What were the risks associated with the Jan. '13 flood hazard event in Jakarta, and what new risk-management strategies can the city implement in the future to reduce them?

Geography Extended Essay

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Abstract

Some are calling it the worst flood to afflict Jakarta since the turn of the millennium. When the flood disaster in January 2013 brought the city to a standstill, Jakartans wanted to know what factors could have contributed to this devastation. And following that, what could be done to prevent floods in the future.

Armed with knowledge in geography, this paper was developed to answer the following research question:

What were the risks associated with the January 2013 flood hazard event in Jakarta, and what new risk-management strategies can the city implement in the future to reduce them?

With such a vast topic, it was essential to focus the scope of the investigation so as to reach a manageable and reasonable conclusion. Research showed that neighborhoods in northwestern Jakarta were worst afflicted by the floods in January. Consequently, a detailed exploration of the area was launched, geographically analyzing the area for potential flood risk factors. Drawing from this analysis, as well as on the basis of expert opinions, it was concluded that Jakarta's vulnerability to floods stems from environmental factors, such as low-lying land and high rates of precipitation, along with land subsidence and waterways that are choking from waste.

In response to these risks, the city has already implemented some measures to mitigate the chances of floods, such as trash screens and expedited dredging, but these are not effective enough and do not address all the potential risks. Instead, this paper discusses some solutions that have not been attempted before, such as biopore infiltration holes, as well as some others that existed in the past and have since been damaged, such as mangrove forests. From their merits, it's clear that these simple solutions hold the key to mitigating complex flood risks.

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- Mrs. Barbara Wiemers, Jakarta International School
- Mr. Christopher McCann, Jakarta International School
- and last but not least, my advisor, Ms. Tannis Waugh, Jakarta International School

Thank you so much!

Contents

Introduction

Jakarta's notorious floods are a well-known phenomenon, threatening the city during the annual rainy season. The devastating floods that occurred here during January 2013 grabbed international headlines with reports that the disaster severely affected 30% of the population and left 103,000 people homeless (Craggs).

Jakarta is also a primate city – a megacity much larger than any other in Indonesia. The extremely rapid rate of development in the last decade means that Jakarta faces unique issues with regards to infrastructure and investment, which influences how floods are dealt with.

As an empathetic and inquisitive geographer, I decided to investigate Jakarta's flooding problem further. Focusing on the causes and possible methods to prevent them, this investigation is driven by the following research question:

What were the risks associated with the January 2013 flood hazard event in Jakarta, and what new risk-management strategies can the city implement in the future to reduce them?

Jakarta is no stranger to natural hazards, yet somehow the city seemed to have been caught off guard during that disastrous week. This paper will attempt to get a better understanding of exactly which risk factors played a role in making this specific flood so much more devastating than previous hazard events. Subsequently, this paper will evaluate the preparedness for future flood hazard events and suggest more effective risk-management policies.

The evaluation of possible future strategies could hold the answer to how Jakarta, or any other megacity, could best prepare itself for the next inevitable flood.

Figure 1- Photograph of severe flooding on January 18 at the Hotel Indonesia, Central Jakarta

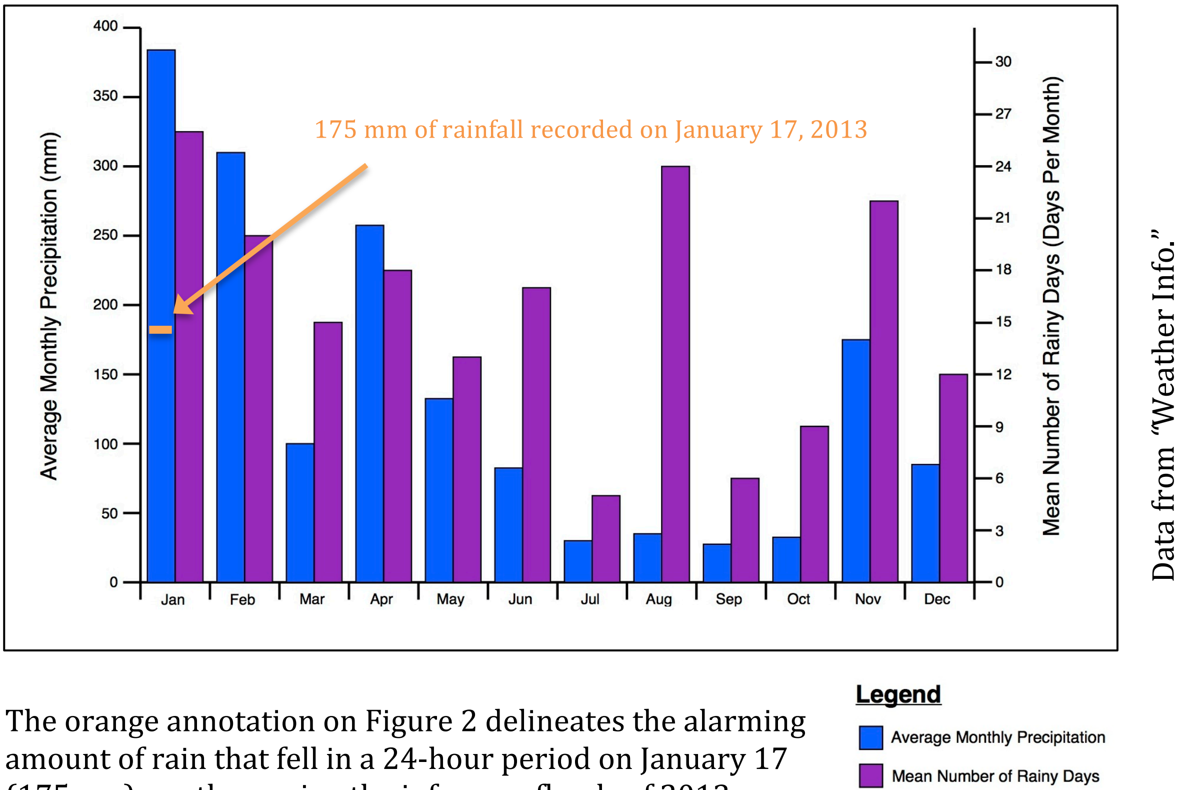
Source: Craggs

Background & Geographical Context:

There are several powerful geographical and climate factors that contribute to this city's perilous flooding.

Firstly, Jakarta suffers heavy rainfall for 7-8 months out of the year, receiving over 100mm of average monthly precipitation from November to May, Figure 2 ("Weather Info."). In particular, during January and February the capital sees 300-400mm of rainfall per month. In fact, during these two months the mean number of rainy days ranges from 20 to 26 ("Weather Info.").

Figure 2- Jakarta's climate indicated by monthly precipitation and mean number of rainy days



The orange annotation on Figure 2 delineates the alarming amount of rain that fell in a 24-hour period on January 17 (175mm), partly causing the infamous floods of 2013 (Jensen and Rahadiana).

Additionally, the metropolis is at a further disadvantage with regards to elevation above sea level. The highest regions in the city are the southern suburbs with an elevation of only 50m, as shown in Figure 3. On the other side of the city, almost 40% of the northern region lies entirely below the sea level (Berg).

One major consequence of this is that run-off water must traverse the entire city before reaching the sea. Jakarta's natural topography has resulted in 15 rivers and many more canals transporting water (along with sewage, solid waste etc.) to the sea (Sofiyah). These can be seen crisscrossing the city in Figure 3 and further below in Figure 5.

Figure 3- 3-dimensional map of Jakarta's elevation above sea level

Source: Hasan

In addition, the northern region must also contend with rising sea levels that inevitably come with the global climate change trend. Figure 4 explores the possible outcomes of various projections of rising sea levels. It is very important to note the dramatic increase in submerged land area between current sea level (Figure 4a) and a 3m increase (Figure 4b) because these are the areas that are immediately threatened by rising sea levels.

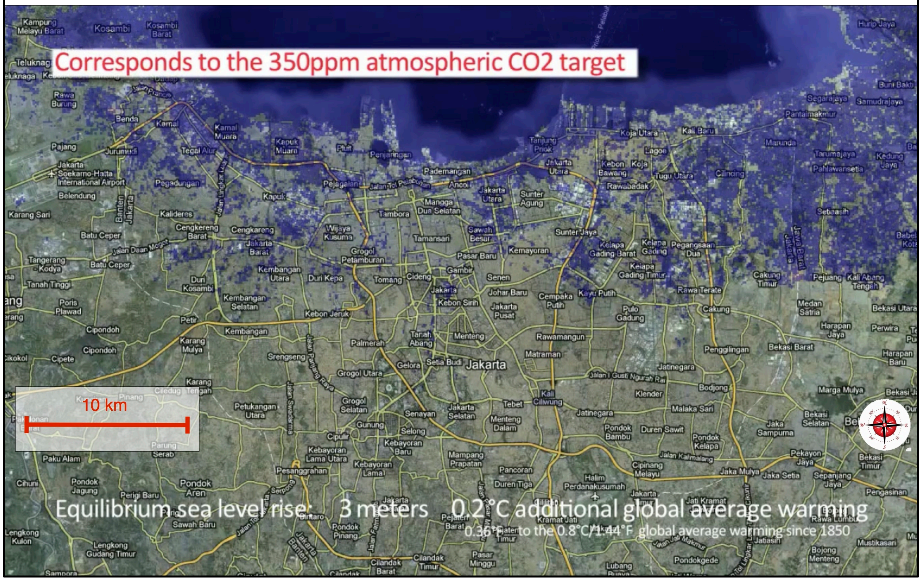
Legend: ■ Land area submerged by sea

Figure 4a- Map of northern coastal area at current sea level

Source: "Jakarta –Sea Level Rise"

Figure 4b Map of coastal area with projected 3m rise in sea level

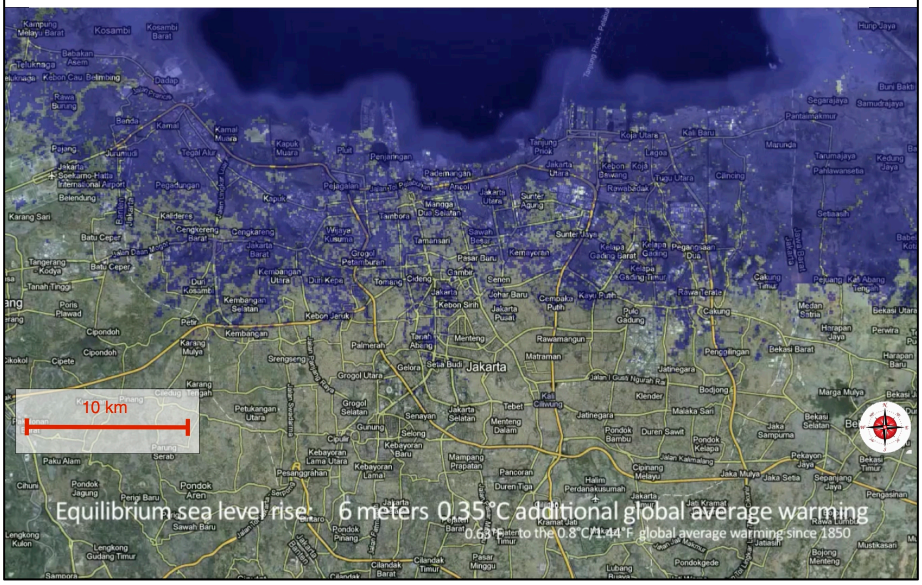
Areas at immediate risk



Source: "Jakarta –Sea Level Rise"

Figure 4c- Map of coastal area with projected 6m rise in sea level

Areas at risk in the future



Source: "Jakarta –Sea Level Rise"

The combination of high annual precipitation, large swaths of low-lying land and rising sea levels lay the groundwork for understanding the fundamental natural hazards that put Jakarta in dire danger.

Methodology

The first portion of this investigation is a comprehensive reconstruction of the January 2013 floods. This is needed to assess the extent of the disaster. Using publications by relevant government agencies, international organizations and NGOs, it was possible to spatially map the movement of floodwater during the disaster, from January 18-25. Additionally, some nearby places of interest, such as floodgates or reservoirs, were also annotated because they are pertinent to the evaluation of flood management systems.

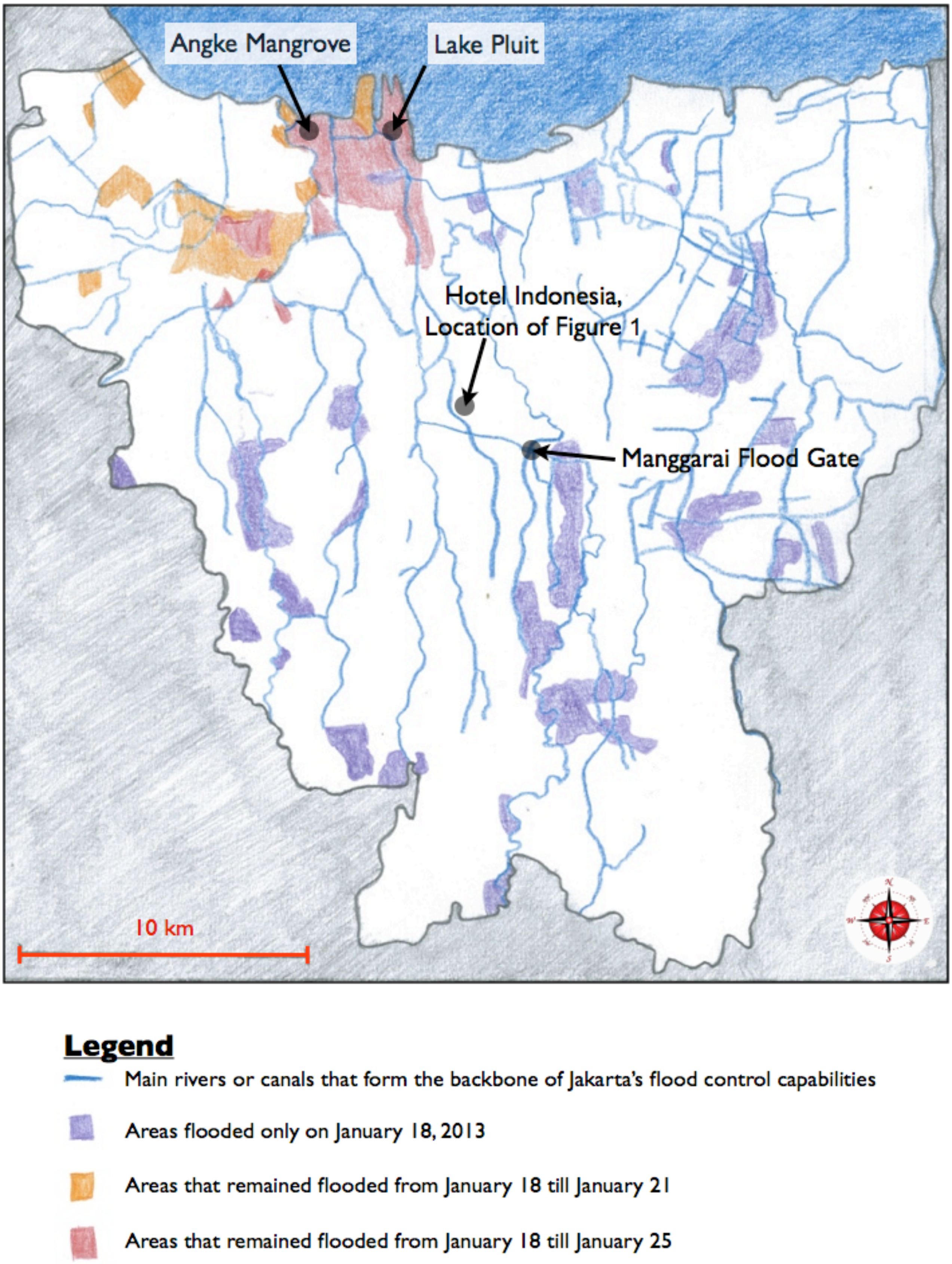
To gain a deeper understanding of the causes of floods in Jakarta, I conducted extensive research into specific risk factors that affect the city's vulnerability to flood hazard events. This extensive research began with in-depth interviews with two experts in flood management. The first interview I conducted was with Mr. Jurjen Wagemaker at HKV Consultants. He is an expert on water systems and his company advises the Indonesian National Disaster Management Agency (BNPB) and has developed flood-mapping software for them. The second interview I conducted was with Mr. Fook Chuan, a flood mitigation project manager at the World Bank. With recommendations from these interviews, I explored the current state of flood management systems in north Jakarta on October 16, 2013, taking pictures of what I found. I chose to focus my exploration to the area worst hit by the floods in January because the evidence I collect there would be most applicable to this specific flood. By analyzing these primary data/observations, I was able to explain the specific risk factors in Jakarta.

By systematically comparing each risk factor to the map of the flood disaster, this paper will show the extent to which these risk factors contributed to the floods of January 2013.

Further evaluation and added information from the same two interviews formed the basis for suggestions for future efforts to manage the city's vulnerability.

Reconstruction of the Flood in January

Figure 5 - Map of spatial distribution of floodwater overlaid on Jakarta's rivers and canals system (and various other annotations)



Compiled from *Sources:* Gengaje, Rep. no. 02; Gengaje, Rep. no. 03; Gengaje, Rep. no. 4

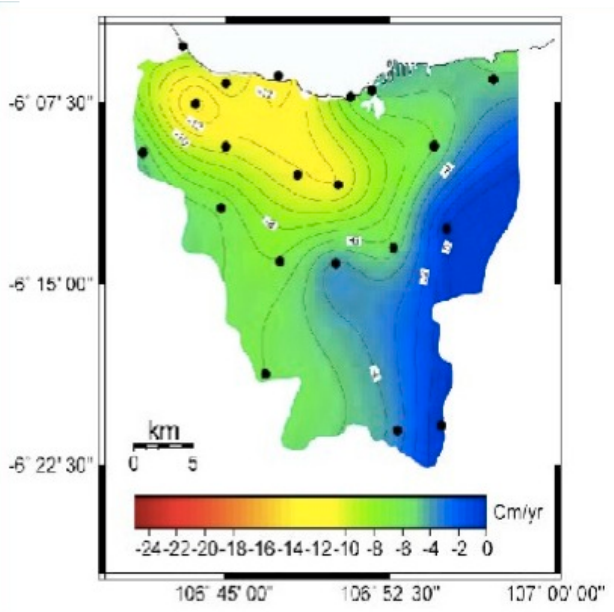
Figure 5 shows how the distribution of floodwater across the city and maps how the water moved over time. On January 18, the first day with available data, floodwater covered approximately 8% of the city's total land area (Gengaje, Rep. no. 02). The map shows a general trend of water draining from the east, central and parts of south Jakarta (areas in purple) as the rivers and canals served their purpose. The map also illustrates that the water moved downstream from these areas to the northwestern region of the city, where the water accumulated two days (areas in orange). The areas in red were severely flooded until January 25 – more than a week after the start of the disaster – as the massive amount of water from purple- and orange-colored areas drained. Overall, this map shows a general pattern of floodwater very slowing making its way to the northwest of Jakarta as the city struggled to cope with the disaster.

Flood Risk Factors in Jakarta

Subsidence in Jakarta

Subsidence is the gradual sinking of land, and is a phenomenon that severely affects Jakarta. According to JanJaap Brinkman, an expert hydrologist at a reputed water research institute, Jakarta is "one of the worst sinking cities in the world" (Berg). His paper on flood hazard mapping in Jakarta highlights subsidence as one of the major reasons that floods could be deeper and more disastrous, especially in the northern regions of the city (Brinkman and Hartman). Figure 6 shows the current rates of land subsidence in Jakarta. According to his study, Jakarta is sinking up to 12 cm per year, culminating in overall subsidence projections of 50 cm at best and an alarming 100 cm at worst by the year 2025 (Brinkman and Hartman). While the cause(s) behind this phenomenon have not yet been fully established some researchers have found a strong correlation between subsidence rates and groundwater level below Jakarta's surface. The correlation is strong enough that the paper suggests that the depletion of groundwater (due to pumping to meet the city's water needs) may be the cause behind such rapid subsidence in the urban area (Djaja et al). The theory is that "when the volume of groundwater decreases, the level of land surface above will be influenced" due to the compaction of soil supporting it (Djaja et al).

Figure 6 - Map of current land subsidence rates in Jakarta



Source: Brinkman and Hartman

In any case, one consequence of these worrying rates of subsidence is that when flood hazard events occur, the extent of damage is much greater. This is because the changes in topography result in more floodwater from surrounding regions to flow into the areas that have sunk the most, creating greater floodwater depths. Furthermore, shifting topography also means that the way water moves in rivers changes from year to year, resulting in uncertainty in flood forecasts because the flow of water is not predictable (Chuan Interview).

Influence of subsidence during the flood in January:
Comparative analysis shows that subsidence did indeed play a role during the flood in January. The subsidence rates in northern and northwestern Jakarta were found to be the highest, as shown in yellow in Figure 6. It is therefore not surprising that these same regions are colored red in Figure 5, indicating they were worst affected by the flood and remained inundated until January 25.

Having said that, Mr. Wagemaker acknowledges that subsidence is only part of story. "Yes, Jakarta is flooding because it's a low-lying area, there are large rivers, there's a high discharge [of run-off water] from the mountains – the precipitation in mountains is really very high and is measured in *meters* – so it's natural that it floods. It's worse because of subsidence. But if the government doesn't have [adequate] measures in place… then you have got a flood ***disaster***" (Wagemaker Interview).

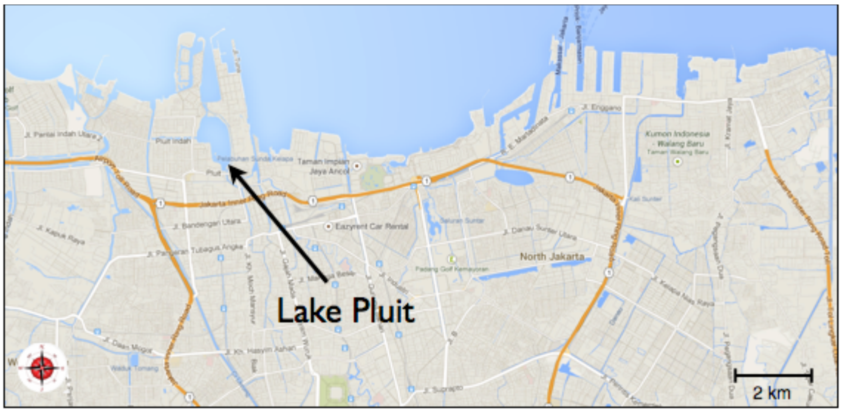
Current State of Flood Management Systems in Jakarta

Jakarta's defense strategy against floods involves several approaches. The city already has a 30-kilometer long seawall that prevents tidal flooding. Experts, however, have found that the seawall itself is sinking (Berg). Some are worried that the shifting of the Earth below means that the structural integrity of the seawall could be compromised, possibly leading to a very devastating collapse. Brinkman is very apprehensive, predicting that "within 48 hours of a breach [in the seawall], a low-lying section of city home to nearly 1 million people would be completely flooded" (Berg). This marks yet another risk factor faced by the northern coastal region.

In addition to that, with the city's rapid urbanization as the capital of a newly industrialized country (NIC), there have been illegal encroachments on the edges of Jakarta's vital rivers. These encroachments are the result of trying to meet the demands of the city's annual influx of a quarter-of-a-million new residents ("Rehabilitating Waterways"). The World Bank reports that "increased sediment loads and inadequate management of solid waste have contributed to waste choked canals and floodways, with some operating at less than a third of their original capacity." ("Rehabilitating Waterways"). Furthermore, rivers that were originally 100m wide have been reduced to only 20-30m now (Tambun et al).

There are also numerous reservoirs in north Jakarta, most of which have also suffered from solid waste reducing their capacity. Figure 7 gives the location of one particular reservoir I chose to visit, Lake Pluit. It serves an important role as a buffer during floods, when excess water has to be pumped out to sea.

Figure 7 - Map of north Jakarta showing many reservoirs, Lake Pluit among them



Base map *Source:* "Map of Lake Pluit"

This map shows that Lake Pluit is the largest artificial reservoir in the city and is in close proximity to the sea in the north. It also shows that Lake Pluit is located in the same region that was extensively flooded during the flood disaster in January, as annotated in Figure 5.

Figure 8- Satellite Map of Lake Pluit from May 2010 (with annotations)

Base map *Source:* "Satellite Map of Lake Pluit"

Figure 9- Photo of eastern shore of Lake Pluit

Source: Personal photograph, Jakarta, October 16, 2013

Figure 8 and Figure 9 illustrate the state of Lake Pluit. The reservoir is clogged with trash and other solid waste, and is burdened by an extreme overgrowth of plants. In addition, the eastern edge in particular is densely populated with slums. The fact that the map and photo show a time span of 3 years means that these are persisting problems. Moreover, the state of Lake Pluit is representative of many of the other reservoirs in northern Jakarta that can be seen in Figure 7 above.

The consequence of these encroachments is that water cannot drain away from the city as fast as storms and heavy rains drop water into the city. In effect, any neighborhoods that are immediately adjacent to any of the thirteen major waterways or many of the lakes and reservoirs face severe risks of being inundated.

Influence of flood management systems during the flood in January:
The effect of not having flood management systems functioning up to optimal capacity is very clearly negative.

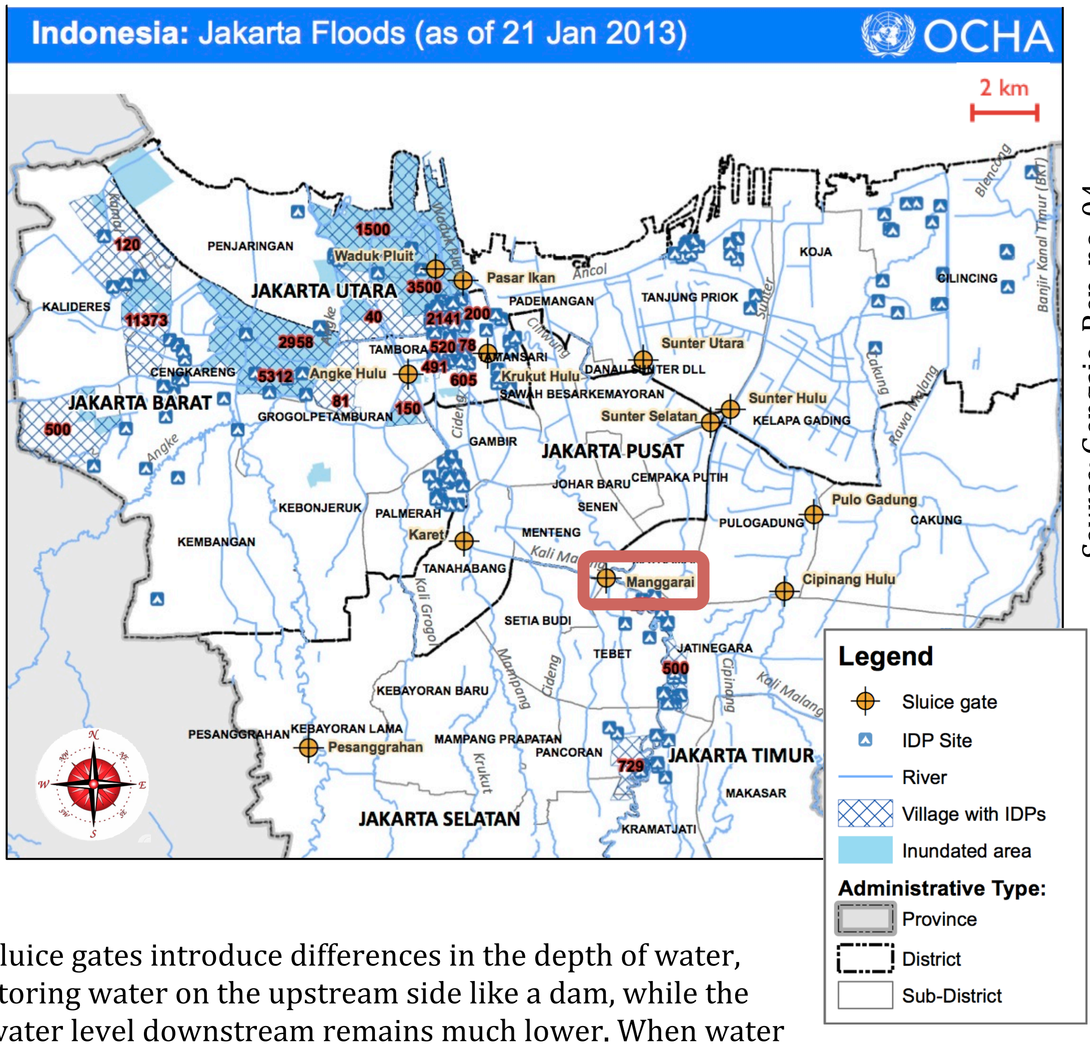
Lake Pluit, despite being the largest reservoir in north Jakarta, is located right in the middle of the area that was extensively flooded for over a week in January. Evidently, this is because Lake Pluit's buffer capacity has been severely reduced by trash, overgrowing plants and encroaching informal settlements.

Furthermore, it can be observed that areas that flooded first (shaded purple in Figure 5) are almost all adjacent to rivers, particularly in east, west and central Jakarta. It is evident once again that this pattern happens because the capacity of these rivers to drain excess water has been diminished by sediment and solid waste.

Sluice Gates

The flow of water in all of Jakarta's rivers is controlled by 'sluice gates' – mechanisms that can be opened and closed to allow for fine control of the rate at which water flows. Ideally, the sluice gates should allow Jakarta's disaster management authorities to keep the amount of water flowing downstream (to the north and northwest) within appropriate limits. Figure 10 shows the locations of 12 of Jakarta's 14 sluice gates used to control the flow of run-off water (Gengaje, Rep. no. 4)

Figure 10 - Disaster relief map showing the locations of sluice gates (as well as internally displaced people and inundated areas)



Source: Gengaje, Rep. no. 04

Sluice gates introduce differences in the depth of water, storing water on the upstream side like a dam, while the water level downstream remains much lower. When water is finally released, this difference in water level can prove to be very destructive at times, eroding and damaging anything in its way.

Influence of sluice gates during the flood in January:

During the first few days of the flood disaster in January, many of the sluice gates remained closed, allowing water to accumulate upstream in southern Jakarta where it was considered to be safe to do so. This is shown by the three purple areas in central Jakarta in Figure 5, upstream from (to the south of) the Manggarai sluice gate, annotated in Figure 5 and also highlighted in red in Figure 10. This was purposely done to protect northern Jakarta by allowing the authorities to release water downstream (to the north) over time, so that the city could cope with excess floodwater more effectively (Chuan Interview).

Unfortunately, the water levels proved to be too high and the authorities were forced to open sluice gates. On January 18, the Manggarai sluice gate was opened allowing water to flow downstream at an estimated rate of 500m^3 per second (Nirmala and Tambun). This immense amount of water flowed downstream to Menteng, where it overwhelmed the waterway, resulting in the collapse of a 30-meter-long section of the river's embankment (Nirmala and Tambun). Consequently, an immeasurably large amount of water from Jakarta's largest river flooded the central business district. The devastating repercussions of this can be seen in Figure 1.

All the evidence supports the conclusion that subsidence, clogged rivers and threats posed by water stored behind sluice gates are three risk factors that were conducive to the flood disaster in January.

Suggested Future Strategies to Mitigate Risk

Combatting Subsidence

The analysis indicated that there could be a positive correlation between increasing ground water extraction and the increasing rates of subsidence. Thus, it follows that a solution to effectively combat subsidence should attempt to fix the problem of diminishing ground water levels.

An innovative technique known as 'biopore infiltration holes' replenishes ground water. Biopores are vertical tunnels bored into the ground, usually about 10-15 centimeters in diameter and only a few meters in depth (AG, Syam). The advantage of this solution is twofold:

1. Firstly, biopores greatly increase the rate of water infiltration into the ground. This is because surface water is able to penetrate several meters into the ground, where it can percolate and reach the ground water table below. In theory, this infiltration could replenish ground water, thereby decreasing subsidence rates.
2. Secondly, these biopores can be used as a more effective means of organic waste disposal. There is evidence mentioned earlier that waste in the rivers and canals have diminished their ability to transport water. By preventing waste from ever clogging this valuable flood control infrastructure, the risk of flood disasters can be diminished.

Other benefits include the fact that as more biopores are constructed, it becomes more effective at enabling water to infiltrate the earth.

In fact, due to the incredible benefits of this solution, the city municipal authority requires citizens to build infiltration wells, as decreed in an obscure policy in 1992 (AG, Syam). This rule, however, has been largely ignored due to a lack of awareness and a complete lack of enforcement.

Nevertheless, there exist some shortcomings to this solution. Biopores require constant maintenance and a high level of social awareness to bring about widespread implementation of biopores in every backyard and neighborhood.

Moreover, with regards to combatting land subsidence, there is still the question of whether replenishing ground water is even within the realm of possibility. According to Mr. Wagemaker, "attempting to get any water back into the ground is quite hopeless" (Wagemaker Interview). In his opinion, the city itself is far too heavy, and has subsided to such a great extent already, that replenishing ground water is not possible. Instead, efforts should be focused on preventing further extraction of ground water, which in turn requires alternative sources of freshwater to be found to match the city's domestic and industrial needs (Wagemaker Interview). Still, constructing biopores would at least slow down further land subsidence, thus preventing further exacerbation of flooding woes.

Removing Garbage, Solid Waste and Silt

The city's authorities have already recognized that trash is choking waterways, and begun to remove trash in a number of different ways.

In the short term, the government has begun 'dredging', a process in which rivers, canals and lakes are cleaned by physically removing garbage, solid waste and sediments. Figure 11 shows an army of excavators floating on makeshift barges, removing waste by the bucket. Once the waste is piled on the shore, as shown in the foreground of the photo, it is transported elsewhere by trucks (background of Figure 12 below).

Figure 11 - Photo of excavators, taken from the western shore of Lake Pluit

Source: Personal photograph, Jakarta, October 16, 2013

Figure 12 - Photo of excavators and trucks removing waste

Source: Personal photograph, Jakarta, October 16, 2013

Furthermore, the World Bank has approved a similar dredging project called the Jakarta Urgent Flood Mitigation Project (JUFMP) (Chuan Interview). $189 million has already been appropriated to dredge several of the major rivers in order to drastically increase their floodwater drainage capacities ("Prevention Gaps"). The goal is to achieve a system that can drain excess water within 24 hours, even if rainfall is greater than the standing 50-year record, thereby planning for contingencies in the future (Chuan Interview).

While it is commendable that the city has invested in this project, this is clearly not sustainable, because it would require permanent teams of excavators and trucks actively remove trash. Instead, long-term and sustainable solutions must be developed.

One such method is the implementation of 'trash screens', which are sieve-like metal structures that traverse flowing rivers to catch any pieces of solid waste that get trapped. Cranes or construction excavators can then easily remove it.

Figure 13 shows how trash screens function. This particular trash screen is located at the mouth of the river flowing into Lake Pluit from the south, as shown in Figure 8.

Figure 13 - Photo of trash screen at Lake Pluit with excavator removing trash in the background

Source: Personal photograph, Jakarta, October 16, 2013

Unfortunately, this method of cleaning waterways comes with its own disadvantages:

1. This method also requires the permanent presence of excavators and trucks, which are a nuisance, can become costly and are simply not sustainable in the long-term.
2. Secondly, the accumulation of trash on the banks of rivers and canals can pose a health risk, particularly if there are people residing nearby. Figure 14, a photo of the excavator near same trash screen in Pluit, shows the potential health risk of waste to children playing nearby.

Figure 14 - Photo of children playing near trash at a slum near Lake Pluit

Source: Personal photograph, Jakarta, October 16, 2013

3. Lastly, when the flow of water becomes too high the trash screen has to be raised. To enable this, the trash screen is fitted with a hoisting mechanism, as annotated in Figure 13. The problem with these mechanisms is that they are prone to failure/malfunctions, and they cannot be operated when it is raining, which is ironically when they are needed most (Wagemaker Interview).

All these shortcomings mean that a radically different approach is required. The most successful one so far has been the mangrove reforestation project in the same area of north Jakarta. Known as the Muara Angke Wildlife Sanctuary, annotated on the map Figure 5, the project protects Jakarta from flooding by restoring the original natural buffer – mangrove forests - that existed here before the city's rapid urbanization ("Mangrove Swamp"). The plan is to plant over 9 million trees in the next 5 years, combatting the accumulation of garbage (Jusuf). Results can already be seen in the nearby lake, Figure 15, and river, Figure 16.

The end result will be a natural flood management system (in pristine conditions no less) that can act as a buffer. Since it is situated in the same, worst-flood-afflicted area in north Jakarta, it will be especially effective in this role.

Figure 15 - Photo of the boardwalk on the lake at the Muara Angke Wildlife Sanctuary

Source: "Mangrove Swamp"

Figure 16 - Photo of a river in the Muara Angke Wildlife Sanctuary, by the side of a major urban toll road

Source: Personal Photograph, Jakarta, October 16, 2013

Conclusion

The aims of this investigation were to:

1. Identify the risk factors that contribute to Jakarta's vulnerability to floods, particularly the floods of January 2013
2. Evaluate and suggest strategies that could mitigate these risks in the future

In terms of risk factors, the evidence shows that Jakarta's vulnerability to floods stems from a trend of land subsidence in the northern regions in tandem with deteriorating conditions of rivers, canals and reservoirs, particularly due to accumulating waste. With regards to the flood disaster in January, these risk factors were amplified by an unusually high amount of rainfall on January 17 along with the catastrophic collapse of a dike in central Jakarta.

With these risk factors in mind, some solutions to each risk factor were evaluated. While it may not be worthwhile to attempt to reverse land subsidence, constructing biopores could help Jakarta reduce rates of subsidence in the long run. Moreover, it was found that the measures currently in place to tackle the problem of solid waste clogging waterways are somewhat ineffective. Presently, Jakarta has resorted to emergency dredging, which is expensive and unsustainable, or implementation of trash screens, which introduce many issues of their own. Instead, the best course of action is to restore natural buffers, such as mangrove forests. These two recommended policies – biopores and mangroves – are the best options to mitigate Jakarta's flood vulnerability.

However, these suggestions leave some unresolved questions: How can waste be stopped from entering the water system in the first place? Could the city benefit from improvements in waste management, which would indirectly mitigate flood risks by keeping waterways clear? What can be done about the problems with sluice gates? Future investigations and further research should be conducted in these areas.

Evaluation

Some limitations of this investigation arise from the primary data collected. It initially was decided that the exploration should remain limited only to the worst affected areas – namely, Pluit in north Jakarta. This was done for simplicity and focus. While this assumption itself is not faulty, it introduces some degree of bias. Due to this, the conclusions reached only lend themselves to Pluit and north Jakarta, neglecting the floods in south Jakarta (where I live). An example of this limitation is the fact that the mangrove restoration project is unique to the north only. It is not feasible to grow mangroves in other parts of the city, since mangroves only flourish in coastal regions. So what can be done to mitigate flood vulnerability in the rest of the city? This question remains outside the scope of the exploration conducted in this investigation, but could be answered by future investigations.

Another limitation originates from the date on which the exploration was conducted. October 16, 2013 was chosen because it was during mid-term break, when the investigator could spend a whole day exploring Pluit. The complication of choosing this particular day is that it was the day after Idul Adha, an Islamic public holiday in Indonesia. The celebrations across the city the day before the exploration would likely have produced extremely large amounts of waste, influencing what was observed. By exploring the water system on a day when it would be in the worst condition (clogged by massive amounts of waste), the investigation could have been exposed to bias. However, this bias can be somewhat discounted by the fact that satellite imagery from 2010 (see Figure 8) and even earlier (not shown) indicate that the problem with waste has persisted for a number of years.

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Appendix 1

The following is the transcript of a personal interview I conducted on September 5 2013, with Mr. Jurjen Wagemaker at HKV Consultants. He is an expert on disaster- and risk-management in Jakarta and his company advises the Indonesian National Disaster Management Agency (BNPB) and has developed flood-mapping software for them.

Wagemaker: So this [city] has been flooding for a long time. If you look around, there's.. um… yes subsidence – so low land – but in Holland we are 5 or 6 meter under sea level…. So it doesn't help to be under the sea level, but of course there are measures that can be taken. Without any dikes, any measures, yes Jakarta is flooding, because it's a low lying area, there's large rivers, there's a high discharge from the mountains – the precipitation in the mountains is really very high and so it's a natural thing that it floods. It's *worse* because of subsidence. But when the government doesn't have measures in place, yeah that's when you've got flood disasters.

So what's causing the floods? There are a hundred answers. But it comes down to the natural situation and the failure of the government to do something about it.

Pranav (Me): So you'd agree that subsidence plays a part but it's not the entire story?

Wagemaker: Definitely. Definitely not the entire story

Me: Okay… So we talked about groundwater extraction. Perhaps… that's something we could work on – to replace the groundwater? … Is that an important thing?

W: Yes… Yes it's a very important thing. But replacing groundwater is not that easy, by the way. We've just got to stop extracting so much, because getting any water *back* into the ground is quite hopeless… Of course you can never *lift* the city any more, that's too difficult. There were also suggestions in one of the meetings we had with one of the vice governors of the previous administration. He said "Let's just pump water back in, then we're rising" haha it's not that simple… haha that would be a great solution by the way.

Me: So what problems might you run into?

W: It's just physically impossible