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Windows of Opportunity: Addressing Climate Uncertainty Through Adaptation Plan Implementation

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Adaptation Plan Implementation*

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1. Introduction

Adapting cities to climate change is a pressing issue, but creating a feasible adaptation planning process is difficult given the uncertainties inherent in the physical manifestations of climate change itself, as well as the modeling uncertainty regarding the timing and magnitude of climate change. The result is that it is easier for policymakers to ignore climate change in their policymaking than risk being wrong, creating a significant barrier to the uptake of climate adaptive actions (Carter, 2011; Dessai and Hulme, 2007). While reducing the *underlying* uncertainty will only occur through improvements to climate science and modeling, reducing the *impact* of uncertainty can occur through improved policy and planning processes. Significant research attention has been paid to improving scenario planning and vulnerability assessments to improve policy and also reduce uncertainty. But the implementation stage of adaptation planning also has a role to play, and there has been less research in this area.

In this paper we propose an approach that focuses on phasing the implementation of adaptation over time in a way that engages both scientific and local

knowledge. Long-term scenarios identify the transformational change that might be needed under extensive climate change, and the phasing shows the route there if it is needed. Rather than planned based on years into the future, phasing should be based on suites of indicators monitored by the community and governance bodies to suggest when an adaptation tipping point has been reached. Tipping points indicate the need to move to a new, more intensive phase of adaptation. Overall this approach has several advantages. One is that there is limited need to differentiate climate variability from climate change, particularly in the early years. Another is that this adaptive approach allows for testing of the efficacy of adaptive responses already undertaken. In-situ monitoring of early and no-regrets policies will help determine how effective they have been in reducing locally-experienced impacts of climate change, and thus inform what more needs to be done. Thirdly, planned phasing can allow for incremental actions to build toward transformative change. We use case studies of two cities that are already approaching adaptation planning this way to explore implementation. Challenges remain—large infrastructural investments or abrupt climate change require one-time, large responses. But for the more gradual impacts of climate change, such as excess heat, increased floods, etc., it may be very helpful.

2. Climate Uncertainty and Urban Planning Policy

The level of climate change that is already underway is startling, and the pace of change is heating up (pun intended) (Kintisch, 2009; Rahmstorf et al., 2007). The hard fact is that global greenhouse emissions, far from declining, are still increasing. In 2010, the annual rate of emissions growth was 2.35%, higher than any of the previous five years (NOAA Earth System Research Laboratory, 2011). Emission levels are

generally following the ‘high emissions scenario’ projected as a worst case by the IPCC in 2007 (European Environment Agency, 2011), and there is no apparent movement towards global governance systems that would lead to significant reductions (Smith et al., 2011). Recent findings that incorporate the growth of emissions since 2007 suggest that the globe is currently headed toward 4°C (7.2 °F) of global average climate change, even if emissions reductions begin soon, and will be worse in northern regions (Joshi et al., 2011).

2.1 Climate Change Timing Uncertainty

From a policy perspective, climate uncertainty can be characterized as a function of magnitude, direction, and timing of change (Joshi et al., 2011). Research suggests that uncertainty over the level of change is a key reason for difficulties in getting policymakers to take action on climate change (Bedsworth and Hanak, 2010; Moser and Ekstrom, 2010).. But given an average 20 year urban planning horizon, the timing of change may be an even larger issue than where global climate eventually lands (Fig. 1). As that figure demonstrates, a thirty-year plan (which is, admittedly, longer than most current policy horizons) could use a 1.2°, a 2.2°, or a 4.0° projection depending on the global or regional forecast, and the longer the time horizon, the greater the uncertainty. And these are not worst-case projections--none assume any ‘abrupt’ climate shifts (Alley et al., 2003).

Figure 1: Timing of regional and global climate change impacts under high-emissions scenarios: The plots show smoothed and simplified approximations of the projections in three reports. The IPCC line is for A1FI scenario, which provides a best estimate of 4°C temperature change at 2090–2099 relative to 1980–1999 (IPCC, 2007 p. 45). Betts, Collins et al (Betts et al., 2011) use the IPCC A1FI scenario to estimate that a 4°C change by 2060–2070 is within the IPCC’s ‘likely’ range. At the regional level, in contrast, for the Boston area Frumhoff et al (Frumhoff et al., 2007; Frumhoff et al., 2008) suggest that a 4°C change could be quite imminent.

2.2 Local Experiences of Climate Variability and Climate Change

Even given the uncertainty in timing noted above, in the one to two decade time-frame that most plans work, the locally-experienced impacts of climate change are likely to be relatively small compared to the impacts of natural climate variability (IPCC, 2012). As a result, simultaneously addressing current climate variability and

climate change may in many cases be a more policy-beneficial approach than focusing on one or the other. Particularly at the local level it may be easier for communities to unite in addressing existing climate variability than in addressing a threat such as climate change that is less directly experienced, and more politically charged. In view of this, we sought to identify an approach that did not explicitly require the separation of natural and anthropogenically-caused climate problems, and instead focused on identifying a pathway that could assist communities in overcoming planning barriers while still allowing for short and long term, climate-change informed planning.

2.3 Urban Micro-Climate and No-Regrets Policies

Scaling down to the urban level, the impact of climate events and thus the experience of climate change can be magnified (or reduced) by the form and/or design of on-going urbanization processes (Hardoy and Pandiella, 2009; IPCC, 2012; Schipper and Burton, 2009), which create micro-climates that influence human climate-experience and ecological functions. One key variable is the amount of impervious surface. Higher imperviousness tends to lead to more flooding, more intense urban heat island effects, and increased desertification (Arnold and Gibbons, 1996; Brabec, 2009; Rosenberg et al., 2010; Stedinger and Griffis, 2011). These affect an environmental feedback loop that results in higher levels of particulates in the air; increased levels of pollutants, particularly ozone; decreases in floral and faunal diversity and numbers; and increasing destabilization of soils and floodplain systems. These in turn result in a higher incidence of human health problems (Few, 2007; Shea et al., 2008), property damage and loss, and ecological degradation and species extinction

(Nitschke and Innes, 2008). The poor tend to be disproportionately affected by these changes as economic forces push them into areas that are highly impervious and flood prone with high heat indexes and unstable soils (United Nations Human Settlements Programme (UN-Habitat), 2011).

Thus, if cities are built with little green space and urban forest and the poor continue to be pushed into high risk areas, vulnerability to climate variability increases regardless of climate change, and is magnified with it (United Nations Human Settlements Programme (UN-Habitat), 2011). A city designed with green infrastructure to reduce urban heat island effects, with on-site stormwater harvesting accompanied by effective watershed management systems, and with climate-adapted buildings built on stable soils, is better positioned to manage current climate variability. These types of policies, which provide sustainable environmental and social benefits beyond mitigation and adaptation, are termed 'no-regrets policies'. They are widely held to be the place to start (Heltberg et al., 2009), for reasons both obvious and subtle. The obvious benefit is that they allow communities to start moving in a climate-adaptive fashion without even having to argue the climate question. The less obvious reason is that the micro-climate impacts of these no-regrets policies mean there is a chance cities will not have to move up the scale of interventions. They have the potential to reduce the humanly-experienced impact of increasing climate change, which is a substantial benefit. Additionally, these no-regrets interventions can serve as adaptive tests to evaluate the responsiveness of the system to interventions (Kato and Ahern, 2008). The result is that knowing when to progress to the next phase of policy is not just an outcome of changes in global climate, but also an outcome of local

experiences of that climate change, and the ability of already-implemented measures to reduce the harm of extreme events.

3.0 Municipal adaptation planning processes

Cities across the globe are addressing these issues through preparation of climate adaptation plans, as well as through ‘mainstreaming’ of policy wherein climate projections influence infrastructure calculations and the like directly, without any specific plan in place. Underlying the various approaches cities are taking are certain theoretical models for how planning should be done. The current best-practices approach to adaptation planning follows closely from traditional comprehensive planning, but adds more focus on risk assessment. This is well-described by the US National Research Council in Figure 2.

FIGURE 5.1 The planning process is envisioned to incorporate the following steps: (1) identify current and future climate changes relevant to the system, (2) assess the vulnerabilities and risk to the system, (3) develop an adaptation strategy using risk-based prioritization schemes, (4) identify opportunities for co-benefits and synergies across sectors, (5) implement adaptation options, and (6) monitor and reevaluate implemented adaptation options.

Figure 2: The Adaptation Planning process as recommended by the U.S. National Academy of Sciences. Note the iterative process steps and focus on co-benefits.

Climate adaptation plans reflect the traditional *comprehensive planning process*, beginning with goal setting and cycling through feedback on the performance of the plan to inform implementation steps and the next plan. While having many benefits, comprehensive planning can be very time and resource intensive. In typical comprehensive plans, the climate is assumed to be stationary (Milly et al., 2008), and so policies roll out over the years without having to reference anticipated change in environment. Mainstreaming, which is a version of *incrementalism*, instead proposes that small steps be taken toward very specific policy goals, with little effort toward a fully comprehensive approach (Lindblom, 1959). In the climate literature, incremental steps are those that aim to improve efficiency within existing systems of technologies and governance, while transformation involves alterations of fundamental attributes of the systems themselves (O'Brien, 2012). *Adaptive management* builds on incrementalism by focusing on the need for consistent testing, monitoring, and revision of policy as new information becomes available (Jacobson et al., 2009; Nelson et al., 2007). This is visible in the image above in step 6, monitor and reevaluate. One of the on-going debates in planning theory is whether incremental steps lead to transformative change, or whether transformative change results from a grander vision and broad sweep (Brooks, 2002). We won't attempt to resolve this here, but will define our terms. Following Park et al, transformation is defined as "a discrete process that fundamentally (but not necessarily irreversibly) results in change in the

biophysical, social, or economic components of a system from one form, function or location (state) to another” while incremental actions seek to maintain the essence and integrity of an incumbent system (Park et al., 2012, p. 119).

While perhaps more discussed than actually practiced, resilience theory demonstrates that rather than the unexpected, change is to be anticipated and tends to occur when thresholds are passed, and that planning needs to prepare social and ecological systems so that when stresses occur, systems can reorganize in a beneficial way to achieve a new and desirable system state (Folke, 2006; Walker and Salt, 2006). This focus on small steps and underlying processes brings significant advantages to the planning process, but may come at the cost of long-term vision and policy coherence. A comprehensive view allows testing for maladaptation – defined by Barnett and O’Neill (2010, p. 211) as “action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of other systems, sectors or social groups.” They identify five distinct types of maladaptation: actions that “increase emissions of greenhouse gases, disproportionately burden the most vulnerable, have high opportunity costs, reduce incentives to adapt, and set paths that limit the choices available to future generations.” A particular challenge in phasing adaptation is the last issue in this set: remedies appropriate to 2 degrees may interfere with 4 degree adaptations—investing in sea walls may make it more difficult to persuade homeowners of the need for planned retreat of their built structures on the lot or indeed off the coast altogether.

To appropriately phase adaptation policies in ways that address current climate variability as well as on-going climate change requires implementation processes that

bring together the advantages of these three planning approaches: the big-picture view of traditional comprehensive planning, the specific goals and policy steps of incrementalism, and the continual testing and utility of adaptive management. One attempt to resolve these conflicts and achieve the best of each is seen in the recent

Figure 3. Steps in adaptation policy development. The shaded boxes are all considered part of local vulnerability assessment.
[Adapted from Boswell, Greve, and Seale, 2012]

Figure 3: California State Adaptation Plan (2012 p. 24). The focus in our research is particularly on Stage 9 and the implementation of the iterative loop, but with implications to on Stages 6 – 8.

3.1 Identifying Climate Adaptation Strategies

Following the processes identified above, in the initial process steps the community utilizes long-horizon scenario planning (2010 p. 211) to imagine a high level of climate change, and what that means for the local area differentiated along vulnerabilities (Steps 1 – 5 above). Moving into the identification of strategies, an

interdisciplinary team of climate scientists, planners, engineers, governance specialists, and community members then identifies the set of transformative interventions that would allow the community to adapt to that high-magnitude climate change. Back-casting from there identifies how to phase the policies such that maladaptation and conflict across time or policy goals is avoided (see Figure 4).

Figure 4: Phasing of policy to match new conditions

The initial steps the community takes are the no-regrets policies that many authorities have identified as the appropriate place to start. The IPCC defines these as decisions that have net benefits over the entire range of anticipated future climate and associated impacts (see also Callaway and Hellmuth, 2007; Heltberg et al., 2009). One of the key benefits to no-regrets policies in urban environments is that they may,

as noted above, reduce or delay the need to move to the next phase of the plan, with more intensive response.

3.2 Tipping points, Indicator Portfolios, Local and Expert Knowledge

Kwadijk et al (Pittock et al., 2001; Wilson, 2009), define Adaptation Tipping Points (ATP) as moments in time where the magnitude of climate change is such that the current management strategies are no longer meeting local objectives, and new strategies need to be put into place; this is similar to Walker and Salt's (Kwadijk et al., 2010) thresholds. The team develops incremental policies that can roll-out as ATPs are reached, and that cumulatively create a transformed state (2006). It is important to stress that while these ATPs/thresholds are based in science, they are not scientific per se – instead, they are representations of local conditions and values.

Perhaps the most challenging aspect of this approach is the local determination of what will constitute an ATP. Assuming that the plan addresses a complex and coupled human-ecological system such as a city, natural and social/experiential indicators will be needed to represent the ATP. Indicators are generally understood to be statistical evaluative rubrics that reflect the status of a more complex system (Kates et al., 2012). Because of the difficulty of separating climate 'noise' from 'signal', scalar considerations (local versus regional), and the complex politics of decision making, using a suite of indicators will be more effective than any attempt to identify one threshold measure that indicates the need to move to the next phase. These indicators may be categorized into three types: climate related, political and /or social, and local urban environmental indicators. A portfolio of indicators can include those that are scientifically robust, and those that are more locally meaningful even if less

scientifically robust (Boulanger, 2008; Feiden and Hamin, 2011). This provides the opportunity to engage local knowledge directly in the adaptation planning and monitoring. Locally meaningful indicators assist in developing community support for and understanding of the need for the policy change, while the more scientific indicators provide validity, and respond to the IPCC's 2012 call for more direct inclusion of local knowledge in planning.

Helpful indicators are likely to include both emissions data for the bigger, global trends, and local data to capture the experience of climate variability and local culture. The long response time of the climate to changes in emissions means that there can be no simple higher-emissions=higher adaptation-needs-this-year kind of conclusions, but a trend toward higher emissions may help politically in establishing the necessity of adaptive plans. Local weather experiences are more prone to random variation than global averages, but tend to be more meaningful for communities and thus should be included if possible. Examples of local environmental indicators might include five-year moving averages of the number of excessive heat days in the region, drought levels, severity of flooding, miles of beach impacted by storms, acres of land underwater in any flood that year, or similar indicators. The number of times a sea wall is overtopped per year, for instance, may be a locally-meaningful indicator that encourages policymakers to take climate change, or at least climate variability, seriously—but for that to happen, the record of occurrences must be made and annually reviewed. Uncertainty is not vanquished, but it is reduced if we only ask for reliability in trends.

Officially blessed national/supra-national level climate-related indicators are beginning to be easily available. In the U.S., for example, NOAA has Global Climate Change Indicators which provide rapid and rigorous data (Gasteyer and Flora, 2000), while the EPA produces a graphically-engaging report (NOAA National Climatic Data Center, 2010). The Annual Greenhouse Gas Index prepared by NOAA provides a simple number of cumulative global emissions (US EPA, 2010). Europe has developed indicators for widespread use, especially the 2008 Indicators report (NOAA Earth System Research Laboratory, 2011) for climate impacts, the 2012 environmental indicators report for greenhouse emissions and environmental conditions (World Health Organization et al., 2008), and the on-going data sets available on the EEA website.

A final set of indicators could be political, such as polls that suggest the public is more accepting of climate change, or indications from elected officials of political support. Prior agreement on indicators and thresholds creates a situation where movement to the next stage of interventions will be less politically problematic. In this way, planning can meet politics and public where they are now, while still making contingency plans for the future. This provides one approach to address the challenge identified by Naess et al, 2005, by better integrating local knowledge systems into formal institutions and working across scales.

4.0 Application in Case Study Communities

Examples may help ground and illustrate the discussion above. To select illustrative cases, we reviewed a wide range of adaptation plans and chose two with the following characteristics: explicit recognition of uncertainty of timing and magnitude

of climate change, presence of cost estimates for adaptation strategies, clearly identified incremental steps that sum up to a long-term transformational policy. The case study communities demonstrate many aspects of the current state of practice in municipal adaptation planning (NRC, 2011; Boswell et al., 2012; California State Adaptation Plan, 2012): Each includes vulnerability assessment, future climate scenarios, and assessment of current adaptive capacity and required adaptation measures. The plans aim to provide a detailed and comprehensive view of the adaptation planning process but fall short of providing concrete information on how plans will be implemented. What makes them different from most is that they specifically include consideration of triggers for movement to the next stage of their adaptation plan, and thus a clear phasing for policy. Our goal is to demonstrate phasing as an emergent approach to reducing uncertainty, and to provide a model of how phasing can be compared across different cases.

4.1 Managing Rising Sea Level Impacts: The City of Clarence, Tasmania, Australia

The Clarence City adaptation plan for coastal areas (Clarence City Council, 2009) provides a road map for adaptation for risk prone areas within the city boundaries. It is worth noting that the final draft of the report was completed in 2009, thus foreshadowing much of the research literature on procedural adaptation planning models. The plan is driven by several principles that match the ideas presented in this article. First, it develops solutions that support continued use of coastal areas while recognizing the need for long term protection, accommodation and retreat as sea levels rise. “While use may be practical and desirable for many years, there will come a trigger when a response will be required to manage increasing risk (Clarence City

Council, 2009, p. iv)”. In Clarence’s case, the triggering event, or ATP in our terminology, is locally experienced sea level rise. Second, the planning and development is based on a community accepted worst-case scenario of future conditions. While it may be appropriate to plan for such worst case situations, the plan suggests emphasis on “encouraging performance based responses that maintain acceptable levels of risk (Clarence City Council, 2009, p. v)”. Third, it demonstrates that managing risk today through adaptation measures can reduce impacts from sea level rise “from a factor of 10 up to a factor of 100, and economic costs of adaptation would be minor compared to the damage avoided (Clarence City Council, 2009, p. iii)”. Fourth, community participation is significant in the decision making process in spite of the challenges this poses to decision makers. Interactive strategies that are participatory and combine bottom-up and top-down approaches can enhance a “community’s ability to cope and maximize community support for policy measures, especially in the case of drastic measures (Clarence City Council, 2009, p. v)”. The combination of these principles render the adaptation plan flexible and open for improvement and revisions as impacts of climate change will arguably increase.

The plan uses focus areas to explore measures needed in the areas most at risk. One of these is Lauderdale and Roches Beach area, which has immediate risk and adaptation work underway (Personal communicate with primary author of the report, August 10, 2012).

The area of Lauderdale is a low-lying sandy isthmus with dunes and housing development. The coastal area at risk is 4,300m long. The plan identifies three major hazards for this area: storm surge and erosion, inundation, and rising water tables

leading to failing septic tanks. The risk assessment acknowledges that current and future coastal beach movement processes¹ (not related to climate change) will continue at a faster pace in the future under a changing climate condition.

The primary risks are associated with low lying residential sites and infrastructure as well as an eroding coastline that will reduce the setback distance from the sea. These risks will be manifested as climate change unfolds and related impacts are felt. Accordingly, this will require a suite of adaptive responses to SLR that are specific to the area and are phased and implemented in an incremental manner according to the gradient from no-regrets to transformative measures. While the scenarios build towards 2100, there is sufficient flexibility within the measures to increase or decrease the pace of implementation based on how climate change impacts are manifesting locally.

Adaptive Measures	Time Frame	Estimated Cost (USD)*	Remarks
• New development within erosion hazard zone need to be constructed on piles, or else restrict to Stable foundation Zone (as long as it can be secured)	Immediate and ongoing		This is being implemented as part of the erosion zoning overlay.
• Minor Sand Nourishment for existing dunes and re-vegetation	0-25 years	\$ 1.4 million	
• Major Sand Nourishment for existing dunes and re-vegetation	25-50 years	2050 mid: \$ 2.7 million 2050 high: \$ 5.4 million 2100 mid: \$13.5 million 2100 high: \$24.3 million	
• Groynes to capture sand; support for sand nourishment. One groyne for every 500m of coastal length	0-25	\$4.7 million	In conjunction with sand nourishment
• Sea walls and harden coastal edges	50-100 years	Present: \$19.4 million	Not a preferred solution

¹ The plan identified any combination of the following coastal processes not related to climate change: adjust to past sea level rise (post ice age) or recent sea level rise, long shore drift, storm cut and rebuild, beach rotation, and changes in sea grass colonies that may trap or release sand (Clarence city Council, 2009, p. 52).

		2100 high: \$35.6 million	as it will change the character and use of the coastline
• Progressive retreat	50-100 years	Avoided cost, not estimated.	Planned retreat is likely to be considered if the value of protection exceeds the value of properties being protected.
• Raise developed land above flood levels	50-100 years	Not estimated	
• Raise level for existing roads to ensure serviceability	50-100 years	Short term: \$3.1-8.4 million Long term: \$ 6.3 million (raise 1 m)	
• Install new sewerage system to replace septic tanks	0-25 years	\$10.5 million	

Table 1: Adaptive Responses to combat SLR risks for Lauderdale.

- Estimates are converted from Australian Dollar to USD based on 1 Australian Dollar = 1.0456 USD. All cost estimates are based on dollar values at the time of issuing the report.

Using our model, we organize the gradient of responses that are applicable to Lauderdale along no-regrets to transformative measure gradient in Figure X. The no-regrets responses are critical for implementation within the next 25 years, and as the plan notes will provide protection and maintain the coastline as an amenity. As conditions change based on observations and plan monitoring, more intense measures kick in, providing adequate responses. More transformational responses such as sea walls and planned retreat, which are planned for longer term implementation, are less favorable with the community and may be necessary at one point in time. Associated with these responses are monetary cost estimates for each phase. The dollar amounts are cumulative across phases.

Figure 1: Phasing Model for Lauderdale Area, City of Clarence, Australia.

+ : items included in the cost estimates. Other items not included either report does not include cost estimates or the cost is unknown because it is not with the scope of the public works.

4.2 Managing flood impacts from Extreme Precipitation Events: The City of Copenhagen, Denmark

The Copenhagen adaptation plan is a state-of-the art document, developed in 2011 to address an array of climate change impacts with focus on extreme precipitation events and rising sea level. Such extreme conditions are already occurring in Copenhagen. The cloudburst event of July 2011 poured 150mm of rain within two hours, a city record since measurements began in the mid-1800s. The result was an estimated insurance damage of 650-700 million Euros (\$ 820-880 million; EEA, 2012). This focusing event helped the City of Copenhagen to expedite research and

development of the comprehensive adaptation plan in a way that allows gradual and “flexible adaptation (City of Copenhagen, 2011, p.6)” over time.

The plan presents many exemplary practices, but for our purposes its main interest is its principle that adaptation should be flexible and staged. The plan is developed for incremental implementation with continuous monitoring and updating to include advancements in climate science, scenario projection methodologies, and climatically responsive planning.

Prioritization, implementation and extent of effectiveness of adaptation measures are categorized based on three levels of intensity: level 1, to reduce the likelihood of occurrence of an extreme event ; level 2, to reduce the scale of impact; and level 3, to reduce the extent of vulnerability. The choice of the appropriate level is based on the feasibility of implementation within a specific zone of Copenhagen. For example, if the reduction of likelihood of an event (level 1) is not feasible within a zone, then reducing the scale of impact (level 2) to manage damage is prioritized. If that is not deemed feasible, then reduction of vulnerability (level 3) becomes the dominant action. In addition to the intensity of measures, the choice of action will also depend on the geographic scale where the action is being implemented. Table 5 shows the relationship of the three levels of measures and the five geographic scales of planning relevant to Copenhagen: the region, the municipality, the district, the street, and the building. This approach ensures that coordination and integration across planning scales and measure intensities will arguably avoid mal-adaptation. For example, disconnecting storm water from the sewer system at the building scale and establishing retarding basins for run-off at the regional scale reduces input into the city pipe

network. Such measures ensure that adaptation measures are concurrent and avoid unnecessary investments. Unlike the City of Clarence coastal planning report, the use of indicator triggers to develop a step-wise approach is not explicit in the plan. However, financial projections are included for each intervention as well as climate risks, allowing for cost-benefit comparisons.

Geography/ Measure	Level1: Reduce Likelihood	Level 2: Reduce Scale	Level 3: Reduce Vulnerability
Region	<ul style="list-style-type: none"> • Delay quantities of rain in catchment: Establishment of retarding basins within catchment areas. • Pumping excess run-off to sea 	<ul style="list-style-type: none"> • Emergency Preparedness and infrastructure protection • Protection of vulnerable infrastructure Metro, S-trains, tunnels, cultural assets. • Establish warning system for high waters 	<ul style="list-style-type: none"> • Protection of vulnerable infrastructure Metro, S-trains, tunnels, cultural assets.
Municipality	<ul style="list-style-type: none"> • Disconnection of stormwater using SUDS* • Increased sewer capacity: New dimensional design based on future new capacities. • Pumping of excess run-off to sea • Establishment of local Dikes • Raise building elevations 	<ul style="list-style-type: none"> • Disconnection of stormwater using SUDS • Planning**** • Warning Systems 	<ul style="list-style-type: none"> • Planning**** • Emergency Preparedness
District	<ul style="list-style-type: none"> • Establishment of Dikes • Decoupling of rainwater using SUDS • "Plan B"*** • Establishment of Dikes • Raised building elevation/threshold*** 	<ul style="list-style-type: none"> • Decoupling of rainwater using SUDS. • Emergency Management: sandbags etc. 	<ul style="list-style-type: none"> • Moving of vulnerable functions and installations Moving of vulnerable functions to safe places
Street	<ul style="list-style-type: none"> • Local management of storm water: Plan B solutions, separation of stormwater from sewer • Raised building elevation/threshold 	<ul style="list-style-type: none"> • Control of stormwater runoff: Disconnection of stormwater using SUDS. Preparedness: sandbags etc., raised building elevation/threshold, sand bags 	<ul style="list-style-type: none"> • Moving vulnerable functions and installations to safe places: Moving electrical cabinets for light regulation, pumping stations etc. from low-lying points
Building	<ul style="list-style-type: none"> • Disconnection of stormwater from sewer • Backwater valve • raised building elevation/threshold 	<ul style="list-style-type: none"> • Backwater valves, sealed basements, Preparedness, sandbags etc. 	<ul style="list-style-type: none"> • Move vulnerable functions away from basement level (service rooms, electrical panels etc.)

Table 2: Example of integrating adaptation measures across geographic scale and reduction of risk for flooding from extreme rain events and rising sea level (Adapted from Copenhagen Climate Adaptation Plan, 2011, p. 27 & 35).

*SUDS: Sustainable Urban Drainage Systems. "SUDS consist of a number of different elements, all of which serve the purpose of managing stormwater locally. These may be elements that delay/store the water, that treat the water either before discharge to bodies of surface water or percolation of the stormwater. The elements are often "green" and low-technology and will therefore be able to contribute to a greener city, for example in the form of rain gardens, green ditches, lakes and canals. If the rainwater is disconnected from the sewer, the load will fall

accordingly. As stormwater during heavy rain makes up most of the water in the sewer, disconnection can have a great effect. The wastewater is roughly distributed one-third household wastewater (black wastewater), one-third stormwater from roads and one-third stormwater from roofs and hardened surfaces in general (Copenhagen Climate Adaptation Plan, 2011, p.26)".

** "Plan B" is using street surfaces as conveyance routes for excessive run-off.

*** Raised threshold: Raising egress edges to prevent surface run-off water from entering building.

**** Planning measures include : 1) "New sewer systems already have to be dimensionally designed today so that they cope with the new volumes of rain and consequently meet the service objective. The dimensional design base has to be incorporated into all relevant municipal plans. 2) Separation of common sewer in SUDS solutions is to be promoted and implemented (Copenhagen Climate Adaptation Plan, 2011, p.27)".

The plan uses a complex analysis of risk and timing by zone and compared to various scenarios. To use this in the cross-case analysis tool we had to undertake a number of reformatting efforts, which are detailed in the Additional Material, available electronically. The planned actions for flooding can be summarized as shown in the figure below.

Figure 1: Phasing Model applied to the Copenhagen Climate Adaptation Plan (2011)

4.3 Case Discussion

The cases show that the use of phasing to reduce uncertainty is occurring in practice, although even with very recent plans, a connection to the principles of adaptive planning through the use of triggering events and monitoring, is not very strong. The Copenhagen climate Adaptation Plan (2011) is well documented and researched providing an example of best practices in high-density urban coastal cities within the northern European context. While the Copenhagen plan includes several innovative ideas, such as the matrix of measures and the risk assessment, but remains somewhat within the conventional planning model where time is the predominant

implementation factor. In contrast, the Clarence coastal adaptation plan clearly addresses a less urbanized region focusing only on rising sea level, with the explicit dependence on triggers to move from one adaptation measure to another.

While both plans vary in the areas addressed, context, and methodology; there are key themes that address the issue of uncertainty. Both plans recognize the need to move ahead with adaptation because the costs are too high to ignore. In the context of uncertainty of information about the future, flexibility to adjust and revise the plans is a core value that will require rigorous follow-up to achieve. In addition, both begin with no-regrets actions that carry wide benefits in the current window of opportunity, and incrementally refine information, advance technology, and monitor implemented projects. To address the barrier of high cost of adaptation, both cities anticipate spreading cost across longer periods of time beginning with no-regrets and integrated measures, allowing the opportunity to begin implementing without going all the way while revising and monitoring previous measures. The use of a full century to consider adaptation plans is significant in its implications. A policy maker adopting such a plan will not see the final results as most planning (and political) time horizons span from five, ten or at most twenty years. Yet what these plans demonstrate is that actions and investments should be carried out beyond the conventional planning time frames. They make maximum use of time by ignoring it.

5.0 Concluding remarks

Urban areas need to begin now to build resilience to climate adaptation as well as increasing their resilience to existing climate variability. There are a wide variety of

barriers to that, and a variety of approaches will be needed to overcome the variety of barriers. Implicit in the approach presented in this article is the subtle but radical suggestion to ignore, to collapse, time, and focus instead on the local experience of environmental change and the outcomes of interventions put into place. Allowing this flexibility reduces one level of uncertainty in policy implementation, as policymakers' fear of acting too precipitously is reduced. Action will only be taken when it is warranted – but plans are in place so that necessary action can be rapidly implemented. Having a long-run view of an implementation path allows testing for maladaptation in proposed policies. And using a suite of indicators allows for the explicit inclusion of local knowledge, and reduces the need to differentiate between climate change and climate variability. Of course, this whole process will depend on the rigorous commitment of communities to invest, follow-up and monitor this process.

There are a variety of governance implications in this approach. Indicator sets need to be developed collaboratively amongst governmental levels, and be translated to common language such that communities can readily use them. Agencies may wish to develop suggestions for local indicators, to help jump-start community considerations. High quality projections of climate data must occur at the national, regional and/or state level, because outside of the largest cities, local governments do not have the expertise, the organizational infrastructure, nor the funding necessary to develop climate projections. Adaptation implementation is, however, inherently local (European Environment Agency, 2012), so the indicators and thresholds must be meaningful to local communities if they are to be used in ways that are politically meaningful. Ultimately, the need for this is a response to the lack of national mandates

for adaptation plans; without mandates, local policymakers tend to need political 'cover' to overcome doubts and resource-constraints, and an approach that lets them focus on phased implementation matched to observed local need will assist in this. But in many countries national mandates might still be better (United Nations Human Settlements Programme (UN-Habitat), 2011).

This approach supports the literature's emerging consensus on the importance of starting with no-regrets policies (Biesbroek et al., 2010; Juhola et al., 2012), many of which are well-established best urban planning practices anyway. These are the policies of sustainable social and environmental development, including strategies for increasing green infrastructure in urban systems, increasing public and non-motorized transportation, and protecting ecosystems. In a given urban micro-environment, implementing these policies for cleaner, greener, healthier cities can slow the need for more radical transformations by directly addressing some of the impacts of climate change.

There is a great deal that is not addressed here. Perhaps the most pressing item is the difficulty of large dollar and long-time-frame investments, those that do not yield to gradual implementation. Permitting major water or shoreline interventions can take ten years, and stormwater piping lasts decades; for these major, one-time investments, climate-adapted policy is needed now. Other challenges come from the need to balance scientific rigor and local meaningfulness in monitoring and choices of indicators; identifying appropriate portfolios is essential. Significant issues revolve around communicating with the stakeholders and elected officials,

accustoming them to working around uncertainty and time concepts suggested by this approach to the planning process. Continuing research on these issues is necessary.

Given the long time horizons of urban land use and infrastructure, it is essential that local officials begin including climate adaptation in their planning, but given the uncertainties inherent in climate projections, it is difficult for them to move forward. The strength of the approach presented in this paper is the ability to make incremental decisions about investments in climate change adaptations, but with a comprehensive view that minimizes maladaptation. While the work utilizes an urban planning framework, the basic approach of adaptive planning with pre-determined thresholds is also applicable to natural resource areas and conservation lands. At least in the beginning phases, many policies can be chosen that do not require a strong commitment to the veracity of climate change projections, even while plans can be laid for more substantive, transformative action. And at this point in time, the imperative is to proceed, but flexibly.

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