Article 49. Any person having an easement for an aqueduct may enter upon the servient land for the purpose of cleaning, repairing or replacing the aqueduct or the removal of obstructions therefrom.

Article 50. Lower estates are obliged to receive the waters which naturally and without the intervention of man flow from the higher estates, as well as the stones or earth which they carry with them.

The owner of the lower estate can not construct works which will impede this natural flow, unless he provides an alternative method of drainage; neither can the owner of the higher estate make works which will increase this natural flow.

Article 51. The banks or rivers and streams and the shores of the seas and lakes throughout their entire length and within a zone of three (3) meters in urban areas, twenty (20) meters in agricultural areas and forty (40) meters in forest areas, along their margins, are subject to the easement of public use in the interest of recreation, navigation, flotage, fishing and salvage. No person shall be allowed to stay in this zone longer than what is necessary for recreation, navigation, flotage, fishing or salvage or to build structures of any kind.

Article 52. The establishment, extent, from, and conditions of easement of water not expressly determined by the provisions of this Code shall governed by the
provisions of the Civil Code.

CHAPTER V
CONTROL OF WATERS

Article 53. To promote the best interest and the coordinated protection of flood plain lands, the Secretary of Public Works, Transportation and Communications may declare flood control areas and promulgate guidelines for governing flood plain management plans in these areas.

Article 54. In declare flood control areas, rules and regulations may be promulgate to prohibit or control activities that may damage or cause deterioration of lakes and dikes, obstruct the flow of water, change the natural flow of the river, increase flood losses or aggravate flood problems.

Article 55. The government may construction necessary flood control structures in declared flood control areas, and for this purpose it shall have a legal easement as wide as may be needed along and adjacent to the river bank and outside the bed or channel of the river.

Article 56. River beds, sand bars and tidal flats may not be cultivated except upon prior permission from the Secretary of the Department of Public works, Transportation and Communication and such permission shall not be granted where such cultivation obstructs the flow of water or increase flood levels so as to cause damage to other areas.

Article 57. Any person may erect levees or revetments to protect his property from flood, encroachment by the river or change in the course of the river, provided that such constructions does not cause damage to the property of another.

Article 58. When a river or stream suddenly changes its course to traverse private lands, the owners or the affected lands may not compel the government to restore the river to its former bed; nor can they restrain the government from taking steps to revert the river or stream to its former course. The owners of the lands thus affected are not entitled to compensation for any damage sustained thereby.

However, the former owners of the new bed shall be the owners of the abandoned bed proportion to the area lost by each.

The owners of the affected lands may undertake to return the river or stream to its old bed at their own expense; Provided, That a permit therefore is secured from the Secretary of Public Works, Transportation and Communication and work pertaining thereto are commenced within two years from the changes in the course of the river or stream.

Article 59. Rivers, lakes and lagoons may, upon the recommendation of the Philippines Coast Guard, be declared navigable either in whole or in part.

Article 60. The rafting of logs and other objects on rivers and lakes which are floatable may be controlled or prohibited during designated season of the year with due regard to the needs of irrigation and domestic water supply and other uses of water.

Article 61. The impounding of water in ponds or reservoirs may be prohibited by the Council upon consultation with the Department of Health if it is dangerous to public health, or it may order that such pond or reservoirs be drained if such is necessary for the protection of public health.

Article 62. Waters of a stream may be stored in a reservoir by a permittee in such amount as will not prejudices the right of any permittee downstream. Whoever operates the reservoir shall, when required, release water for minimum stream flow.

All reservoir operations shall be subject to rules and regulations issued by the Council or any proper government agency.

Article 63. The operator of a dam for the storage of water may be required to employ an engineer possessing qualifications prescribed for the proper operations, maintenance and administration of the dam.

Article 64. The Council shall approve the manner, location, depth, and spacing in which borings for subterranean or ground water may be made, determine the requirements for the registration of every boring or alteration to existing borings as well as other control measures for the exploitation of subterranean or ground water resources, and in coordination with the Professional Regulation Commission prescribe the qualifications of those who would drill such borings.

No person shall drill a well without prior permission from the Council.

Article 65. Water from one river basin may be transferred to another river basin only with approval of the Council. In considering any request for such transfer, the Council shall take into account the full costs of the transfer, the benefits that would accrue to the basin of origin without the transfer, the benefits would accrue to the receiving basin on account of the transfer, alternative schemes for supplying water to the receiving basin, and other relevant favors.

CHAPTER VI
CONSERVATION AND PROTECTION OF WATERS AND WATERSHEDS AND RELATED LAND RESOURCES

Article 66. After due notice and hearing when warranted by circumstances, minimum stream flows for rivers and streams and minimum water levels for lakes may be established by the Council under such conditions as may be necessary for the protection of the environment, control of pollution, navigation, prevention of salt damage, and general public use.

Article 67. Any watershed or any area of land adjacent to any surface water or overlying any ground water may be declared by the Department of Natural Resources (DENR) as a protected area. Rules and regulations may be promulgated by such Department to prohibit or control such activities by the owners or occupants thereof within the protected area which may damage or cause the deterioration of the surface water or ground water or interfere with the investigation, use, control, protection, management or administration of such waters.

Article 68. It shall be the duty of any person in control of a well to prevent the water from flowing on the surface of the land, or into any surface water, or any porous stratum underneath the surface without being beneficially used.

Article 69. It shall be the duty of any person in control of a well containing water with minerals or other substances injurious to man, animals, agriculture, and vegetation to prevent such waters from flowing on the surface of the land or into any surface water or into any other aquifer or porous stratum.

Article 70. No person shall utilize an existing well or pond or spread waters for recharging subterranean or ground water supplies without prior permission of the Council.

Article 71. To promote better water conservation and usage for irrigation purposes, the merger of irrigation associations and the appropriation of waters by associations instead of by individuals shall be encouraged.

No water permit shall be granted to an individual when his water requirement can be supplied through an irrigation association.

Article 72. In the consideration of a proposed water resource project, due regard shall be given to ecological changes resulting from the construction of the project in order to balance the needs of development and the protection of the environment.

Article 73. The conservation of fish ad wild life shall receive proper consideration and shall be coordinated with other features of water resources development programs to insure that fish and wildlife values receive equal attention with other project purposes.

Article 74. Swamps and marshes which are owned by the State and which have a primary value for waterfowl propagation or other wildlife purposes may be reserved and protected from drainage operations and development.

Article 75. No person shall, without prior permission from the National Pollution Control Commission, build any works that may produce dangerous or noxious substance or perform any act which may result in the introduction of sewage, industrial waste, or any pollutant into any source of water supply.

Water pollution is the impairment of the quality of water beyond a certain standard. This standard may vary according to the use of the water and shall be set by the National Pollution Control Commission.

Article 76. The establishment of cemeteries and waste disposal areas that may affect the source of a water supply or a reservoir for domestic or municipal use shall be subject to the rules and regulations promulgated by the Department or Health.

Article 77. Tailings from mining operations and sediments from placer mining shall not be dumped into rivers and waterways without prior permission from the Council upon recommendation be the National Pollution Control Commission.

Article 78. The application of agriculture fertilizers and pesticides may be prohibited or regulated by the National Pollution Control Commission in areas where such application may cause pollution of a source of water supply.

CHAPTER VII
ADMINISTRATION OF WATERS AND ENFORCEMENT OF THE PROVISIONS OF THIS CODE

Article 79. The Administration and enforcement of the provisions of this Code, including the granting of permits and the imposition of penalties for administrative violations hereof, are hereby vested in the council, and except in regard to those functions which under this Code are specifically conferred upon other agencies of the government, the Council is hereby empowered to make all decisions and determinations provided for in this Code.

Article 80. The Council may deputize any official or agency of the government to perform any of its specific functions or activities.

Article 81. The Council shall provide a continuing program for data collection, research and manpower development need for the appropriation, utilization, exploitation, conservation, and protection of the water resources of the country.

Article 82. In the implementation of the provisions of this Code, the Council shall promulgate the necessary rules and regulations which may provide for penalties consisting of a fine not exceeding One thousand Pesos (P1,000.00) and/or suspension or revocation of the water permit or other right to the use of water. Violations of such rules and regulations may be administratively dealt with by the Council.

Such rules and regulations shall take effect fifteen (15) days after publication in newspapers of general circulation.

Rules and regulations prescribed by any government agency that pertain to the utilization, exploitation, development, control, conservation, or protection of water resources shall, if the council so requires, be subject to its approval.

Article 83. The Council is hereby authorized to impose and collect reasonable fees or charges for water resources development from water appropriators, except when it is for purely domestic purpose.

Article 84. The Council and other agencies authorized to enforce this Code are empowered to enter upon private lands, with previous notice to the owner, for the purpose of conducting surveys and hydrologic investigations, and to perform such other acts as are necessary in carrying out their functions including the power to exercise the right of eminent domain.

Article 85. No program or project involving the appropriation, utilization, exploitation, development, control, conservation, or protection of water resources may be undertaken without prior approval of the Council, except those which the council may, in its discretion, exempt.

The Council may require consultation with the public prior to the implementation of certain water resources development projects.

Art. 86. When plans and specifications of a hydraulic structure are submitted for approval, the government agency whose functions embrace the type of project for which the structure is intended, shall review the plans and specifications and recommend to the Council proper action thereon and the latter shall approve the same only when they are in conformity with the requirements of this Code and the rules and regulations promulgated by the Council. Notwithstanding such approval, neither the engineer who drew up the plans and specifications of the hydraulic structure, nor the constructor who built it, shall be relieved of his liability for damages in case of failure thereof by reason of defect in plans and specifications, or failure due to defect in plan construction, within ten (10) years from the completion of the structure.

Any action recover such damages must be brought within five (5) years following such failure.

Article 87. The Council or its duly authorized representatives, in the exercise of its power to investigate and decide cases brought to its cognizance, shall have the power to administer oaths, compel the attendance of witnesses be subpoena duces tecum.

Non-compliance or violation of such orders or subpoena and subpoena duces tecum shall be punished in the same manner as indirect contempt of an inferior court upon application by the aggrieved party with the proper Court of First Instance in accordance with the provisions of Rule 71 of the Rules of Court.

Article 88. The Council shall have original jurisdiction over all disputes relating to appropriation, utilization, exploitation, development, control, conservation and protection of waters within the meaning and context of the provisions of this Code.

The decisions of the Council on water rights controversies shall be immediately executory and the enforcement thereof may be suspended only then a bond, in an amount fixed by the Council to answer for damages occasioned by the suspension or stay of execution, shall have been filed by the appealing party, unless the suspension is by virtue of an order of a competent court.

All dispute shall be decide within sixty (60) days after the parties submit the same for decision or resolution.

The Council shall have the power to issue writs of execution and enforce its decisions with the assistance of local or national police agencies.

Article 89. The decisions of the Council on water rights controversies may be appealed to the court of first Instance of the province where the subject matter of the controversy is situated within fifteen (15) days from the date the party appealing receives a copy of the decision, of any of the following grounds: (1) grave abuse of discretion; (2) question of law; (3) questions of fact and law.

CHAPTER VIII
PENAL PROVISIONS

Article 90. The following acts shall be penalized by suspension or revocation of the violator's water permit or other right to the use of water and/or a fine of not exceeding One thousand Pesos (P1,000.00), in the discretion of the Council:

a. Appropriation of subterranean or ground water for domestic use by an overlying landowner without registration required by the Council;

b. Non-observance of any standard of beneficial use of water.

c. Failure of the appropriator to keep a record of water withdrawal when required.

d. Failure to comply with any of the terms or conditions in a water permit or a water rights grant.

e. Unauthorized use of water for a purpose other than that for which a right or permit was granted.

f. Construction or repair of any hydraulic work or structure without duly approved plans and specifications, when required.

g. Failure to install a regulating and measuring device for the control volume of water appropriated, when required.

h. Unauthorized sale, lease, or transfer of water and/or water rights.

i. Failure to provide adequate facilities to prevent or control diseases when required by the Council in the construction of any work for the storage, diversion, distribution and utilization of water.

j. Drilling of a well without permission of the Council.

k. Utilization of an existing well or ponding or spreading of water for recharging subterranean or ground water supplies without permission of the Council.

l. Violation of or non-compliance with any order, rules and regulation of the Council.

m. Illegal taking or diversion of water in an open canal, aqueduct or reservoir.

n. Malicious destruction of hydraulic works or structures valued at not exceeding P5,000.00.

Article 91. A. A fine of not exceeding Three Thousand Pesos (P3,000.00) or imprisonment for not more that three (3) years, or both such fine and imprisonment, in the discretion of the Court, shall be imposed upon any person who commits any of the following acts:

1. Appropriation of water without a water permit, unless such person is expressly exempted from securing a permit by the provisions of this code;

2. Unauthorized obstruction of an irrigation canal.

3. Cultivation of river bed, sand bar or tidal flat without permission.

4. Malicious destruction of hydraulic works or structure valued at not exceeding Twenty-Five Thousand Pesos (P25,000.00)

B. A fine exceeding Three Thousand Pesos (P3,000.00) but not more than Six Thousand Pesos (P6,000.00) or imprisonment exceeding three years (3) years but not more than (6) years or both such fine and imprisonment in the discretion of the Court, shall be imposed on any person who commits any of the following acts:

1. Distribution for public consumption of water which adversely affects the health and safety of the public.

2. Excavation or enlargement of the opening of a hot spring without permission.

3. Unauthorized obstruction of a river or waterway, or occupancy of a river bank or seashore without permission.

4. Establishment of a cemetery or a waste disposal area near a source of water supply or reservoir for domestic or municipal use without permission.

5. Constructing, without prior permission of the government agency concerned, works that produce dangerous or noxious substances, or performing acts that result in the introduction of sewage, industrial waste, or any substance that pollutes a source of water supply.

6. Dumping mine tailings and sediments into rivers or waterways without permission.

7. Malicious destruction of hydraulic works or structure valued more than Twenty-five Thousand (P25,000.00) but not exceeding One Hundred Thousand Pesos (P100,000.00)

C. A fine exceeding Six Thousand Pesos (P6,000.00) but not more than ten Thousand Pesos (P10,000.00) or imprisonment exceeding six (6) years but not more than twelve (12) years, or both such fine and imprisonment, in the discretion of the Court, shall be imposed upon any person who commits any of the following acts:

1. Misrepresentation of citizenship in order to qualify for water permit.

2. Malicious destruction of a hydraulic works or structure, valued at more than One Hundred Thousand Pesos (P100,000.00).

Article 92. If the offense is committed by a corporation, trust, firm, partnership, association or any other juridical person, the penalty shall be imposed upon the President, General Manager, and other guilty officer or officers of such corporation, trust, firm, partnership, association or entity, without prejudice to the filing of a civil action against said juridical person. If the offender is an alien, he shall be deported after serving his sentence, without further proceedings.

After final judgment of conviction, the Court upon petition of the prosecution attorney in the same proceedings, and after due hearing, may when the public interest so requires, order the suspension of or dissolution of such corporation, trust, firm, partnership association or juridical person.

Article 93. All actions for offenses punishable under Article 91 of this code shall be brought before the proper court.

Article 94. Actions for offenses punishable under this Code by a fine of not more than Three Thousand (P3,000.00) or by an imprisonment of not more than three (3) years, or both such fine and imprisonment, shall prescribed in five (5) years; those punishable by a fine exceeding Three Thousand Pesos (3,000.00) but not more than six thousand Pesos (P6,000.00) or imprisonment exceeding three (3) years but not more than six years (6) years or both such fine and imprisonment, shall prescribe in seven (7) years; and those punishable by a fine exceeding Six Thousand Pesos (P6,000.00) but not more than Ten Thousand Pesos (P10,000.00) or an imprisonment exceeding Six (6) years but not more than Twelve (12) years, or both such fine and imprisonment, shall prescribe in ten (10) years.

CHAPTER IX
TRANSITORY AND FINAL PROVISIONS

Article 95. Within two (2) years from the promulgation of this code, all claims for a right to use water existing on or before December 31, 1974 shall be registered with the council which shall be confirm said rights in accordance with the provisions of this Code, and shall set their respective priorities.

When priority in time of appropriation from a certain source of supply cannot be determined, the order of preference in the use of the waters shall be as follows:

a. Domestic and municipal use;

b. Irrigation;

c. Power generation;

d. Fisheries;

e. Livestock raising;

f. Industrial use; and

g. Other uses.

Any claim not registered within said period shall be considered waived and the use of the water deemed abandoned, and the water shall thereupon be available for disposition as unappropriated waters in accordance with the provisions of this code.

Article 96. No vested or acquired right to the use of water can arise from acts or omissions which are against the law or which infringe upon the rights of others.

Article 97. Acts and contracts under the regime of old laws, if they are valid in accordance therewith, shall be respected, subject to the limitations established in this Code. Any modification or extension of these acts and contracts after the promulgation of this code, shall be subject to the provisions hereof.

Article 98. Interim rules and regulations promulgated by the Council shall continue to have binding force and effect, when not in conflict with the provisions of this Code.

Article 99. If any provision or part of this Code, or the application thereof to any person or circumstance, is declared unconstitutional or invalid for any reason, the other provisions of parts therein shall not be affected.

Article 100. The following laws, parts and/or provisions of laws are hereby repealed:

a. The provisions of the Spanish law of waters of August 3, 1866, the Civil Code of Spain of 1889 and the Civil Code of the Philippines (R. A. 386) on ownership of waters, easement relating to waters, use of public waters which are inconsistent with the provision of the Code;

b. The provisions of R. A. 6395, otherwise known as the Revised Charter of the National Power Corporation, particularly section 3, paragraph (f), and section 12, so far as they relate to the appropriation of waters and the grant thereof;

c. The provisions of Act. No. 2152 as amended, otherwise know as the Irrigation Act, section 3, paragraphs (k) and (m) of P.D. No. 813, R. A. 2056; Section 90, C. A. 137; and

d. All Decrees, Laws, Acts, parts of Acts, Rules of Court, executive orders, and administrative regulations which are contrary to or inconsistent with the provisions of this Code.

Article 101. This Code shall take effect upon its promulgation.

Done in the City of Manila, this 31st day of December, Nineteen Hundred and Seventy-Six.

FERDINAND E. MARCOS
President of the Philippines

By the President:

JACOBO C. CLAVE
Presidential Executive Assistant