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FLOOD MITIGATION IN METRO MANILA

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ABSTRACT

Tropical Storm Ondoy (Ketsana) crossed Metro Manila and the adjacent river basins in a late wet-season episode of 2009, starting in the evening of September 25, 2009 and continuing into the next day of September 26, 2009. TS Ondoy brought very intense and heavy rainfall to the region: meaning that record amounts of rains fell over a very short time period of 12 hours to 24 hours, which are estimated to occur at an average annual frequency of 1 in 100 years or even higher, depending on the measuring location in the region. The rains generated record-magnitude flood flows and inundation in the Pasig-Marikina River Basin in Metro Manila, and the Laguna de Bay region. This article briefly explains the present situation in the flood management in Metro Manila, covers the various government flood-mitigation projects, and after briefly describing the pattern and statistics of the rainfall and flood flows associated with the major storm and their resulting physical impacts, risks and damages to the metropolis, provides recommendations, both in terms of structural and non-structural mitigation measures, for everyone concerned.

1. STORMS, FLOODS AND EXPECTATIONS

It is now the middle of a dry April 2010, more than six months since Tropical Storm Ondoy (Ketsana) crossed Metro Manila and the adjacent river basins in a late wet-season episode of 2009, starting in the evening of September 25, 2009 and continuing into the next day of September 26, 2009. TS Ondoy brought very intense and heavy rainfall to the region: meaning that record amounts of rains fell over a very short time period of 12 hours to 24 hours, which are estimated to occur at an average annual frequency of 1 in 100 years or even higher, depending on the measuring location in the region. Has the passage of six months since the deluge given adequate time to review the experience and gather the valuable lessons out of which the population can be enabled and empowered with solutions and measures to better cope with and mitigate the damaging effects of typhoon-caused rains and flooding as well as other kinds or types of flooding, whether they have the magnitude of TS Ondoy or less?

That the metropolis will be visited by the record-breaking TS-Ondoy hydrological event (storm and floods) is not at all surprising in the physical sense, given the country's geographical location and climatic zone within the so-called "typhoon monsoon sub-region", as aptly labeled by WMO and UNESCO, along with other typhoon-prone countries such as Vietnam and the southern parts of China and Japan, with the addendum that the Philippines has the highest annual frequency of typhoons and will mostly have "the first crack at, before exporting" the typhoons. What is surprising (amazing and eye-awakening) to many people that we know is the singular reality that it had occurred in their own life time (maximum of 70 to 80+ age).

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DPWH reported a preliminary annual flood frequency of 1 in 500 years for the resulting TS Ondoy-caused record-magnitude flood in the Pasig-Marikina River (ADB 2009. http://www.adb.org/water/topics/pdfs/OKF-SSantiago.pdf.). An average return period or recurrence interval of so number of years, does not represent a fixed cycle like that of the earth's orbit around the sun or the lunar tides, but is probabilistically similar to the uncertain time of waiting for the random appearance of a desired big winning number in a roulette wheel spun repeatedly, or a wanted 7-11 combination in a pair of dice thrown successively. Instead of counting spins and throws, random intervals of years are counted for the return periods of certain rainfall and flood magnitudes. This probabilistic characterization of rainfall and floods stems from the lack of perfect and complete knowledge, understanding and predictability that the natural sciences have of the climatic and weather processes which give rise to rainfall-producing monsoons and typhoons.

That it has occurred in their own life time makes us hear people say that now either God or Mother Nature is returning back to the populace the bad consequences of the overexploitation, abuse and mismanagement of the environment which have been practiced in the past decades and centuries, and it is not to be dismissed that "climate change" (be it a cause of the disaster or other factors as well) is one such giant reminder. There is also a disturbing element of dismay, or a case of shortage of better public information, in the way people had expressed in the media and the Internet the mistaken fear that certain dams such as La Mesa Dam or Angat Dam were spilling and contributing to the flooding in the Pasig-Marikina River Basin and flood plain. The two dams are not located in the Pasig-Marikina River Basin. Great expectations are raised after the big storms and floods that the government, the communities and society as a whole would or should be able to prepare better for the future. What is probably positive in the present situation is the way that people have expressed their complains and fears with a higher (or heightened) level of awareness (with expectations) in the use of terms such as "climate change" and "forest denudation" and reference to specific dams which are inside or closest to Metro Manila, all of which can be discussed objectively and provided a scientific explanation for and hence become the basis of better-informed plans and measures.

It is not a totally hopeless situation which one may see but a futuristic vision that something better (flood mitigation measures) can be planned, funded and put in place. It is the wish and expectation that, with the effort and commitment of government and the "haves" of society, more can be achieved to protect, save lives of, and benefit the "have nots" - the most highly-risked, vulnerable, and economically-disadvantaged segment of the flood-prone population. The most vulnerable "have nots" include the river bank, under-the-bridge and flood plain dwellers, the steep marginal-land inhabitants, and some fishermen, farmers and upland workers, who must be given safety, protection and assistance in addition to the broader flood mitigation and protection given to people, properties, infrastructure and other investments in the main residential, commercial, industrial and institutional areas of the region.

This article aims to present and explain briefly the present situation in the flood management in Metro Manila, cover the various government flood-mitigation projects, and provide recommendations for everyone concerned. The same or similar advice has also been expressed and discussed in previous fora conducted with or by NAST, other government agencies (DOST, DPWH, DENR, Senate-COMSTE, etc.), universities (UP, ADMU, MIT, etc.), professional societies and NGOs (PICE, PWP), and international institutions (JICA, ADB).

2. KNOWING METRO MANILA BASINS

Metro Manila is composed of 16 municipalities (Figure 1): KAMANAVA (Kalookan, Malabon, Navotas, Valenzuela), Manila, Quezon City, San Juan, Mandaluyong, Marikina, Pasig, Pateros-Taguig, Makati, Pasay, Parañaque, Las Piñas and Muntinlupa. Metro Manila is occupied by seven (7) small highly urbanized sub-basins (totaling 702 sq. km.), including Pasig River, which all drain directly to Manila Bay, and also serves as outlet of the Marikina River Basin (535 sq. km.) and the Laguna de Bay Basin (Figures 2, 3 and 4), composed of 21 tributary sub-basins (2300 sq. km.) and a lake (929 sq.km), for a total area of 3229 sq. km. (UNESCO-IHP, 2005)

METRO-MANILA:

Kamanava: Kalookan, Malabon, Navotas, Valenzuela

Manila	**Quezon City, San Juan, Mandaluyong,**	**Marikina, Pasig,**
	Makati, Pasay,	**Pateros-Taguig,**

Parañaque, Las Piñas, Muntinlupa.

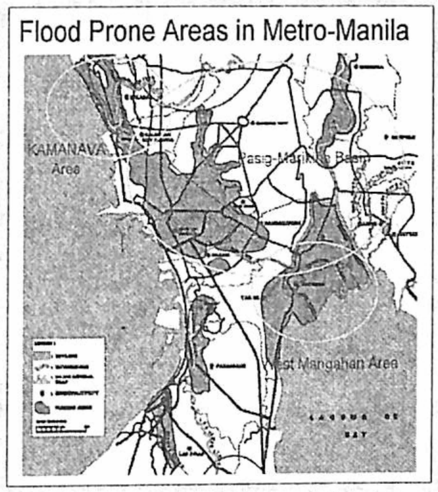
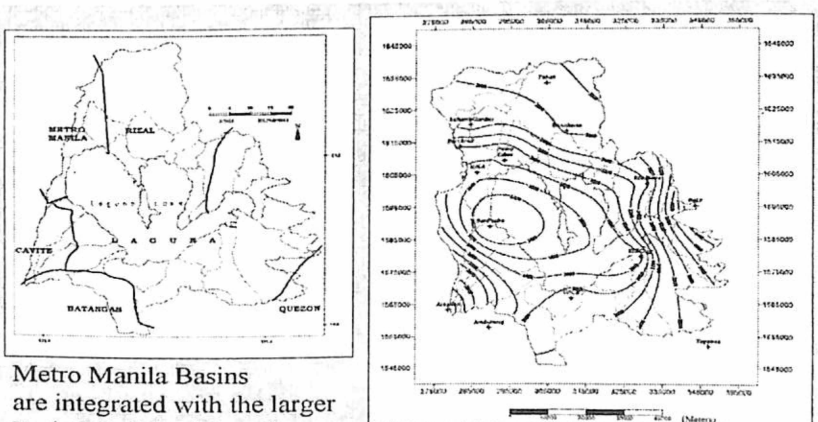


Fig. 1- Metro Manila municipalities and flood-prone areas.



Metro Manila Basins are integrated with the larger Pasig-Marikina River & Laguna de Bai Basins.

Mean Annual Rainfall Map (in millimeters)

Fig. 2 – Metro Manila Basins, Pasig-Marikina and Laguna de Bay Basins.

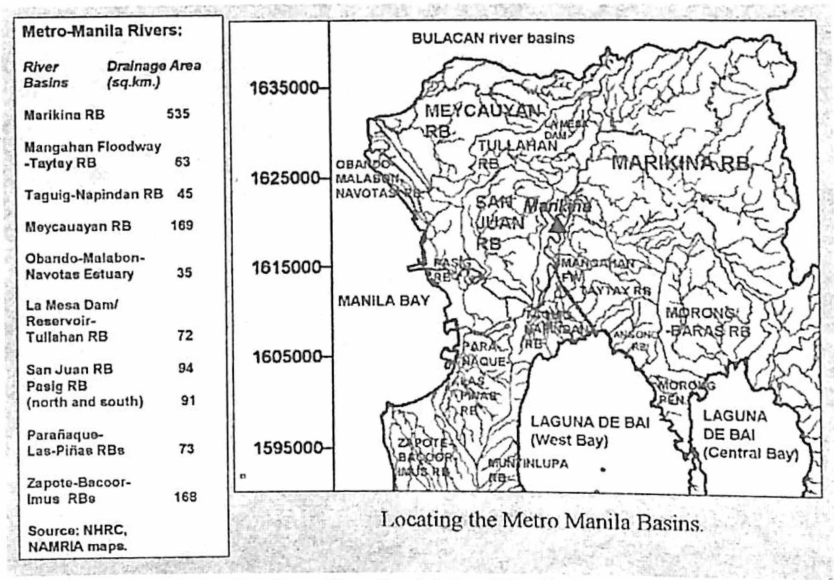


Fig. 3 – Locating the Metro Manila Basins.

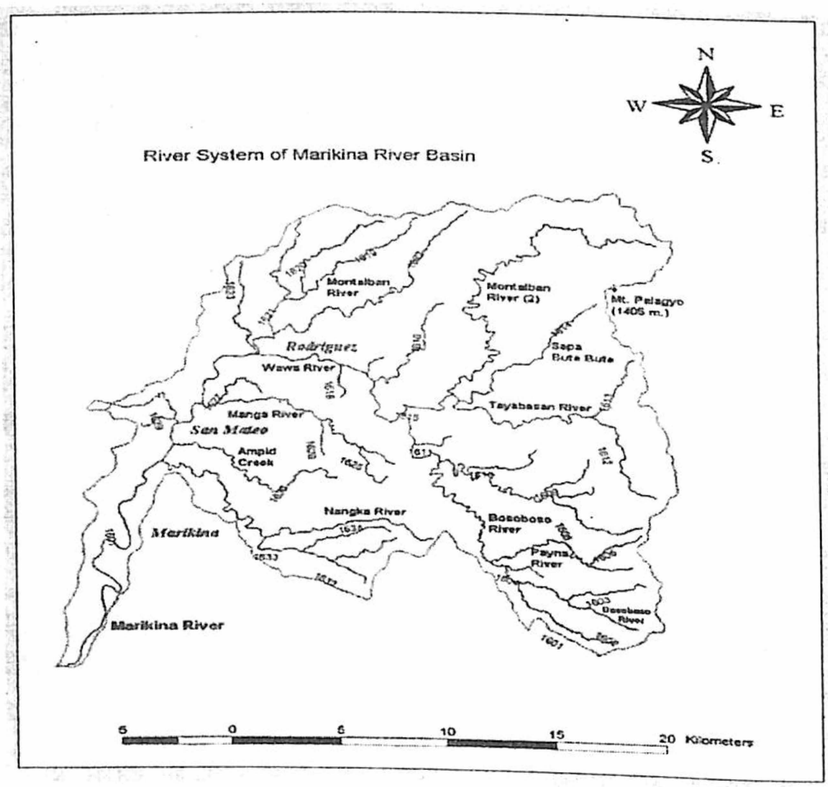
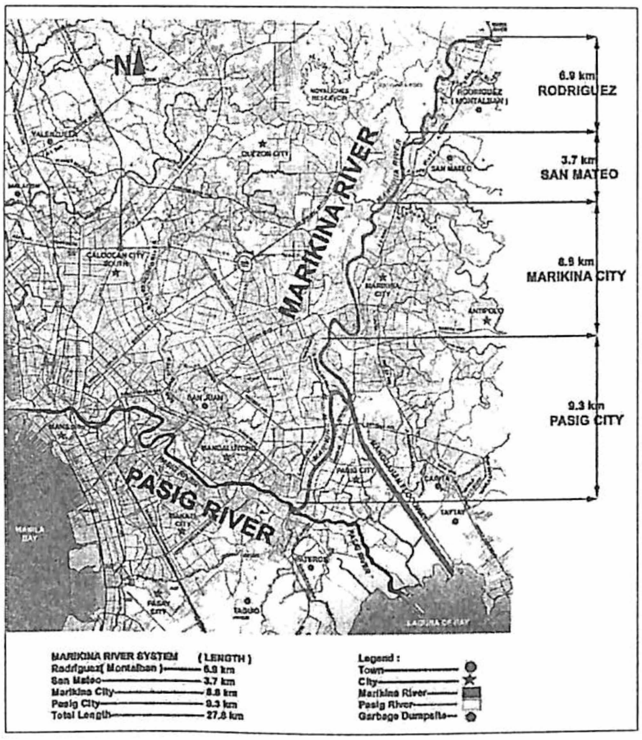


Fig. 4 – Marikina River Basin.

Name of River or Area	Return Period	Design Discharge m^3/sec	Catchment area Km^2	Specific Discharge: q $(m^3/sec)/Km^2$
Laoag	1/25	11,200	1,332.1	8.41
Agno	1/10	6,410	5,910	1.08
Pampanga delta flood way	1/20	3,800 – 4,300		
KAMANAVA	1/30: river 1/10: drainage	450	18.5	
Pasig-Marikina	1/30	2,900	500 (Sto.Nino)	5.8
Mangahan Flood way	1/30	2,400		
Iloilo	1/20: rivers (1/50) 1/5: drainage	1,000 (1,400)	412	2.4 (3.4)
Agusan	1/25	8,010	10,621	0.754
Ormoc	1/50	610	25.2	24.21

Source: DPWH, October 2009

Fig. 5 – Major flood control projects of the DPWH.



Top: Marikina River @Wawa Dam at Montalban gorge as seen in the early 1990's.

Left: The towns of Rodriguez (Montalban), San Mateo, Marikina & Pasig along Marikina River.

Fig. 6 – Pasig-Marikina River.

The flood-prone areas in Metro Manila are the KAMANAVA area, Pasig-San Juan River (Core Area), Pasay-Parañaque area, Marikina River area, and Taguig-Pasig area (Figures 5 and 6). The Marikina River Basin is the largest river basin (535 sq. m.), and in order to minimize the Marikina River floodflow coming down to Pasig River and hence protect the lower towns, the Mangahan Floodway was constructed in the late 1980s (with control gates at Rosario weir, Pasig) in order to divert towards Laguna de Bay the peak of 2400 cu.m./s out of the 30-year (return period) peak flood flow of 2900 cu.m./s of Marikina River, and allow only 500 cu.m./s to pass through Pasig River. Another hydraulic control structure that was constructed in the 1980s is the Napindan Hydraulic Control Structure (NHCS), located at Taguig near the C-5 bridge. This structure was originally intended to control or limit the saline water intrusion from Pasig River into the lake (as it may evolve to a future fresh water supply source) by gate opening and closure. However, it has been generally kept open throughout the year in order to allow boat navigation to the lake, preserve the brackish lake water quality required by the prevailing fish pen and fish cage cultures in the western portion of the lake, and to allow the seaward exit of floodwater from the lake to the Pasig River (and closed only if Pasig River level is higher than the lake level during peak flood episodes). Just finished in 2009 is the KAMANAVA project (river dikes and pumping stations) while just started is the on-going DPWH Pasig-Marikina River Channel Improvement Project (PMRCIP, with construction of river dikes and river walls), in Phase II or lower Pasig River phase.

Based on the review done in 2005 by the UP National Hydraulic Research Center (NHRC) on the DPWH-PMRCIP reports (UPERDFI-NHRC-CTI 2005), some of the highlights of the hydrologic design parameters considered in the PMRCIP are here given in terms of both rainfall and flood discharge data and their probabilities. Having the longest period of record (1907-2000) (prior to the TS Ondoy event), the maximum rainfall data for the Port Area synoptic PAGASA station, Manila were used as basis (with a regional or basin-wide adjustment) of the flood design of PMRCIP. Given below is a partial 15-year listing of the historically highest 1-day rainfall (mm per day) at Port Area station arranged by year starting from the highest:

Year (year)	Max 1-day Rainfall (mm) (post-WW2 values with asterisks)
1970	403.1 *
1976	371.6 *
1919	310.6
1923	309.1
1924	285.0
1918	271.5
1931	265.7
1972	265.1*
1921	263.6
1985	252.8*
1997	241.5*
1958	239.8*
1961	236.2*
1914	234.7
1977	234.4*

Based on the said rainfall data, the probabilities or annual frequencies (return period) of maximum rainfall for two durations (1 hour and 1 day) were Estimated for Port Area, Manila:

Return period (years)	1-hour Rainfall (mm)	1-day Rainfall (mm)
2	53.3	147.2
5	68.4	210.6
10	78.4	252.5
20	88.1	292.7
30	93.6	315.9
50	100.5	344.8
100	109.8	383.8
150	115.3	406.6

It may be stated that based on the rainfall statistics prior to TS Ondoy, the nearly 150-year-return-period 1-day-duration rainfall of 406.6 mm was experienced in 1970 (at 403.1 mm), while the nearly 100-year-return-period 1-day-duration rainfall of 383.8 mm was experienced in 1976(at 371.6 mm) at Port Area, Manila. Hence, the rainfall history of Manila, as recorded, has been very near the extreme 100-year rainfall experience in the record of 1907-2000. Today in 2010, it is only natural as well as logical to admit and accept a 100-year rainfall experience, given a historical record dating back to 1907 (and this is even ignoring the rainfall record of the Spanish colonial period). The flood record, however, is considerably shorter, as the next paragraph shows.

The same 2005 UP-NHRC review of the PMRCIP presented the data of the historical annual maximun discharge of Marikina River at the DPWH-BRS streamflow gaging station at Sto. Niño, Marikina and the corresponding probabilities (return periods). This station is located a few kilometers upstream of the Rosario weir control gate of the Mangahan Floodway.

Historical Annual Maximum Discharge of Marikina River at Sto. Niño station (period of record 1958-2000):

Year	Max. Discharge, m^3/s (partial top 10 values)
1986	2650
1970	2464
1959	2072
1977	2051
1966	2036
2000	1895
1998	1680
1995	1676
1999	1642
1967	1609
etc.	

Probable Annual Maximum Discharge of Marikina River at Sto Niño and Rosario station:

Return period (years)	Max. Discharge, m^3/s Existing Land Use Sto. Niño	Future Land Use Sto. Niño	Future Land Use Rosario
	1350	1470	1480
5	1870	2020	2000
10	2210	2350	2320
20	2550	2740	2720
30	2740	2900	2890 (design flood)
50	2980	3120	3070
100	3310	3430	3440

It may be stated that the 30-year-return period annual maximum flood of 2740 m^3/s had not yet been experienced in the 42-year period of record, 1958-2000. However, the 20-year-return period annual maximum flood of 2550 m^3/s was exceeded in 1986. Partly on this basis, the 30-year return-period flood design criterion was selected as a feasible engineering and economical option for flood mitigation along the Pasig-Marikina River.

Since Laguna de Bay level will rise and low-lying lakeshore towns will be flooded due to diversions by the Mangahan Floodway, another structure has been proposed to remove excess flood water from the lake directly into Manila Bay, namely the Parañaque Spillway. This structure has not been constructed, being overtaken by lack of funds, land development and urbanization along the intended right way (which is currently expensive in terms of land values). Other proposed structural measures of DPWH are the Laguna Lakeshore (ring) Dike (along the southern towns such as Cabuyao, Calamba and Los Baños, this being in addition to the recently finished Lakeshore Diking west of Mangahan to protect Taguig and Pasig), the Marikina Control Gate Structure (in order to control and therefore assure the diversion capacity of the Mangahan Floodway towards the lake), and the high Marikina Dam (Figure 7) upstream near Wawa, Montalban, which can reduce the 100-year flood flow to the 30-year flood flow of upper Marikina River by flood storage-and-spillway regulation, and also provide multi-purpose water benefits.

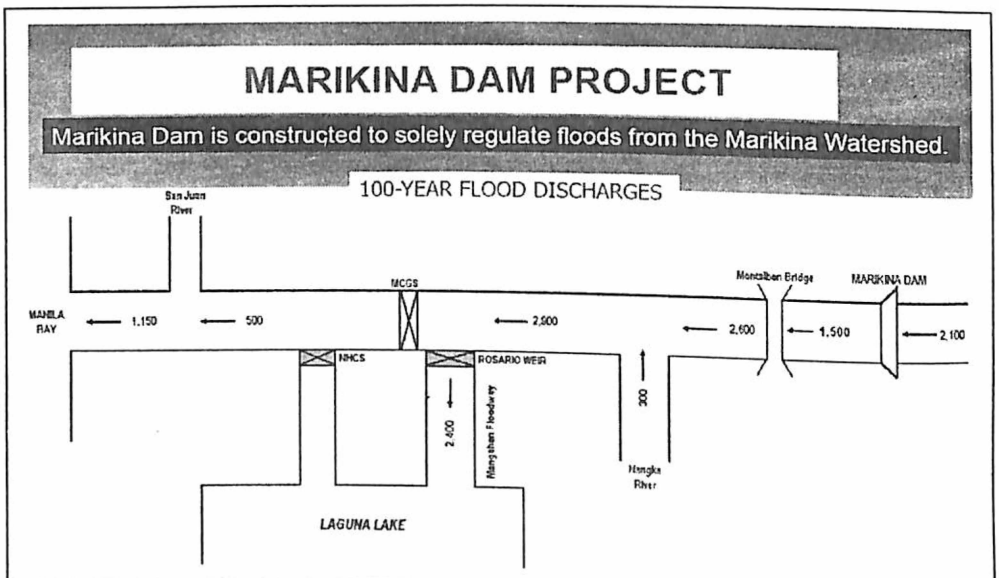


Fig. 7 – The proposed Marikina Dam Project 9source: DPWH).

The major non-structural measure for Metro Manila is the EFCOS, or "Effective Flood Control Operation System" (Figure 8), which aims to achieve an effective flood control operation for Pasig-Marikina-Laguna Lake Complex through real time rainfall and water level data collection at the Rosario Master Control Station (MCS) via telemetry system; the effective use of the warning system along Mangahan Floodway; and the multiplex communication system among Rosario MCS, Napindan HCS, DPWH Central Office and PAGASA Data Information Center. Its operation along with those of Rosario MCS and Napindan HCS was turned over to MMDA in 2002. EFCOS was de-operationalized in 2009 for budget reasons, and although quite-old-yet-operable, was not used for flood warning during the passage of TS Ondoy in September 2009.

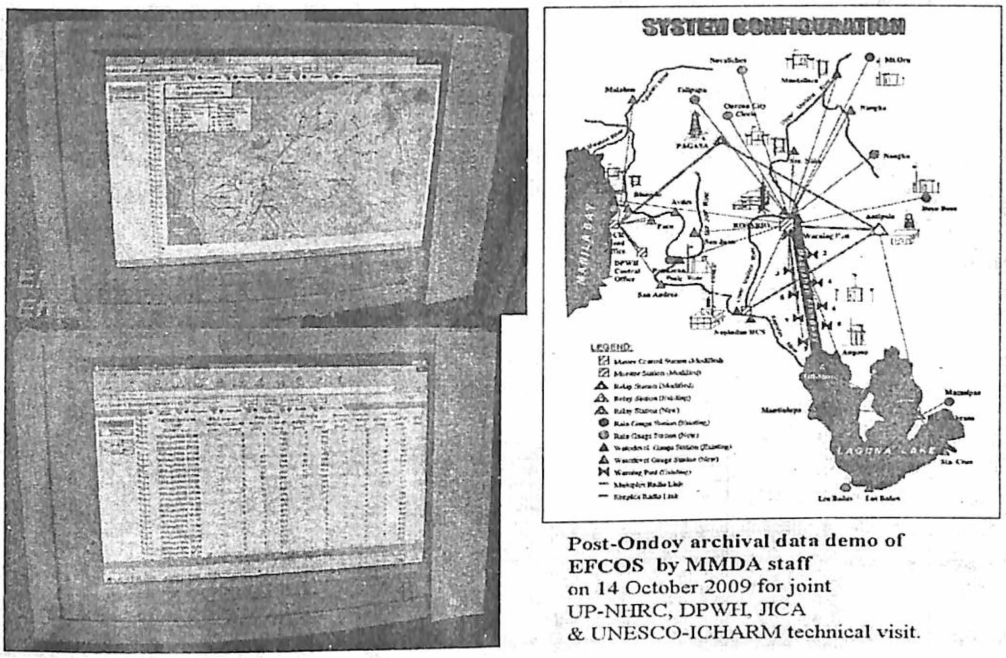


Fig. 8 – The Effective Flood Control Operations system (EFCOS).

3. THE PASSAGE OF TS ONDOY

TS Ondoy passed in the night of 25th September 2009 and into the entire day of 26th September 2009. The rainfall measurements (PAGASA FFWS 2009) taken at various city locations indicate more than a peak 400 mm. rainfall depth in 12 hours, with estimated return periods in the range of 100-150 years (Figure 9). There is spatial or geographical variation in the TS Ondoy rainfall distribution, as exemplified by two rainfall stations below:

Storm rainfall inside the Marikina River Basin - Boso Boso, Antipolo
EFCOS rainfall station, on September 26, 2009:
286 mm (6-hour duration from 8:00 am to 2:00 pm)
340 mm (12-hour duration from 8:00 am to 8:00 pm)
348 mm (24-hour duration from 8:00 am to 8:00 am next day) – no return period given.

Storm rainfall outside and west of the Marikina River Basin - Science Garden, Quezon City PAGASA rainfall station, on September 26, 2009:

347.5 mm (6-hour duration from 8:00 am to 2:00 pm)
413.0 mm (9-hour duration from 8:00 am to 5:00 pm)
448.5 mm (12-hour duration from 8:00 am to 8:00 pm) – approx. 120-year return period.

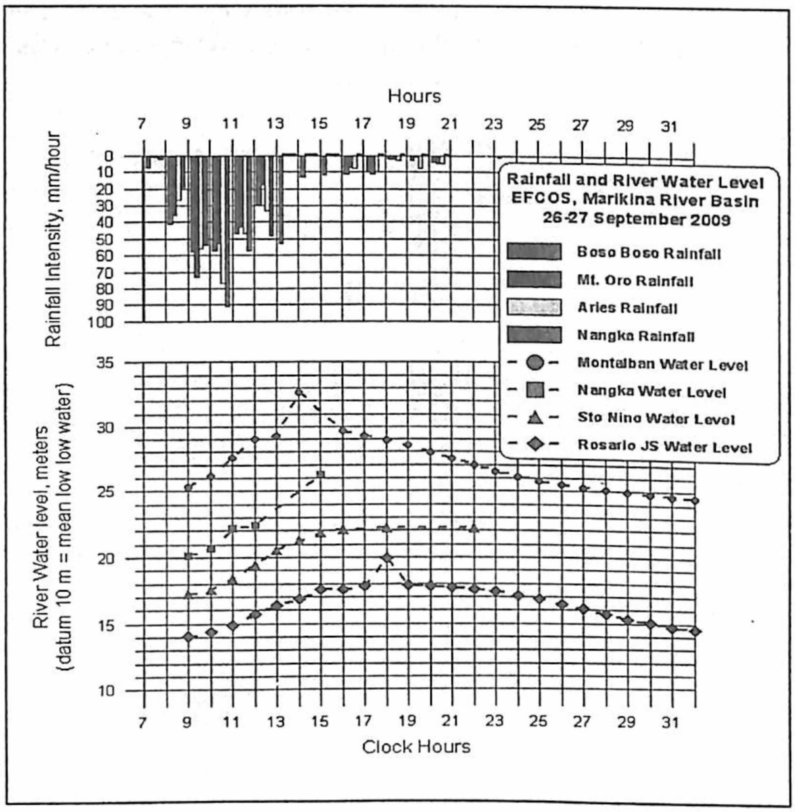


Fig. 9 - The graphs of the EFCOS rainfall and river stage records during the passage of TS Ketsana (Ondoy), September 26-27, 2009.

It is officially a 100-year storm rainfall, and DPWH also estimated the resulting flood as a 500-year flood (ADB 2009). UP NHRC independently obtained a flood peak discharge of 5700 cu.m/s by running its own Marikina River watershed hydrologic and floodplain hydraulic model, and using the rainfall inputs from PAGASA and EFCOS stations (which are archived) (UP ICE 2009). The maximum flood rise of eight (8) meters along the Marikina river bank near Marcos Highway was also predicted by the models and verified in the field (post-flood ocular visit within 48 hours).

During the most intense period of the storm in the morning of September 26, 2010, the soil cover of the Marikina River watershed (including its tributaries) would already be saturated with rain water which had fallen in the preceding night. This can be illustrated by a simple computation: for example, a 0.5 meter or 500 mm depth of upper soil layer with a typical 50-60 per cent porosity can be saturated by 500 mm x (0.5 to 0.6) = 250 to 300 mm of rainfall which will fill the pores of the soil. At full saturation of the soil, no additional infiltration of water into the soil takes place, and the unabsorbed or uninfiltrated excess rainfall (above 300 mm) rapidly becomes pure runoff, carrying along with it the eroded soil particles already dislodged by rainfall impact and picked up by the frictional force exerted by the water flowing on the soil surface. Worse, huge chunks of earth, loose trees and debris, which are located at steep slopes, made heavier due to water saturation and made slippery by the water itself, will go down as landslide, turning fast into debris flows or mudflows, and pose the greatest danger to dwellers in steep areas. Water flooding (with higher inundation depths and swifter currents, with sharper peaks and larger volumes, but with shorter lead-time or warning) and zero-warning landslides, debris flows/mudflows, fast bank erosions, breaching of walls and collapse of buildings are the worst life-threatening combined hazards to be expected.

At this juncture, the flash floods and debris flows are considered, quite correctly in the minds of many people, as the partial returns from all the past "sins" of forest denudation, loss of forest cover and biodiversity, and loss of soil cover and its strong anchoring with structural interconnection with the tree-root network, base rocks and outcrops. Loss of forest and soil cover reduces the soil-water-retentive property of the watershed to delay and diminish (attenuate) the intensity of the flood wave (also called a flood hydrograph with certain peak discharge and time duration). Moreover, lower retention of water in the soil leaves a lower chance for recharge or replenishment of the groundwater aquifer below, which may provide the dry-season flow for springs, perennial streams and man-made water supply wells.

The physical impacts (hazards and vulnerability) of TS Ondoy on September 25-27, 2009 may thus be summarized:

- The record-high 12-hour rainfall amounts in Metro Manila on 26 Sept 2009 attained the annual maximum rainfall values for 100-year return period (or even higher).
- The peak flood flows of Pasig-Marikina River (around 5000 m^3/s or higher) may be assigned a very high return period greater than 100 years (DPWH gives 500 year, for further studies). It exceeded the 30-year design flood capacity of 2900 m^3/s for the DPWH flood control project, PMRCIP.
- Laguna de Bay level reached a maximum of 14 meters compared to Manila Bay low-water datum of 10 meters, due to flood diversions through the Mangahan Floodway as well as inflows from other risen rivers such as Pagsanjan River, Sta Cruz River, etc. in the Laguna Lake basin. Lakeshore towns were inundated.
- The overflow of rivers inundated villages and towns in the banks and floodplains.
- Flash floods and inundation also occurred in elevated communities due to inadequate storm drainage facilities and failing walls ("dam breaks").

The effects (risks and damages) on the communities and infrastructure are also summarized as follows:

- Rainfall and flood forecasting and warning under EFCOS in Metro Manila was apparently not operational during TS Ondoy. Measurements at EFCOS telemetry rainfall and river level stations were done however. The people did not expect the record-high magnitude of the rainfall and floods from the early weather reports.

- The construction of the DPWH diking system under PMRCIP for Pasig River (Phase II) is still on-going and unfinished, while Phase III for Marikina River has not yet been started. The on-going/unfinished 30-year return period design of PMRCIP was naturally surpassed and overwhelmed by the 150-year-plus storm and flood event.
- The inundated low towns inside the finished DPWH lakeshore diking system West of Mangahan had to contend with two merging sources of flooding: Pasig-Marikina River and Laguna de Bay. There were news reports of failure of pumping stations to function due to submergence of electrical systems.
- Poor settlements in the river banks, as well as upscale communities in the floodplain, suffered inundation, property damage and loss of lives. Strong water currents were also cause of death by drowning. Erosion and debris flows occurred in steep or exposed localities, affecting the urban poor more in particular.
- Due to inadequate or poorly designed local storm drainage facilities in elevated communities, the risks are also present for inundation, backflow of sewers and septic tanks, and the consequent damage to property. Flood recession is slower especially where dumped solid waste and encroachment in waterways impede the retreat of water.

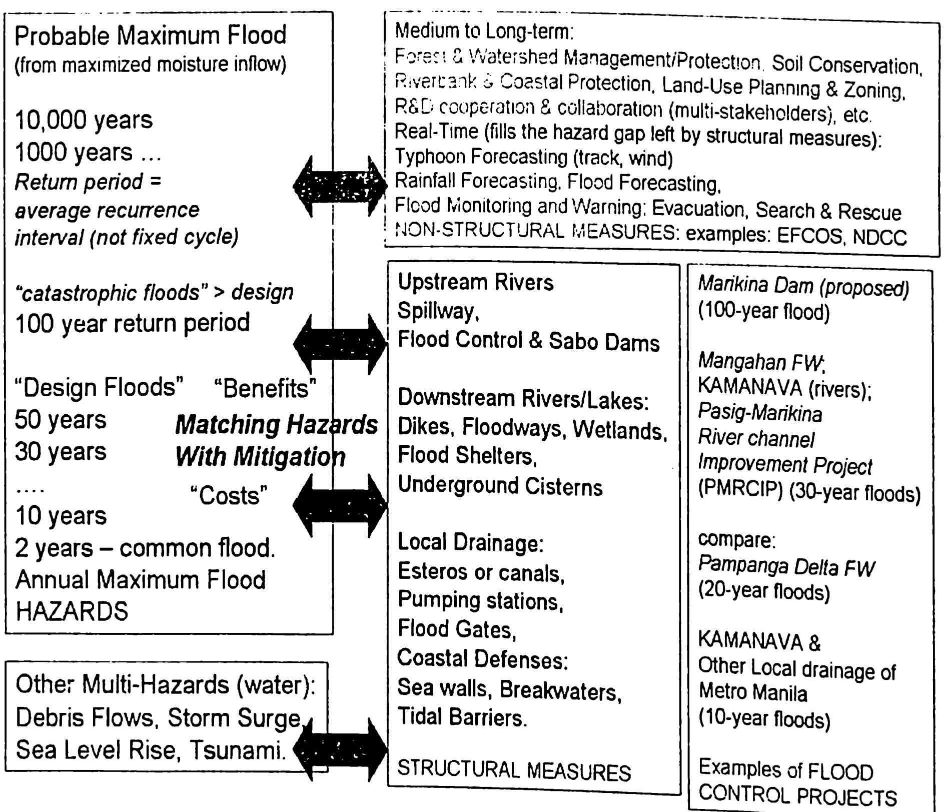


Fig. 10 – Flood hazards, structural and non-structural mitigation measures.

4. RECOMMENDATIONS

4.1 Structural Mitigation Measures

Flood mitigation measures fall into two complementary types, the structural and non-structural measures (as illustrated in the general diagram, Figure 10). In the case of Metro Manila, the structural measures include the finished KAMANAVA project in the northeast part and several projects located in the river-lake complex of Marikina-River and Laguna de Bay, namely: the ongoing PMRCIP, the near-complete Lakeshore Dike West of Mangahan (protecting Taguig, Pateros, Pasig Cainta and Taytay, whole or parts thereof), and the two proposed major flood-control structures: the lower Marikina Control Gate Structure (MCGS) in Pasig, and the upper high Marikina Dam in Montalban, Rizal. The occurrence of TS Ondoy flooding logically prescribes for a thorough hydrological review of the existing project plans in order to assess the updated risks and vulnerability, with the anticipation that improvement and/or revision in the design can be made to address any identified new risks, within the most cost-effective, economical, socially-acceptable and environmentally-friendly manner that is feasible. Certain projects may require a revisit and a re-computation of inland design flow criteria used in the river and coastal protection works design, in the light of new and significantly different rainfall and flood flow statistics implied by the new data of the TS Ondoy event.

The idea of a single high Marikina Dam is that of a single upstream major flood-control structure designed to reduce downstream flood hazard and risk through attenuation of released flood peaks. This is achieved by utilizing reservoir storage and spillway outflow regulation, from a 100-year inflow flood peak flow to a lowered 30-year outflow flood peak flow, so that the downstream structures are still working effectively at 30-year design capacity (without being overwhelmed). There is also technical merit, worth examining, in the alternative ideas of some engineers, both local and foreign, to replace the single high dam with a cascade of two, three or more lower dams, accomplishing the same overall flood hazard reduction, without creating big hazards and risks of dam-break floods, excessive rates of dam seepages and other earthquake-related dangers if a high dam is constructed.

4.2 Non-structural Mitigation Measures

Very specific recommendations are being made here for non-structural mitigation measures in view of the opportunities that they offer for an improved cost-effectiveness and economy and a broader multi-sectoral participation in flood management (by national and local governments, NGOs, academe and research institution, private sector and international institutions) in addition to the government's principal infrastructure agencies which implement structural mitigation measures. The key roles of NDCC and its departmental members such as DOST (with PAGASA, PHIVOLCS), DENR, DPWH, DSWD, DOH, DA, DILG and other agencies as well as the academe are very important and critical for the successful application and implementation of non-structural measures.

- New topographic survey with centimeter-vertical precision (such as LIDAR) in order to develop accurate digital elevation models (DEM) and other GIS-based models of all flood-prone areas in Metro Manila,
- Development of the GIS overlays of soils type , land-use, slope, river/lake network, and other themes,

- Next development of the GIS-based hydrological catchment and hydraulic river-and-floodplain inundation models, whose results shall be basis for evaluating the effectiveness of flood control plans and assessing of their economic and environmental benefits.
- And the desired products of quantitative GIS-based flood risk and vulnerability models (with indicated depths and directions of inundations according to return period), under projected scenarios of climate change, sea-level rise, urbanization and other drivers to change. The models will be decision-support instruments for land-use planning and zoning as well as bases for community-based warning and actions programs.
- Improving the monitoring and forecasting of real-time storm rainfall (through more and better use of the scientific tools of telemetry, doppler radar, NASA TRMM or tropical rainfall measuring mission, statistical models, etc.) and flood forecasting using both the rainfall telemetry and forecasts, flow-to-flow correlation, and physically-based hydrological (rainfall-runoff) models, and hydraulic flood-and-inundations models. Likewise, the same models can be used for long-term risk assessment and mitigation plans.
- Inclusion in community-based warning and action programs for high-risk areas of the complementary structural protection measures such as construction of village-sized emergency high safe commons/places (multi-purpose for usual athletics and community functions), and provision/acquisition affordably by the village associations/barangay LGUs of rescue rubber boats or else fiberglass boats (such as used in coastal towns whose resilience to coastal flooding is afforded by stilt houses and boats).
- Implementation of capacity-building programs (with "DM cookbooks") such that the appropriate advanced tools as mentioned can be adopted and made operational by agencies and LGUs tasked with flood management. DM cookbooks must evolve into quantitative handbooks.
- Better explained and more understandable flood bulletins in media and Internet, using vernaculars, graphics, multi-media, as well as printed guides or comics. Technical flood terms must be made understood.

5. CONCLUSION

The problems and solutions of flood management involve four major sectors of the national economy with their own sets of agenda, programs and policy, namely energy, hazards, climate change and water management, which concern and share (and often compete over) the same earth resources and limited government assets and capacities. The final diagram of this article (Figure 11) illustrates the need to identify, understand and operationalize the various linkages between integrated water resources management (IWRM) which has a subset of flood management, hazards reduction and mitigation, climate change agenda and policy, and energy programs and policy. The various driving factors in the evolution of flood hazards and risks – population change, urbanization, environmental degradation, climate change (all of which are affected by human behavior) – also affect the other sectors. This is a suggested framework to adopt or follow, which recognizes the inter-dependencies as well as the separabilities of certain aspects of programs and policies. There are details to be fleshed out, so to speak, which for lack of space in this article can not be elaborated. Suffice to say that opportunities are present under this framework for more effective combination of scientific investigations, government planning and management, private sector participation, and community-based actions in the provision of flood mitigation benefits to the population of the city.

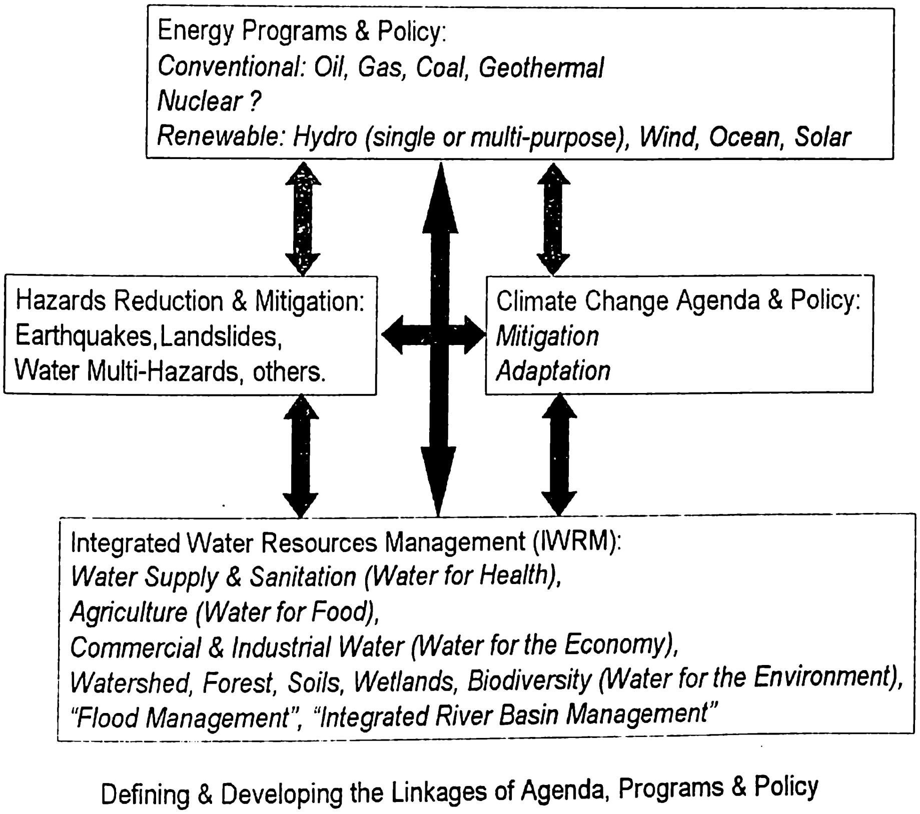


Fig. 11 – Defining and developing the linkages of agenda, programs and policy.

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