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Environmental impact assessment of structural flood mitigation measures by a rapid impact assessment matrix (RIAM) technique: A case study in Metro Manila, Philippines

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HIGHLIGHTS

- The RIAM is used in the EIA of flood control projects in the Philippines.
- Project phasing is proposed as additional feature in the RIAM method.
- A slight modification in the B criteria and range bands of the RIAM was proposed.
- The modified RIAM provides highly organized and more meaningful EIA results.
- Results of the modified RIAM indicates improved transparency in the EIA process.

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ABSTRACT

In recent decades, the practice of environmental impact assessment (EIA) in the planning processes of infrastructure projects has created significant awareness on the benefits of environmentally sound and sustainable urban development around the world. In the highly urbanized megacities in the Philippines, like Metro Manila, high priority is given by the national government to structural flood mitigation measures (SFMM) due to the persistently high frequency of flood-related disasters, which are exacerbated by the on-going effects of climate change. EIA thus, should be carefully and effectively executed to maximize the potential benefits of the SFMM. The common practice of EIA in the Philippines is generally qualitative and lacks clear methodology in evaluating multi-criteria systems. Thus, this study proposes the use of the rapid impact assessment matrix (RIAM) technique to provide a method that would systematically and quantitatively evaluate the socio-economic and environmental impacts of planned SFMM in Metro Manila. The RIAM technique was slightly modified to fit the requirements of this study. The scale of impact was determined for each perceived impact, and based on the results, the planned SFMM for Metro Manila will likely bring significant benefits; however, significant negative impacts may also likely occur. The proposed modifications were found to be highly compatible with RIAM, and the results of the RIAM analysis provided a clear view of the impacts associated with the implementation of SFMM projects. This may prove to be valuable in the practice of EIA in the Philippines.

1. Introduction

Environmental impact assessment (EIA), in principle, is the systematic approach used in the identification and evaluation of beneficial and harmful impacts on the physical, biological and socio-economic components of the environment, which may arise from the implementation of projects, plans, programs or policies (Petts, 1999; Wang et al., 2006). At present, EIA is a common feature in the appraisal of planned infrastructure projects (Tamura et al., 1994) such as roads (Zhou and Sheate, 2011), flood protection systems (Ludwig et al., 1995) and water supply systems (Al-agha and Mortaja, 2005). Flood protection systems, particularly structural flood mitigation measures (SFMM), are being undertaken throughout the centuries to reduce flood damages and losses (Poulard et al., 2010). In Southeast Asia, most of

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its key cities, including Jakarta (Indonesia), Bangkok (Thailand) and Metro Manila (Philippines), to name but a few, are highly vulnerable to immense inundations and violent floods. Recent studies on climate change (The World Bank, 2010; Yusuf and Francisco, 2009) indicated that this region will experience higher frequency of extreme flood events, creating greater demands for SFMM. The use of SFMM has perhaps become very valuable in many urbanized areas; however, poor management decisions in the implementation of these infrastructures may lead to geomorphological, ecological and/or social ramifications (Everard, 2004). For instance, in the past, several channelization works in Europe (for the purpose of flood control) brought adverse ecological consequences in many European river systems (Brookes and Gregory, 1983). EIA thus is a necessary step during the early planning stages of SFMM in order to gain clear insights of the structures' probable impacts with respect to the different components of the total environment. Likewise, the use of appropriate EIA techniques can aid the decision-makers to formulate appropriate actions based on informed decisions in light of project urgency and limited resources, which are common constraints in the developing countries (Shah et al., 2010).

In the Philippines, through Presidential Decree No. 1586 (1978) — a law that requires the assessment of a proposed project to determine its effects on the "quality of the environment" — EIA is mandatorily being carried out on planned SFMM. The EIA methods commonly used are generally descriptive and qualitative in nature (e.g. Department of Public Works and Highways, DPWH, 1998; City Office of Navotas, 2009), which are similar to the EIA methods (i.e. ad hoc and simple checklist methods) described by Lohani et al. (1997). The ad hoc method is a non-structured approach that generally relies on the "experience, training and intuition" of the assessing expert. The problem with the ad hoc method is that it generally lacks the means to meaningfully organize considerable amounts of information about the biophysical, social and economic environment. It merely describes the pertinent information concerning the impacts without much emphasis on importance and magnitude. This process of assessment is non-replicable, which makes the EIA conclusions at times difficult to review or even criticize (Lohani et al., 1997). The simple checklist method, on the other hand, is structured, elaborative and more systematic compared to the ad hoc method. It typically displays a list of environmental parameters (or potential impacts) that are evaluated against a set of assessment criteria (Barthwal, 2002; Lohani et al., 1997). One disadvantage of this method is that it often fails to account for the spatial and cumulative effects of the identified impacts (Munier, 2004). The simple checklist method is also deficient when it comes to providing the necessary guidelines for estimating and interpreting the degrees of impacts (Lohani et al., 1997), which essentially precludes the transparency of the EIA process. According to Villaluz (2003), one way to advance the EIA system in the Philippines is to select methods that will provide better transparency to help "maintain the impartiality of the entire process".

An EIA approach that provides for the quantitative analysis of subjective judgments may help address the limitations of the two traditional EIA methods mentioned above (Ijäs et al., 2010). Such concepts, including the assessment of cumulative effects, are fundamental in the rapid impact assessment matrix (RIAM) technique (Pastakia and Jensen, 1998). The RIAM technique is a semi-quantitative impact assessment approach that utilizes standardized evaluation criteria and rating scales. It has been favored in many case-studies from various sectors (Mondal et al., 2010; El-Naqa, 2005; Al Malek and Mohamed, 2005; Yeboah et al., 2005) primarily due to its simplicity and robust application. In spite of its wide reception, there has been no reference, as far as the authors know, of its use in the EIA of SFMM in any part of the world. The applicability of the RIAM in the Philippine EIA system is also yet to be established. The Philippines can benefit from adopting this EIA method, thus it is important to provide references of its application. It is necessary however to ensure the conformity of the RIAM technique with the general impact assessment approach prescribed in the Philippine EIA system. In this EIA system, the evaluation and prediction of the likely impacts must be made in terms of project phase timelines (i.e. pre-construction, construction, operation and abandonment phases), which have not been given emphasis in the past RIAM studies that the authors are aware of.

This paper mainly explores the benefits of using the RIAM technique in the evaluation of SFMM by examining the results of the EIA of selected planned SFMM projects in Metro Manila. The primary aim is to improve the transparency and minimize subjectivity in the EIA process specific to the SFMM projects in Metro Manila. Furthermore, a slight modification of the RIAM method is proposed not only to enhance the transparency and sensitivity of the evaluation process, but also to cope with the requirements of the EIA system in the Philippines. These modifications are intended to improve the outcome of the EIA, but may also find application in other infrastructure projects. The following sections introduce the basic profile and environmental conditions of the study area; elaborate and demonstrate the application of the RIAM method; analyze and discuss the results of the impact assessment; and offer some recommendations and conclusions with the aim of providing valuable insights for decision makers, planners and policy makers for the improvement of the EIA practice in the Philippines.

2. Environmental setting

Metro Manila is an administrative region in the Philippines that serves as a focal point for major political and economic activities in the country. The geographic location of Metro Manila is shown in Fig. 1. Based on this map, Metro Manila is situated in a semi-alluvial fan that opens to Manila Bay on the west and Laguna de Bay Lake on the southeast. At present, the metropolis is comprised of 17 highly urbanized municipalities that are sharing a relatively small area of 638 km^2. The population in Metro Manila is about 11,758,000 persons (National Statistics Office, 2007), making it the most densely populated administrative region in the country. According to the study of the National Statistical Coordination Board (2009), about 30% of the country's gross domestic product comes from Metro Manila. Despite the high economic activities in this region, the economic growth and urban development in many of its municipalities is persistently slow, which according to Page (2000), is partly due to the frequently occurring disasters caused by immense and violent floods that takes place during the monsoon and storm periods (from May to October). The costs of flooding in Metro Manila (based on 2008 values) can range from PhP 15 billion ($337 million) to PhP 111 billion ($2.5 billion), which is 3% to 24% of the region's gross domestic product (The World Bank, 2010). Recent flood events (Rabonza, 2009) are increasingly devastating, resulting in the loss of many lives and causing immense damages to properties. According to Fano (2000), the occurrences of floods in Metro Manila have been documented as early as 1898. However, there seems to be no record of the actions taken to mitigate the occurrences of floods until 1943. The major flood event that took place in 1943 compelled the Philippine government, shortly after the incident, to initiate its first comprehensive flood study and flood control plan, which were completed in 1952 (Bureau of Public Works, 1952). The flood control plan consisted mainly of drainage improvements covering most parts of the present day Metro Manila.

This paper focuses on the flood-prone sub-drainage area (approximately 20 km^2) that is located at the north-northwest part of Metro Manila, as indicated in Fig. 1. This sub-drainage area is home to approximately 160,000 residents. Its topography is generally characterized by flat and low-lying coastal plains with ground elevation ranging from 0 to 1.5 m above mean sea level. It has a mixed land use comprised of commercial districts, industrial districts, residential areas and fishponds. As shown in Fig. 1, the study area is bordered by

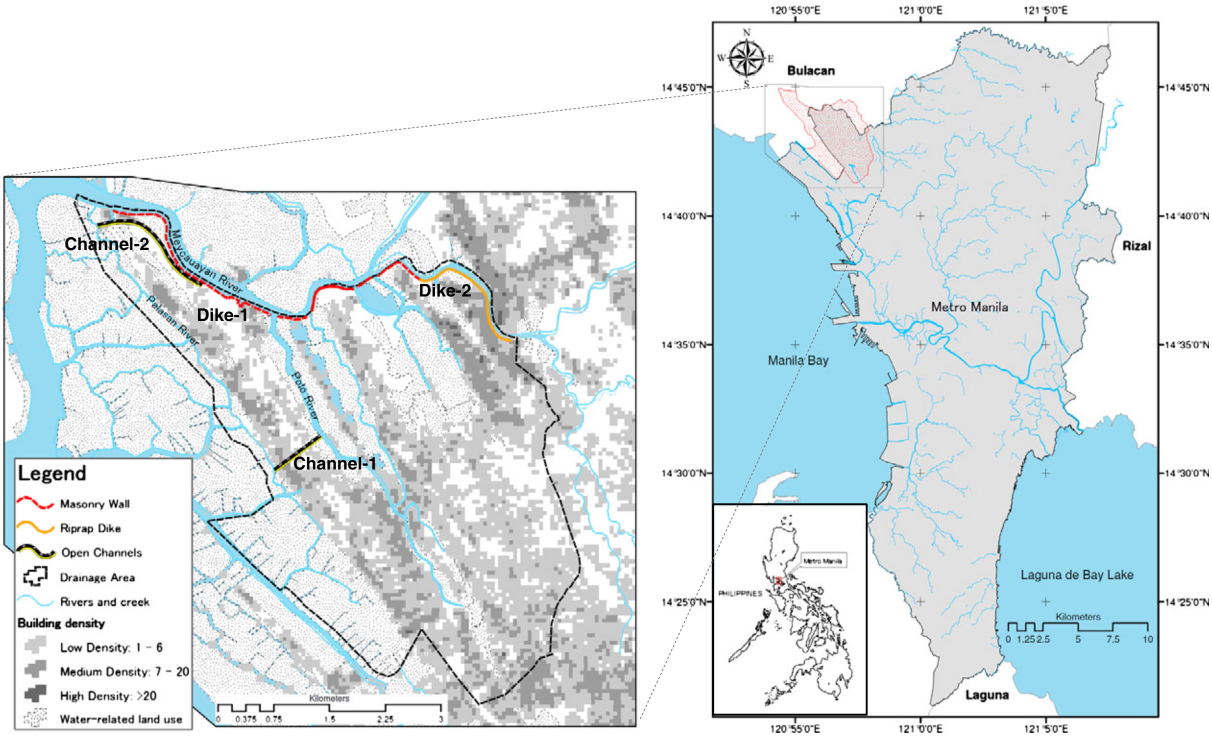

Fig. 1. Geographical locations of Metro Manila and the study area (right), and locations of the planned structural flood mitigation measures (left). The structural flood mitigation measures are labeled as follows: Dike-1 and Dike-2 for the lower stream and upper stream dikes, respectively; and Channel-1 and Channel-2 for the diversion channel and small open channel, respectively.

two rivers and three creeks with 3 minor river systems traversing the drainage area from southeast to northwest. The average annual rainfall is less than 3000 mm. The river system has limited aquatic biota due to the poor water quality condition. Garbage, especially commercial plastics, was observed deposited along the riverbanks and floating along the river mid-streams. Migratory birds that feed on insects, fishes and invertebrates were observed wandering and nesting close to the Meycauayan River, while few patches of mangroves exist at the lower section of the Meycauayan River. Most mangrove areas have been converted to fishponds and settlement areas. Water hyacinths were observed at the approaching upstream of the Meycauayan River. High volume of settlers is found at and near the left bank of the upper section of the Meycauayan River and along narrow natural waterways. Due to the very poor discharge capacity in this drainage area, floods can easily manifest during the rainy seasons, contributing to the slow economic growth rate of the affected municipalities.

To improve the drainage conditions, 2 river improvement works and 2 open channels were proposed by the Department of Public Works and Highways (DPWH) (2001), under the Metro Manila flagship program on flood management. Table 1 shows salient information of the 4 planned SFMM investigated in this study. The locations of these structures are shown in Fig. 1. The river improvement works as described in Table 1 involves the construction of masonry walls (Dike-1) and riprap dikes (Dike-2) at the left bank of the lower and upper sections of the Meycauayan River, respectively. These structures will serve as preventive measures from bank overflow, and protection from the scouring effects of turbulent flow against the river's critical bends and bridge abutments. The open channels consist of a diversion canal (Channel-1) that will discharge excess water from the Polo River to the Palasan River; and a small drainage channel (Channel-2) that will aid in the draining of surface water near the lower section of the Meycauayan River (Fig. 1). Settlements can be found along the alignment of the planned open channels. The authors evaluated the environmental impacts of these 4 planned SFMM with the aid of the RIAM technique.

3. The rapid impact assessment matrix method

Evaluation and review of the EIA was carried out using the RIAM technique to determine the degree of impacts of the planned flood mitigation structures along the immediate and surrounding environment of the study area. Table 2 shows the scope of the EIA indicated by the list of 32 environmental components. Impacts that will arise from the implementation of the planned structures (i.e. Dike-1, Dike-2, Channel-1 and Channel-2) on each environmental component are denoted by the symbol (●). The symbol (X), on the other hand, indicates that the implementation of the planned SFMM have no perceived

Table 1
Salient features of the selected proposed structural flood mitigation measure in Metro Manila.

Structural flood mitigation measure	Description of activities	Length (m)	Width (m)	Depth (m)
Dike-1	Raising of masonry wall, installation of ripraps and alteration of river bank configuration at the lower section of the Meycauayan River	4900	4.0	–
Dike-2	Raising of riprap dike, installation of new ripraps, and alteration of river bank configuration at the upper section of the Meycauayan River	2340	4.0	–
Channel-1	Construction of diversion canal between the Polo River and the Palasan River by excavation	850	9.6	3
Channel-2	Construction of drainage channel in the lower reaches of the Meycauayan River by excavation	1650	5.6	2.1

Table 2
Summary checklist of potential impacts of each planned structural flood mitigation measure.

Environmental categories	Item no.	Environmental components	Code	Structural flood mitigation measures			
				Dike-1	Dike-2	Channel-1	Channel-2
Physical/chemical	1	Land/soil disturbance due to site clearing	PC-P-1	●	●	●	●
	2	Change in land use	PC-C-1	X	X	●	X
	3	Local geology and soil erosion	PC-C-2	●	●	●	●
	4	Drinking water	PC-C-3	●	●	●	●
	5	Erosion and riverbank scouring	PC-C-4	●	●	X	X
	6	Surface and groundwater hydrology	PC-O-1	●	●	X	X
	7	Hydraulic conditions	PC-O-2	●	●	●	●
Biological/ecological	8	Aquatic habitat	BE-C-1	●	●	X	●
	9	Wildlife and terrestrial impacts	BE-C-2	●	●	X	●
	10	Riparian and wetlands	BE-C-3	●	●	X	X
	11	Waste generation from construction and excavation	BE-C-4	●	●	●	●
	12	Aquatic/freshwater biology	BE-C-5	X	X	●	●
	13	Surface water quality	BE-C-6	●	●	●	●
	14	Aquatic habitat	BE-O-1	●	●	●	●
	15	Water quality	BE-O-2	●	●	●	●
Social/cultural	16	Involuntary Resettlement	SC-P-1	●	●	●	●
	17	Public acceptance	SC-P-2	X	X	●	●
	18	Air quality	SC-C-1	●	●	●	●
	19	Noise levels	SC-C-2	●	●	●	●
	20	Population dynamics	SC-C-3	●	●	●	●
	21	Dependency burden	SC-C-4	●	●	●	●
	22	Housing characteristics and utilities	SC-C-5	●	●	●	●
	23	Health and safety of construction workers	SC-C-6	●	●	●	●
	24	Health and safety of general public	SC-C-7	●	●	●	●
	25	Aesthetic and cultural scenic sites	SC-C-8	●	●	●	●
	26	Local planning, coordination and economic growth	SC-C-9	●	●	●	●
	27	Public utilities and infrastructure	SC-C-10	●	●	●	●
	28	Natural environmental and health hazards	SC-O-1	●	●	●	●
	29	Urban living conditions	SC-O-2	●	●	●	●
Economics/operational	30	Property and infrastructure	EO-O-1	●	●	●	●
	31	Development potential	EO-O-2	●	●	●	●
	32	Local revenue and economy	EO-O-3	●	●	●	●

"●" — potential source of impact; "X" — no perceived impact.

impact on the environmental components. Each of the environmental component falls under one of the 4 environmental categories defined by Pastakia and Jensen (1998): physical/chemical (PC), biological/ecological (BE), social/cultural (SC) and economics/operational (EO). Typically, the grouping of environmental components stops here, but for the purpose of this study, the RIAM method is slightly modified to further sub-group the environmental components in terms of project phases. As earlier discussed, project phasing improves the outcome of the EIA, since this allows the review of a wider scope of impacts that benefits the formulation of environmental management plans. In the Philippines, based on the national environmental impact statement system (Department of Environment and Natural Resources, DENR Administrative Order No., 2003-30, 2003), the typical project phases to be considered for infrastructure projects are pre-construction phase, construction phase, operation phase and abandonment phase. The term *abandonment phase* refers to a project phase wherein a project is decommissioned (or abandoned) upon reaching the end of its productive life (e.g. Kaiser, 2006; Rapantova et al., 2012), or when it simply ceases its operation for whatever reason. In this study however, open channels and river improvements are considered as *permanent* structures that are only subject to either maintenance or further enhancement due to their long term (or perpetual) necessity in Metro Manila, thus the abandonment phase was not included in this study. The abbreviations used for the project phases in this study are as follows: Construction Phase (C), Pre-construction Phase (P) and Operation Phase (O). Giving emphasis to project phases, each of the environmental components is labeled using the following syntax: environmental category — project phase — sequence number (e.g. Item #2 in Table 2 is labeled as PC-C-1, which stands for physical/chemical category, construction phase and first in the sequence of the group PC-C, respectively). In this study, there are 7, 8 and 14 environmental components in the physical/chemical, biological/ecological and social/cultural categories, respectively.

The economics/operational category has 3 components that focus only on major economic considerations during the operation phase. Similar to most infrastructure projects in the Philippines, the comprehensive study of the economic aspect was separately carried out by the Department of Public Works and Highways (DPWH) (2001), which ensured that the projects, when implemented, can provide the desired economic benefits within the covered areas. In addition, the projects in this study are in part funded through overseas development assistance, which reduces the burden of project cost.

The RIAM method has provisions for the semi-quantitative evaluation of environmental components using a set of standardized assessment criteria. Unlike the simple checklist approach described in Section 1, the evaluation of the assessment criteria in RIAM is clearly explained by a standard scaling procedure (Pastakia and Jensen, 1998). The assessment criteria are categorized into 2 groups, namely group *A* and group *B*. The *A* group consists of the Importance Criterion (*A1*) and Magnitude Criterion (*A2*), while the *B* group consists of the Permanence Criterion (*B1*), Reversibility Criterion (*B2*) and Cumulative Criterion (*B3*). The scale values of *A1* and *A2* and the impact description of each scale are shown in Table 3. The range of scales of *A1* is from 0 to 4 while the range of scales of *A2* is from −3 to 3. In the *B* group, as shown in column I of Table 4, the range of scales of each criterion is from 1 to 3, where the scale value of 1 denotes *no change/not applicable*. The impact descriptions of the scale values 2 and 3, however, vary between *B1*, *B2* and *B3* (Pastakia and Jensen, 1998).

The values of the assessment criteria of groups *A* and *B* are determined either by using the experience and intuition of the assessing team, or by referring to empirical evidences (if available), such as those acquired from experiments or from generally known past experiences. The descriptions of the scales as shown in Tables 3 and 4 serve as guidelines for the appraisal of each assessment criterion.

Table 3
Assessment criteria of Group *A* (Pastakia and Jensen, 1998).

Assessment criteria	Scale	Description
A1 (importance of conditions)	4	Important to national/international interests
	3	Important to regional/national interests
	2	Important to areas immediately outside the local condition
	1	Important only to the local condition
	0	No Importance
A2 (magnitude of change)	3	Major positive benefit
	2	Significant improvement in status quo
	1	Improvement in status quo
	0	No change/status quo
	−1	Negative change to status quo
	−2	Significant negative disbenefit or change
	−3	Major disbenefit or change

These descriptions however, are vague and may have various interpretations depending on the assessing individual. The worth of the environmental scores can be compromised if the bases or references used in the appraisal are not consistently applied in the assessment of the projects. These bases (or references) were decided upon by the assessing team prior to the appraisal of each criterion of groups *A* and *B*. In this study, the assessment criteria in Tables 3 and 4 are further explained using the following descriptions:

a) Assessment criterion *A1* (Importance of conditions): Pastakia (1998) defined *A1* as the measure of importance of a project within a specified spatial boundary. In this study, prior to the appraisal of *A1*, the spatial boundaries were decided upon by the assessing team using the study area and the administrative boundaries as reference. For instance, the term "local condition" (when $A1 = 1$) refers to the environmental condition confined within the boundary of the drainage area (as shown in Fig. 1). This drainage area encompasses 3 municipalities (i.e. Valenzuela City, Obando and Meycauayan City). The area that is "immediately outside the local condition" (when $A1 = 2$ in Table 3) refer to the parts outside the drainage area, but within the boundaries of the 3 municipalities. The term "regional" (when $A1 = 3$ in Table 3) refers to the administrative regions that cover the 3 municipalities hosting the proposed projects (i.e. Metro Manila and Region III). The term "national" (when $A1 = 4$ in Table 3) extends to the boundaries of the Philippine territory.
b) Assessment criterion *A2* (Magnitude): Pastakia (1998) defined *A2* as a "measure of scale of benefit/dis-benefit of an impact or a condition". The "measure of scale" (or *significance*) typically depends on the expert judgment of the assessing team, which could be based on calculable environmental thresholds or perceived magnitude of impact. Take for example the assessment of river water quality in terms of dissolved oxygen. If a project is predicted (or perceived) to cause a slight (or temporary) depletion of dissolved oxygen, the corresponding magnitude is *negative change* (or $A2 = -1$). If the project however, is predicted to substantially cause the depletion of dissolved oxygen (but still within the permissible limit), the corresponding magnitude is *significant negative change* (or $A2 = -2$). If the project will cause the depletion of the dissolved oxygen below the permissible limit, then the corresponding magnitude is *major negative change* ($A2 = -3$). Each environmental component may have several indicators for the identification of magnitude. The indicator with the worst/best magnitude is taken as the basis for the environmental component being assessed. For example, the construction of Dike-1 will not affect the concentration of heavy metals on the river, but will temporarily affect turbidity due to soil disturbance. Turbidity is thus favored as the magnitude indicator for water quality instead of heavy metals. The same principle is applied on the positive scales with focus instead on environmental improvement.
c) Assessment criterion *B1* (Permanence): Pastakia (1998) defined *B1* as the "measure of the temporal status of the condition". This determines whether the impact of a project is temporary or permanent. For example, the construction of dike rip raps in Dike-1 is considered permanent, while the noise that will be generated during its construction is a temporary condition.
d) Assessment criterion *B2* (Reversibility): Pastakia (1998) defined *B2* as the "measure of control over the effect of a condition". It was pointed out that *B2* should not be confused or equated with *B1*. For example, the removal of soil during open channelization is permanent but its effect on the nearby aquatic habitat is reversible.
e) Assessment criterion *B3* (Cumulative): Pastakia (1998) described *B3* as the "measure of whether the effect will have a single direct impact or whether it will be a cumulative effect over time, or a synergistic effect with other conditions". This criterion is used to judge the compounding effects of a condition. For instance, the open channels, over long periods of non-flow, will stagnate resulting in poor water quality, which can also be a source of disease causing vectors. The effect is said to be "cumulative", thus the assessment criterion *B3* should carry a scale value of 3 according to Table 4.

To clearly represent the image of "no change" or "not applicable" in the evaluation of the *B* criteria, the impact descriptor *no change/not applicable* is re-assigned to the scale value 0, while the scale value of 1 takes a new impact descriptor *negligible change*, as shown in column II of Table 4. The impact descriptor *negligible change* is proposed in this study to make a distinction between non-significant impacts and significant impacts, which is not clearly delineated in the original procedure. As pointed out by Kuitunen et al. (2008), the evaluation of the *B* criteria

Table 4
Assessment criteria of Group *B* showing the original (Pastakia and Jensen, 1998) and slightly modified scales of each criteria.

Assessment criteria	I Original		II Slightly modified	
	Scale	Description	Scale	Description
B1 (permanence)			0	No change/not applicable
	1	No change/not applicable	1	Negligible change
	2	Temporary	2	Temporary
	3	Permanent	3	Permanent
B2 (reversibility)			0	No change/not applicable
	1	No change/not applicable	1	Negligible change
	2	Reversible	2	Reversible
	3	Irreversible	3	Irreversible
B3 (cumulative)			0	No change/not applicable
	1	No change/not applicable	1	Negligible change
	2	Non-cumulative/single	2	Non-cumulative/single
	3	Cumulative/synergistic	3	Cumulative/synergistic

becomes difficult when the significance of impacts "seems to vary and whose characteristics also vary", necessitating the need for disambiguation. In this study, to address the ambiguity of varying impact significance (particularly in the assessment of the *B* criteria) the impact descriptor *negligible change* (which represents non-significance) is included in the evaluation options. The modifications mentioned above are intended to enhance the transparency of the RIAM method.

Using the scales determined in each of the assessment criteria, the environmental score (*ES*) is calculated using the simple formula (Pastakia and Jensen, 1998):

$$ES = [A1 \times A2] \times [B1 + B2 + B3]. \quad (1)$$

The environmental score is used to classify the impact in terms of the degree of change represented by range bands as defined by Pastakia and Jensen (1998). Table 5 shows the range bands with the corresponding range of environmental scores and impact descriptions. For example, an environmental component with a computed environmental score of 38 would fall within the range band [+D]. However, in response to the slight modification made in the original assessment criteria in Table 4, the range bands were slightly revised to replace [N] with [NI] and [NC], where [NI] stands for no identified impact and [NC] for negligible change. Both [NI] and [NC] have an environmental score of 0. The difference between [NI] and [NC] is that the range band [NI] is given when all the scale values of the assessment criteria are zero, while the range band [NC] is applied when there is at least one non-zero scale value in any of the assessment criteria. Consequently, this enhances the efficiency of the evaluation process by allowing the identification of the range band [NI] for an environmental component with *no perceived impacts* (symbol "X") in Table 2 prior to the actual implementation of the RIAM technique. To illustrate, with reference to Table 2, Dike-1 has no impact on Item #2 (PC-C-1), hence, the scale values of all the assessment criteria automatically take the value of zero, and equivalently, a range band of [NI].

4. EIA using the rapid impact assessment matrix technique

Table 6 shows the summary of the RIAM analysis of Dike-1, Dike-2, Channel-1 and Channel-2 showing the appraisal of the assessment criteria, the calculated environmental scores and the corresponding range bands. To illustrate how the range bands were determined using the slightly modified RIAM, consider the impact assessment of Dike-1 at Item #3 (PC-C-2) in Table 6, which represents the impacts on local geology and potential soil erosion in Table 2. Dike-1 was evaluated to determine the impacts of its activities on the environmental component PC-C-2 (which stands for physical/chemical environmental component; construction phase; and specifically, geological and soil aspects in Table 2) during the construction phase. The activities involved in Dike-1 are: construction of masonry wall, installation of ripraps, and improvement of river bank configuration to enhance the river capacity. Its specific activities, particularly site clearing, riverbed excavation and river bank incision, based on the feasibility study may temporarily cause soil erosion along the Meycauayan River. The activities in Dike-1 will cover a length of 4.9 km along the lower section of Meycauayan River, encompassing several municipalities and subdrainage areas. These activities, however, are confined only along the main river channel, thus $A1 = 1$, indicating PC-C-2's extent of importance; $A2 = -2$, since the perceived magnitude of change will generate significant primary (increase of total suspended solids in the river stream) and secondary negative impacts (deposition of eroded soil along the river downstream, which may also affect the mangrove areas); Then $B1 = 2$, since the condition that will be caused by Dike-1's activities is only temporary; $B2 = 2$, since the negative impacts of Dike-1 activities can be considered reversible; and $B3 = 3$, since silts from eroded river banks may accumulate downstream. Hence, using Eq. (1), $ES = -14$. Using Table 5, the environmental score falls within the range band [−B], which means that Dike-1 will probably cause negative impacts on PC-C-2 during the construction phase.

Another example is the assessment of Channel-2 against the environmental component BE-C-1 (Aquatic habitat). Emergent aquatic vegetation contributes to water quality and nutrient cycling that is vital to any estuary. The removal of riparian vegetation in some portions of the Meycauayan River and along the alignment of the new open channel in Barangay Tawiran and Barangay Paco could result in reduced inputs of leaves and twigs, which are important as a food base for some aquatic organisms, and may contribute to the increased in-channel photosynthesis. These changes can shift the aquatic ecosystem from a heterotrophic to an autotrophic state, at least for the adjacent streams and spawning grounds in Meycauayan and Obando. Such impacts would have a localized ($A1 = 1$), medium intensity ($A2 = -2$), medium term/temporary ($B1 = 2$) impacts. To mitigate these impacts, several bank protection methods that incorporate vegetation can be carried out. Essentially, these designs have the same environmental benefits as vegetative designs. Four of the most widely used and successful of these techniques are erosion control matting, cellular concrete blocks, seeded soil-covered riprap, and stem-sprouting woody plants in combination with engineering materials; another option is through replanting of mangroves and nipas along the riverbanks. For inland vegetation, buffer zones should be established along the naked open channel where the use of native or endemic trees is highly recommended, thus the impact is reversible ($B2 = 2$) and negligibly cumulative ($B3 = 1$). Using Eq. (1), $ES = -10$, which is equivalent to range band [−B] according to Table 5.

The study was carefully carried out by a team of EIA practitioners and researchers that have a combined experience of more than 10 years in the preparation of feasibility studies and environmental impact assessment of SFMM in the Philippines. The main assessing team is composed of the authors and experienced EIA consultants. The authors are academics and experts in the field of hydrology and water resources management. The EIA consultants include a civil/environmental engineer, hydrogeologist, aquatic/marine and terrestrial biologist, air and water quality specialist, and social development specialist (urban planner). Using the modified procedures of the RIAM method described in Section 3, Table 6 was created using collected information from actual field investigation and secondary data. The actual field investigation included environmental surveys (i.e. water quality, sediment quality, air quality and terrestrial surveys) and social (stakeholder perception) surveys. Other socially relevant concerns were acquired through focus group discussions participated by key stakeholders (composed of community leaders, government representatives, academics and residents

Table 5
Conversion table of environmental scores to range bands (Pastakia and Jensen, 1998) with slight modification.

Range bands	Environmental scores	Description
+E	+72 to +108	There will be a major positive change or impact
+D	+36 to +71	There will be a significant positive change or impact
+C	+19 to +35	There will be a moderate positive change or impact
+B	+10 to +18	There will be positive change or impact
+A	+1 to +9	There will be a slight positive change or impact
NI	0	No identified impact (A1, A2, B1, B2 and B3 have zero scores)
NC	0	Negligible change (At least one assessment criterion is non-zero)
−A	−1 to −9	There will be a slightly negative change or impact
−B	−10 to −18	There will be a negative change or impact
−C	−19 to −35	There will be a moderate negative change or impact
−D	−36 to −71	There will be significant negative change or impact
−E	−72 to −108	There will be a major negative change or impact

Table 6
RIAM analysis and results of the selected planned structural flood mitigation measures in Metro Manila.

Item no.	Code	Structural flood mitigation measures																											
		River improvement works at the lower section of the Meycauayan River (Dike-1)							River improvement works at the upper section of the Meycauayan River (Dike-2)							Diversion channel between the Polo River and the Palasan River (Channel-1)							Small open channel near the lower reaches of the Meycauayan River (Channel-2)						
		RIAM analysis							RIAM analysis							RIAM analysis							RIAM analysis						
		A1	A2	B1	B2	B3	ES	RB	A1	A2	B1	B2	B3	ES	RB	A1	A2	B1	B2	B3	ES	RB	A1	A2	B1	B2	B3	ES	RB
1	PC-P-1	0	−1	2	2	1	0	NC	0	−1	2	2	1	0	NC	0	−1	2	2	1	0	NC	0	−1	2	2	1	0	NC
2	PC-C-1	0	0	0	0	0	0	NI	0	0	0	0	0	0	NI	1	−2	3	3	1	−14	−B	0	0	0	0	0	0	NI
3	PC-C-2	1	−2	2	2	3	−14	−B	1	−2	2	2	3	−14	−B	1	−2	2	2	1	−10	−B	1	−2	2	2	1	−10	−B
4	PC-C-3	4	0	2	2	1	0	NC	4	0	2	2	1	0	NC	4	0	2	2	1	0	NC	4	0	2	2	1	0	NC
5	PC-C-4	1	2	3	2	1	12	+B	1	2	3	2	1	12	+B	0	0	0	0	0	0	NI	0	0	0	0	0	0	NI
6	PC-O-1	1	−1	2	2	1	−5	−A	1	−1	2	2	1	−5	−A	0	0	0	0	0	0	NI	0	0	0	0	0	0	NI
7	PC-O-2	2	3	3	2	1	36	+D	2	3	3	2	1	36	+D	1	3	3	2	1	18	+B	1	3	3	2	1	18	+B
8	BE-C-1	1	−2	2	2	1	−10	−B	1	−2	2	2	1	−10	−B	0	0	0	0	0	0	NI	1	−2	2	2	1	−10	−B
9	BE-C-2	1	−1	3	3	1	−7	−A	1	−1	3	3	1	−7	−A	0	0	0	0	0	0	NI	1	−1	3	3	1	−7	−A
10	BE-C-3	1	−2	3	2	0	−10	−B	1	0	2	2	3	0	NC	0	0	0	0	0	0	NI	0	0	0	0	0	0	NI
11	BE-C-4	1	−1	2	2	3	−7	−A	1	−1	2	2	3	−7	−A	1	−1	2	2	3	−7	−A	1	−1	2	2	3	−7	−A
12	BE-C-5	0	0	0	0	0	0	NI	0	0	0	0	0	0	NI	1	−1	2	3	1	−6	−A	1	−1	2	3	1	−6	−A
13	BE-C-6	1	−1	2	1	3	−6	−A	1	−1	2	1	3	−6	−A	1	−1	2	1	3	−6	−A	1	−1	2	1	3	−6	−A
14	BE-O-1	1	1	3	2	1	6	+A	1	1	3	2	1	6	+A	1	0	3	2	1	0	NC	1	0	3	2	1	0	NC
15	BE-O-2	1	1	3	2	1	6	+A	1	1	3	2	1	6	+A	1	0	3	2	1	0	NC	1	−1	3	2	1	−6	−A
16	SC-P-1	2	−2	3	3	1	−28	−C	2	−3	3	3	1	−42	−D	2	−3	3	3	1	−42	−D	2	−2	3	3	1	−28	−C
17	SC-P-2	0	0	0	0	0	0	NI	0	0	0	0	0	0	NI	1	−1	3	3	0	−6	−A	1	−3	3	3	0	−18	−B
18	SC-C-1	1	−1	2	1	2	−5	−A	1	−1	2	1	2	−5	−A	1	−1	2	1	2	−5	−A	1	−1	2	1	2	−5	−A
19	SC-C-2	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A
20	SC-C-3	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A
21	SC-C-4	2	1	2	1	1	8	+A	2	1	2	1	1	8	+A	2	1	2	1	1	8	+A	2	1	2	1	1	8	+A
22	SC-C-5	2	0	2	1	1	0	NC	2	0	2	1	1	0	NC	2	0	2	1	1	0	NC	2	0	2	1	1	0	NC
23	SC-C-6	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A
24	SC-C-7	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A
25	SC-C-8	0	−1	2	1	1	0	NC	0	−1	2	1	1	0	NC	0	−1	2	1	1	0	NC	0	−1	2	1	1	0	NC
26	SC-C-9	1	1	2	1	1	4	+A	1	1	2	1	1	4	+A	1	1	2	1	1	4	+A	1	1	2	1	1	4	+A
27	SC-C-10	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A	1	−1	2	1	1	−4	−A
28	SC-O-1	2	3	3	1	1	30	+C	2	3	3	1	1	30	+C	1	−2	2	2	0	−8	−A	1	−2	2	2	0	−8	−A
29	SC-O-2	2	3	3	1	1	30	+C	2	3	3	1	1	30	+C	1	3	3	1	1	15	+B	1	3	3	1	1	15	+B
30	EO-O-1	1	1	3	1	1	5	+A	1	1	3	1	1	5	+A	1	1	3	1	1	5	+A	1	1	3	1	1	5	+A
31	EO-O-2	1	3	3	1	1	15	+B	1	3	3	1	1	15	+B	1	3	3	1	1	15	+B	1	3	3	1	1	15	+B
32	EO-O-3	2	3	3	1	1	30	+C	2	3	3	1	1	30	+C	2	3	3	1	1	30	+C	2	3	3	1	1	30	+C
	No. of RB (−)							15							14							15							16
	No. of RB (+)							9							9							7							7

within the study area). Other information were acquired from the unpublished studies of SFMM under the flood control projects of the Department of Public Works and Highways; reports from internationally funded studies along the study area; and socio-economic profiles of local government units, as well as from the interviews of relevant government agencies and municipal offices.

5. Results and discussion

Negative impacts often require serious attention from planners and decision-makers, since these eventually become the backbone of environmental management and monitoring plans, and sometimes the basis for the acceptance or rejection of a proposed project (Lohani et al., 1997). In this section, more attention is given on the examination of negative impacts, with focus on the environmental categories (i.e. physical/chemical, biological/ecological, social/cultural and economics/operational categories) and project phases. Basic suggestions for the reduction of negative impacts are offered whenever deemed necessary and applicable. According to Table 6, the assessment criteria (*A1*, *A2*, *B1*, *B2* and *B3*) were evaluated and the environmental scores were calculated to determine the range band of each environmental component affected by the 4 planned structures (i.e. Dike-1, Dike-2, Channel-1 and Channel-2). The item numbers in Table 6 correspond to the description of environmental components in Table 2. For example, Item #1 (PC-P-1) in Table 6 corresponds to description "Land/soil disturbance due to site clearing" in Table 2.

5.1. Physical/chemical category

In Table 6, under the physical/chemical category, the lowest scores and corresponding range bands of Dike-1, Dike-2, Channel-1 and Channel-2 are (−14,[−B]), (−14,[−B]), (−14,[−B]) and (−10,[−B]), respectively, which mainly occur in Item #4 (PC-C-2), except for Channel-1, which occurs in Item #2 (PC-C-1). This indicates that all of the seriously adverse impacts on the physical/chemical category, particularly with regard to the local geology and soil erosion Item #3 (PC-C-2), will occur during the construction phase. The range band of Channel-1with regards to the change in land use during the construction phase (Item #2, PC-C-1) is [−B], which indicates that substantial change will occur, and that there may be secondary consequences on the biological/ecological and social/cultural categories.

The range band of the dike structures concerning the surface and groundwater hydrology (Item #6, PC-O-1) is [−A], while the open channel structures have the range band [NI]. The main reason for this difference is that the interlocking revetments, which will be constructed in the dike structures, will partly interrupt the exchange between the surface water and groundwater. However, the impact is considered to be of low intensity since the exchange will continue through the river bed.

With regard to other impacts on land/soil disturbance (Item #1, PC-P-1) and water quality (Item #4, PC-C-3), the effects are surmised to be negligible (range band [NC]), indicating that any of these structures will not pose any severe impacts on those environmental components within the study area. Significantly high positive range band [+D] occurs in Item #7 (PC-O-2) for Dike-1 and Dike-2, which indicates that the hydraulic conditions of the Meycauayan River will substantially be improved when the dike structures are completed.

5.2. Biological/ecological category

Under the biological/ecological category, the lowest scores and corresponding range bands of Dike-1, Dike-2, Channel-1 and Channel-2 are (−10, [−B]) on Item #8 (BE-C-1) and Item #10 (BE-C-3); (−10, [−B]) on Item #8 (BE-C-1); (−7, [−A]) on Item #11 (BE-C-4) and (−10, [−B]) on Item #8 (BE-C-1), respectively. These results indicate that the most adverse impacts in the biological/ecological category, particularly on the aquatic habitat (Item #8, BE-C-1), will occur during the construction phase. Presence of riparian species (Item #10, BE-C-3) were observed along the proposed location of Dike-1 in the Meycauayan River, thus would result to a negative impact. If the removal of mangroves cannot be prevented, the negative impact of Dike-1 can be reduced by replanting equivalent riparian species in other viable sections of the river (for example, at the right bank).

The range band [+A] occur only for Dike-1 and Dike-2 on Item #14 (BE-O-1, aquatic habitat) and Item #15 (BE-O-2, surface water quality), which indicates that the operation of the dike structures will slightly bring benefits to the river environment in the ecological sense. On the other hand, the operation of the open channels will not experience substantial change, as indicated by the range band [NC]. However, slight negative impact [−A] in Channel-2 may occur due to the decay of inundated vegetation and water stagnation (non-flow of water) during the dry seasons that would further diminish the quality of the surface water due to eutrophication (Huang et al., 2003; Kneis et al., 2009).

5.3. Social/cultural category

Under the social/cultural category, the lowest scores and range bands of Dike-1, Dike-2, Channel-1 and Channel-2 are (−28, [−C]), (−42, [−D]), (−42, [−D]) and (−28, [−C]), respectively. These results show that among the 4 environmental categories, the planned structures will generate the most severe impacts [−D] in the social/cultural category, which will occur particularly in Item #16 (SC-P-1, involuntary resettlement). This indicates that the displacement of settlers along the affected areas is a highly sensitive issue that requires serious attention to address just compensation, and allocate ample resources (Lohani et al., 1997) for resettlement. Tamura et al. (1994) emphasized that consensus with the regional inhabitants must be obtained before any project is realized to avoid serious problems afterwards.

With regard to significant negative impacts, the range bands in Item #16 (SC-P-1) show that Dike-2 and Channel-1 have more severe impacts than Dike-1 and Channel-2, which is primarily due to the higher density of settlers residing directly along Dike-2 and Channel-1, as confirmed during the site survey. Other negative impacts (i.e. [−A] and [−B]) during the pre-construction phase may occur on Item #17 (SC-P-2, public acceptance), but only for the planned open channels as a result of the general public's fears due to the lack of understanding on the project's benefits and negative impacts. The negative impacts however, may be resolved through proper information and education campaign.

During the construction phase, several slightly negative impacts (range band [−A]) will occur, particularly in Item #18 (SC-C-1, air quality), Item #19 (SC-C-2, noise level), Item #20 (SC-C-3, population dynamics), Item #23 (SC-C-6, health and safety of workers), Item #24 (SC-C-7, health and safety of public) and Item #27 (SC-C-10, public utilities and infrastructures). The negative impacts in Item #18 (SC-C1) and Item #19 (SC-C-2) are manageable as long as the contractors operate their equipment in compliance with the local environmental standards. With regard to Item #20 (SC-C-3), the expected impacts are only temporary, which may improve after the SFMM are completed. The negative impacts that will occur on Item #23 (SC-C-6), Item #24 (SC-C-7) and Item #27 (SC-C-10) can be addressed by requiring the contractors to prepare and strictly adhere to their construction safety procedures.

During the operation phase, positive impacts ([+B] and [+C]) are generally anticipated, however, slightly negative impact may occur on Item #28 (SC-O-1, natural environmental and health hazards) during the operation of open channel structures. As mentioned above, water stagnation may occur in the open channel structures, which in turn may become the breeding ground for disease-carrying vectors (such as dengue-carrying mosquitoes) since the incidence of dengue has been reportedly quite prevalent around the study area (Department of Health, DOH, 2008). These hazards, imposed by the open channel structures, may be reduced by ensuring the constant flow of surface water either by engineering design or by operational means.

5.4. Economics/operational category

Finally, under the environmental/operational category, no negative impact was identified, since it is believed that the SFMM will contribute significantly in the regional economy influenced by the study area. The highest score ($ES = 30$) with range band [+C] occurs in Item #32 (EO-O-3, local revenue and economy), which strongly supports the presumption of the positive contributions of the planned structures. The cost of implementation was not included in the assessment since, as mentioned in Section 3, the planned structures are the alternatives found economically feasible for flood mitigation in the study area. This creates the presumption that the cost of implementation (without the mitigation measures to reduce the negative impacts) can be shouldered by the budget provided by the national government.

5.5. General analysis

As a whole, the total of the negative and positive range bands of Dike-1, Dike-2, Channel-1 and Channel-2 are (15,9), (14,9), (15,7) and (16,7), respectively (shown in Table 6). The relatively close values of these sums indicate that there is not much difference in the number of positive and negative impacts among the 4 planned SFMM. However, to further examine the positive and negative impacts of the 4 planned structures, the sum of environmental scores were calculated for the physical/chemical, biological/ecological, social/cultural and economics/operational as shown in Table 7. As seen in this table, there exists a clear gap between the positive impacts of the dike structures (Dike-1 and Dike-2) and the open channel structures (Channel-1 and Channel-2). The dike structures are generally more desirable compared to the open channel in terms of the physical/chemical, biological/ecological and social/cultural categories, while the economics/operational category generates the same cumulative scores. On the other hand, the cumulative scores of the negative impacts do not show any clear conclusion as to which structure will generate more severe impacts. The results in the social/cultural

Table 7
Summary of the summed environmental scores of the structural flood mitigation measures.

Structural flood mitigation measures	Cumulative positive environmental scores				Cumulative negative environmental scores			
	PC	BE	SC	EO	PC	BE	SC	EO
Dike-1	48	12	72	50	−19	−40	−53	0
Dike-2	48	12	72	50	−19	−30	−67	0
Channel-1	18	0	27	50	−24	−19	−81	0
Channel-2	18	0	27	50	−10	−42	−79	0

PC, physical/chemical; BE, biological/ecological; SC, social/cultural; EO, economy/operational.

category, however, indicate that open channel structures are less socially desirable compared to the dike structures.

To compare further the impacts of the 4 planned structures in terms of the environmental categories, a histogram was created to represent the impact profiles as shown in Fig. 2. By inspection, [−A] is the most numerous range band in all the 4 planned structures (dominated by the social/cultural category), while [−E] and [+E] are not present in any of the proposed projects. Negative impacts are much more numerous than the positive impacts, however, most of the negative impacts are within the range band [−A]. The positive impacts on the other hand are fairly distributed in the scale of positive range bands. Generally, the impact profiles of Dike-1 and Dike-2 are very similar to each other. Likewise, the impact profiles of Channel-1 and Channel-2 are also very similar, which implies that similar types of structural flood mitigation projects will likely generate the same impacts provided that the environmental conditions are also similar (such as in the case of co-located projects).

To examine the impacts of the planned structures used in this study in terms of the project phases, a histogram was created as shown in Fig. 3. By closer inspection, the most number of negative impacts occur during the construction phase, while the least number of negative impacts take place during the pre-construction phase. The most severe impacts however, are generated during the pre-construction. Most of the positive impacts occur during the operation phase, and some even occur during the construction phase, which indicates that upon completion, the planned structures will generally benefit the environment, which indicates that implementation of the 4 planned structures will in the long run provide benefits to both the human and ecological environments.

The entirety of the EIA examination in this study shows that the evaluation process using the RIAM technique has gone much farther than the simple EIA techniques being used in the Philippines in the past. This method of assessment has improved the impartiality of the EIA process, particularly in the use of subjective judgments, to achieve more meaningful results. The bases of the assessment were made clearer and more transparent during the examination of the EIA conclusions. There is however a limitation when examining the cumulative effects of co-located (with the same study area) projects, since the procedure for this has not yet been developed in the RIAM. Subjectivity of judgment, however, may still persist when the availability of empirical evidence is not sufficient, thus relying on the experience and intuition of the assessor.

The assessment criteria in group *A* heavily affect the outcome of the Environmental Score. Take for example the scale values for the assessment criterion *A1* (Table 3). A value of zero may immediately mean that the project has no impact. Further, the descriptions referring to the spatial boundaries are quite vague (e.g. local condition, regional, etc.). It is thus necessary for the assessing team to define the spatial boundaries as a preliminary step prior to appraisal. It is also important to take caution when assigning a value of zero for both *A1* and *A2*.

For future studies, the application of the RIAM technique could be extended to soft-structural (e.g. mangrove re-forestation) and non-structural (e.g. early flood warning system) flood mitigation measures to achieve a more complete insight concerning the environmental impacts associated with flood mitigation. The soft structural and non-structural measures often serve as complement to the structural measures that reduce not only the consequences of flood risks, but also adverse impacts on the surrounding environment.

6. Conclusion

The case of the EIA of SFMM in Metro Manila has demonstrated the applicability of the RIAM technique as an alternative EIA method in the Philippines. The study also demonstrated the flexibility of the RIAM technique to cope with the modifications made to enhance the efficiency and transparency of the evaluation process, with particular reference to the slight modification of the assessment criteria in the *B* group and the integration of the project phases in the EIA examination process. The inclusion of the impact descriptor *negligible*

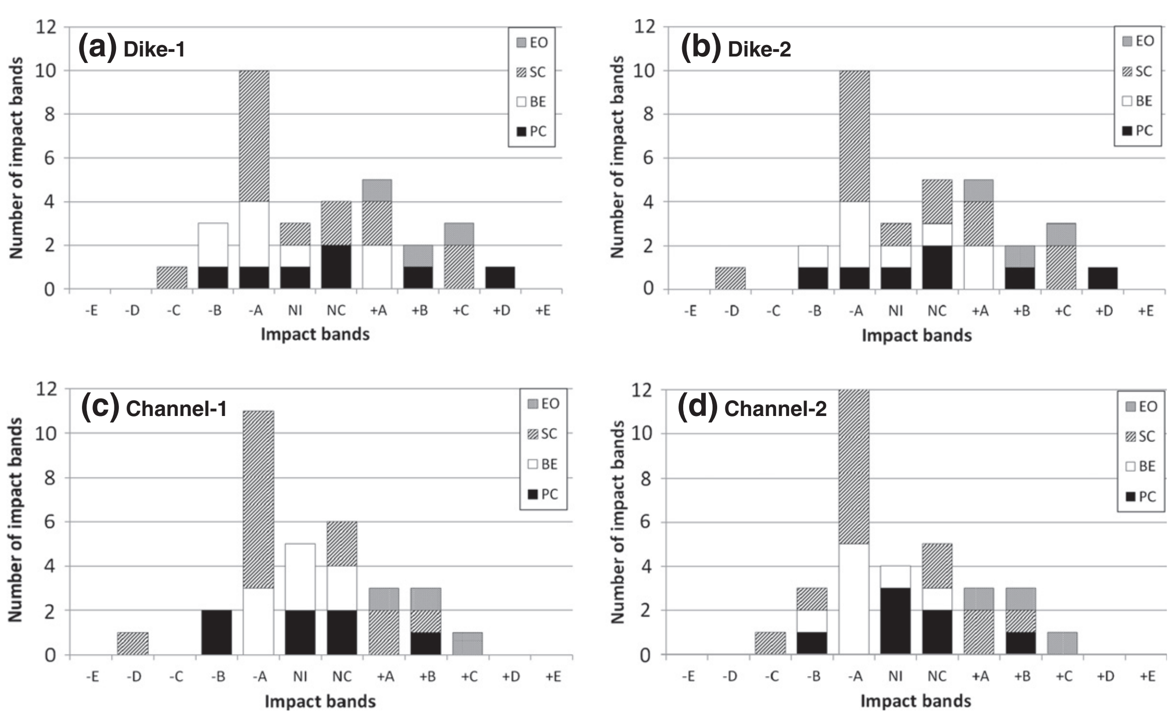

Fig. 2. RIAM histogram of the environmental categories for each structural flood mitigation measure (i.e. Dike-1, Dike-2, Channel-1 and Channel-2). The histograms represent the aggregated impacts of environmental components of each environmental category. The environmental categories are identified as follows: physical/chemical (PC), biological/ecological (BE), social/cultural (SC) and economics/operational (EO).

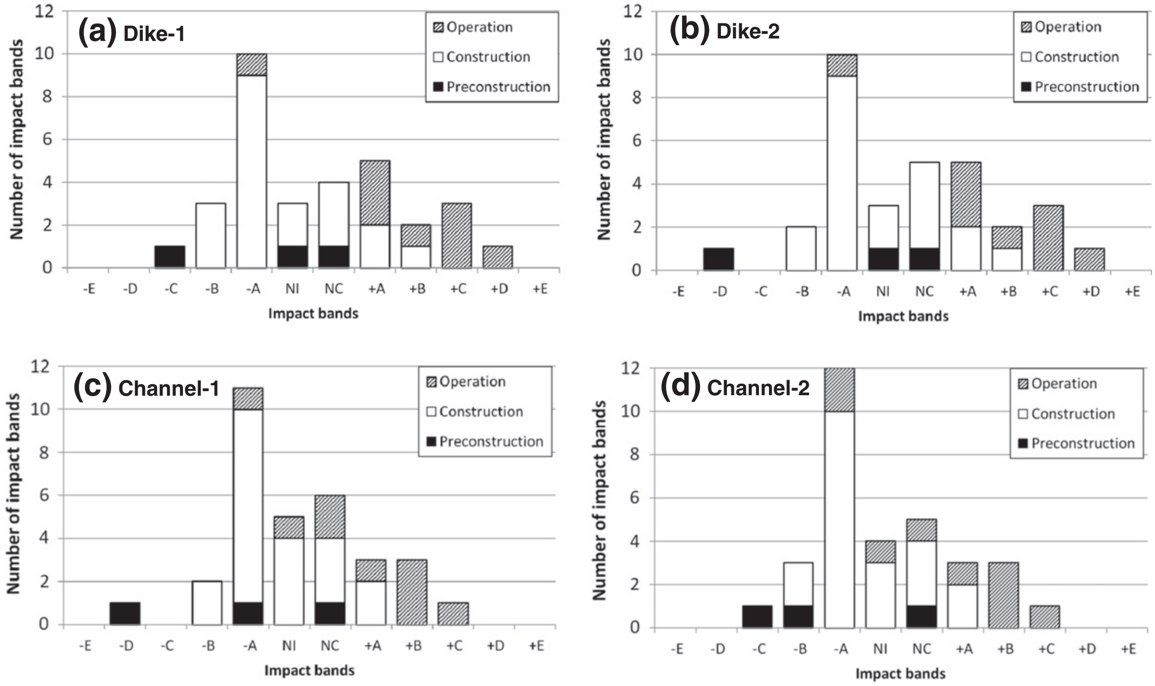

Fig. 3. RIAM histogram of the 3 project phases at each structural flood mitigation measure (i.e. Dike-1, Dike-2, Channel-1 and Channel-2). The histograms represent the aggregated impacts of environmental components during each of the project phase (i.e. pre-construction, construction and operation phases).

impact provided the means to distinguish the results that show "negligible impacts" with the results that indicated "no change". Essentially, the RIAM technique complements very well with the general EIA approach in the Philippines, making it highly viable for application in other project types. Subjective judgment however is still evident in the assessment process, but the combination of appraisal by quantitative scaling and estimation of the degree of impacts by means of the range bands presents an improvement compared with the traditional methods with regards to the impartiality of the entire EIA process. Another limitation of the RIAM technique is that it currently does not provide for the evaluation of aggregated impacts of co-located SFMM projects, which could perhaps be addressed by assigning weights on the importance and magnitude of each of the planned structure. In general, the EIA of SFMM by the RIAM technique provides a simple but very effective means to identify the significance of potential impacts in a very transparent manner, leading to clearer and more meaningful EIA conclusions. The results of this study may be useful in the improvement of the EIA practice in the Philippines.

Conflict of interest

The authors have no conflict of interest to declare.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version, at doi: http://dx.doi.org/10.1016/j.scitotenv.2013.03.063. These data include Google map of the most important areas described in this article.

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