Greenspace Acquisition as Adaptation Policy in Response to Storm Risk in an Urban Landscape

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Abstract

Background: Coastal urban areas are experiencing the effects of sea level rise in the form of more frequent and intense flooding. Retreat from vulnerable at-risk areas and the creation of open green space that may be used for both storm water retention and enhanced recreational activities is a common mitigation strategy.

Objective: The objective of this research is a methodology for the identification and acquisition of privately owned urban parcels in an effort to reduce risk to property and wellbeing, create green space, and manage water. This methodology is illustrated by way of suggested clustered parcel buyouts in Portsmouth, Virginia.

Methodology: Urban parcels most at risk are identified by way of modelling and simulation of both theoretical and historical storms, yielding flooding and structural damage. Coterminous high-damage urban blocks are targeted for sequential buyout and ranked based on weighted composite damage estimates. Costs of acquisition are adjusted for market value, administrative overhead, strategic acquisition outlays, and demolition expenditures. An analysis of return on investment includes the over time savings in the housing of displaced populations, reductions in mortality, and over time health savings stemming from reduced acute injury, exacerbation of chronic conditions, and mental illness.

Results: It is found that parcel acquisition is more costly and time consumptive than previously theorized. Although acquisition outlays are large, with a single severe storm event there is a positive return on investment stemming from property savings and population wellbeing. The construction of a water retention basin adds substantial costs, but also has co-benefits and may reduce risk to surrounding neighbourhoods and nearby shipyard.

Methodology

Part 1: Identification of Target Area

The high-level process employed to identify a target area for clustered parcel buyout is illustrated in Figure 1. Various storm scenarios are modeled and simulated to generate damage to single family residential structures. Quantification of relative risk stems from the juxtaposition of damage across these simulated storms scenarios and a weighting of damage estimates. Once the target area is identified, the blocks are ranked by the weighted risk stemming from these storm scenarios. This is followed by identification of the sequence of parcel buyout.

Figure 1: High-level Process for Identification of Target Area

Storm Scenarios
The impacts of a severe storm in terms of structural damage and population wellbeing is conditioned by the intensity and breadth of the storm, storm track, tidal conditions, and sea level rise. We have developed a three-type categorization of storm and modeled and simulated these storm scenarios under a future Relative Sea Level Rise projection of 2 feet.

Category	Modeled Storm
Historic Storms	1933 Chesapeake-Potomac Hurricane
Quasi-Historic Storms	Sandtrina Hurricane (derived from Sandy + 2012 Katrina Hurricane)
Black Swan Storms	Hugoswan Hurricane (derived from 1989 Hugo Hurricane)

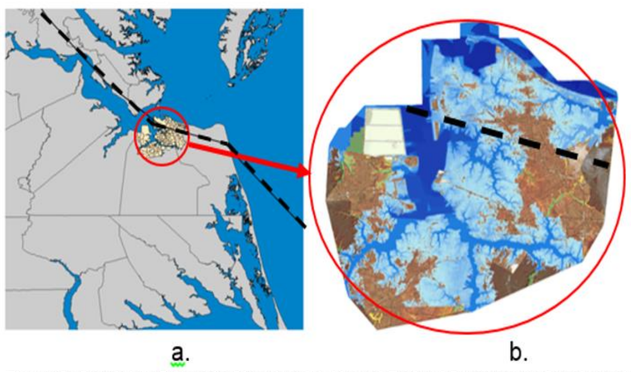

Figure 2: Sandtrina Scenario Showing (a) Altered Path of Superstorm Sandy and (b) Extent of Surge and Flooding in Portsmouth

Coterminous Substantial Damage
Figure 3 shows a view of the southern portion of Portsmouth illustrating, by block, the percent of single family residential structures with substantial damage. Blocks are segregated into three groupings reflecting the range in the percentage of the structures with substantial damage, the dark colored blocks indicating at least 61 percent of the structures being total loss (substantially damaged). This southern portion of Portsmouth is of interest specifically because of the evident coterminous substantial damage across the three storms.

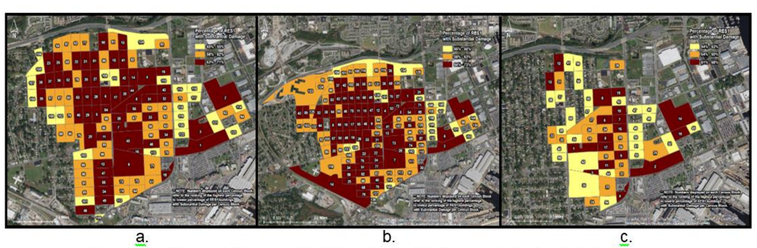

Figure 3: Percent Residential Structures Suffering Substantial Damage by Chesapeake-Potomac (a), Sandtrina (b), and Hugoswan (c)

Damage Coefficients
Table 1 reports the ranking of the fourteen blocks based on substantial damage incurred in preparation for buyout activities.

Table 1: Substantial Damage

Ranking	Block	Substantial Damage % (Sandtrina)	Substantial Damage % (Ches-Potomac)	Substantial Damage % (Hugoswan)	Weighted Damage % Coefficient
1	2002	70.90	67.70	58.00	66.88
2	2019	68.40	63.30	68.40	66.11
3	2013	64.30	64.70	64.30	64.48
4	2007	64.20	64.30	64.50	64.31
5	2008	62.40	64.20	64.20	63.57
6	2001	63.60	62.40	63.60	63.06
7	2021	64.70	63.20	52.90	61.67
8	2011	61.50	61.00	61.50	61.28
9	2018	61.30	59.90	61.53	60.72
10	2004	62.50	61.00	56.20	60.57
11	2022	60.00	58.20	60.00	59.19
12	2012	61.50	58.00	53.80	58.39
13	2017	58.30	57.00	58.30	57.72
14	2014	57.20	57.10	57.10	57.14

Target Area
Figure 4 illustrates what the algorithm has produced, a clustered set of blocks, located in the southern portion of Portsmouth. Figure 5 shows a more localized view of the target area

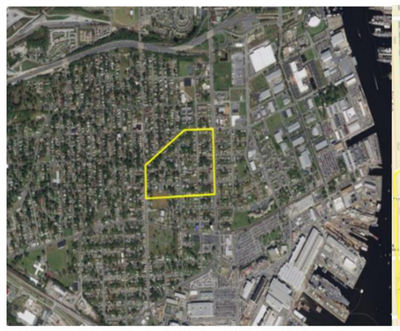

Figure 4: Target Area

Figure 5: Footprints

Neighborhood Characteristics
The area targeted for buyout encompasses the Prentis Place neighborhood. Figure 7 illustrates both typical housing stock and new construction.

Figure 7: Housing Stock

Neighborhood Vulnerability
Figure 8 shows mapping of hotspots that represent a composite measure of household vulnerability (previously developed by the authors) as it captures situational and behavioral elements of vulnerability, especially as it relates to medical fragility.

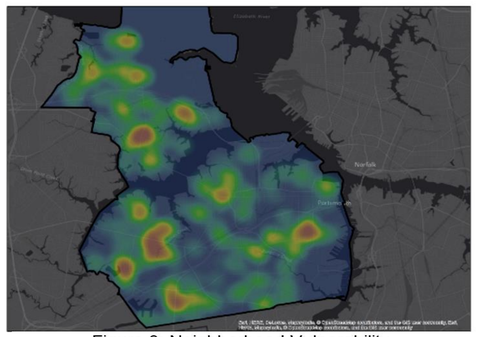

Figure 8: Neighborhood Vulnerability

Part 2: Acquisition & Construction

The process of acquisition takes place following the identification of the target area and the ranking of blocks (Part 1 above). This high-level process is illustrated in Figure 9 with the prioritization of parcels within the ranked blocks, establishing the cost of acquisition of each parcel, and creating a timeline based on budgeted funds. Once all properties are acquired and structures razed, construction of the storm water retention infrastructure may begin.

Figure 9: High-level Process for Acquisition

Parcel Prioritization
The approach to parcel order buyouts ranks the blocks based on weighted risk. This is refined by the current use of the parcels -- 1) vacant parcel, 2) parcel with residential structure, 3) parcel with religious structure, and 4) parcel with commercial structure -- prioritizing the acquisition of vacant parcels prior to the acquisition of parcels containing structures.

Acquisition Costs
The costs incurred by the city to transfer the ownership over the course of three decades is reflected in the acquisitions costs, which are markedly higher than the assessed values. The average percent higher difference between assessed values and acquisition costs for blocks is 24.9 percent. The assessed values of the 68 vacant parcels and 219 parcels with structures total $24.3m and the total acquisition costs are 32.6m dollars. Table 2 lists the calculated acquisition costs factors:

• Added market value margin (10 percent)	• Escalation (conservative ½ percent per year).
• Administrative-legal (2 percent)	• Razing structures, debris removal (10k)
• Negotiation (3 percent).	• Capping utilities (sewerage, water, gas) ($500).

Acquisition Period
Given the annual one million budgeted investment, Table 3 illustrates the first 11 years of the 32 year acquisition period, with year one spent entirely on the buyout of vacant parcels and the next 31 years spent on the buyout of parcels with structures.

Table 3: Acquisition Period by Parcel Function by Block

		Vac: 1-14	Vac: 1-14	Res: 1	Res: 1	Res: 2	Res: 2	Res: 3	Res: 3
	Blocks w	Acquisition	Number of	Acquisition	Number of	Acquisition	Number of	Acquisition	Number of
	Acquisition	Costs	Vacant Parcels	Costs	Resid. Parcels	Costs	Resid. Parcels	Costs	Resid. Parcels
end of…	Transactions	$1,758,636	Acquired	$4,938,586	Acquired	$2,251,104	Acquired	$1,935,754	Acquired
year 0									
year 1	Vac:1-8	$1,000,000	38.67						
year 2	Vac:8-14;Res:1	$758,636	29.33	$241,364	1.95				
year 3	Res:1			$1,000,000	8.10				
year 4	Res:1			$1,000,000	8.10				
year 5	Res:1			$1,000,000	8.10				
year 6	Res:1			$1,000,000	8.10				
year 7	Res:1-2			$697,221	5.65	$302,779	2.42		
year 8	Res:2					$1,000,000	8.00		
year 9	Res:2-3					$948,325	7.58	$51,675	0.32
year 10	Res:3							$1,000,000	6.21
year 11	Res:3-4							$882,079	5.47

Retention Basin Construction
Figure 10 illustrates the co-benefits of recreation, open space, and flood mitigation of nearby neighbourhoods as well as downstream flooding in the shipyard.

Figure 10: Greenspace with Co-benefit of Recreation (a) and Storm Water Retention (b)

Part 3: Return on Investment (ROI)

As illustrated in Figure 11 an analysis of return on investment includes the over time savings in reduction in mortality, reduction in need to house displaced populations, and over time health savings stemming from reduced acute injury, reduced exacerbation of chronic conditions, and reduced prevalence of mental illness.

Figure 11: High-level Process for Quantifying Return on Investment (ROI)

Damage
Table 4 shows that, over the course of 31 years, the entirety of 217 parcels with single family residential units are bought out, averaging 7 residential properties per year and 15.5 units per block.

Table 4: Residential Units by Damage State

	Residences Purchased	Substantial	Moderate	Slight
Average (31 years):	7.00	4.41	2.07	0.52
Average (14 blocks):	15.50	9.77	4.58	1.15
Total	217.00	136.79 (63.0%)	64.17 (29.6%)	16.04 (7.4%)

Replacement & Repair
Table 5 presents the repair and replacement costs savings associated with a single storm and are derived from the composite damage estimates, market price for repair or replacement, and escalation.

Table 5: Replacement & Repair Costs x Damage State

	Substantial		Moderate		Slight	
	Units	Costs	Units	Costs	Units	Costs
Average (31 years):	4.41	$596,040	2.07	$137,343	0.52	$7,430
Average (14 blocks):	9.77	$1,319,804	4.58	$304,116	1.15	$16,453
Total	136.79	$18,477,254	64.17	$4,257,629	16.04	$230,345

Mortality

Table 6: Mortality & Costs x Damage State

	Substantial		Moderate		Slight	
	Mortality	Costs	Mortality	Costs	Mortality	Costs
Average (31 years):	1.33	$16,119	0.33	$3,780	0.01	$236
Average (14 blocks):	2.95	$35,692	0.74	$8,371	0.02	$523
Total	22.06	$499,699	5.17	$117,203	0.32	$7,324

Displaced Persons

Table 7: Displaced Persons & Costs

	Persons Avoiding Displacement	Displaced Persons x Damage State		Displacement Cost Savings	Displacement Cost x Damage State	
		Substantial	Moderate		Substantial	Moderate
Avg. (31 years):	15.56	10.59	4.97	$267,234	$229,978	$37,256
Avg. (14 blocks):	34.45	23.45	11.00	$591,733	$509,238	$82,495
Total	482.30	328.30	154.00	$8,284,264	$7,129,327	$1,154,937

Acute Injury

Table 8: Acute Injuries & Costs by Damage State

	Persons Avoiding Acute Injury	Substantial		Moderate		Slight	
		Acute Injuries	Treatment Costs	Acute Injuries	Treatment Costs	Acute Injuries	Treatment Costs
Avg. (31 years):	2.12	1.78	$124,542	0.33	$23,368	0.01	$730
Avg. (14 blocks):	4.70	3.94	$275,772	0.74	$51,746	0.02	$1,617
Total	65.82	55.15	$3,860,813	10.35	$724,438	0.32	$22,636

Chronic Conditions

Table 9: Exacerbated Conditions & Costs by Damage State

	Persons Avoiding Exacer-bation	Substantial		Moderate		Slight	
		Worsened Condition	Treatment Costs	Worsened Condition	Treatment Costs	Worsened Condition	Treatment Costs
Avg. (31 years):	1.89	1.42	$36,295	0.42	$10,641	0.05	$1,330
Avg. (14 blocks):	4.19	3.15	$80,368	0.92	$23,563	0.12	$2,945
Total	58.68	44.12	$1,125,151	12.94	$329,878	1.62	$41,230

Mental Illness

Table 10: Mental Illness & Costs by Damage State

	Persons Avoiding Mental Illness	Substantial		Moderate		Slight	
		Mental Illness	Treatment Costs	Mental Illness	Treatment Costs	Mental Illness	Treatment Costs
Avg. (31 years):	2.54	1.96	$34,249	0.50	$8,763	0.08	$1,460
Avg. (14 blocks):	5.46	4.33	$75,837	1.11	$19,405	0.18	$3,234
Total	78.78	60.67	$1,061,724	15.52	$271,664	2.59	$45,272

ROI Summary
The acquisition costs are approximately 32.6m dollars. The total savings costs are approximately 39.3m dollars, representing a summation of 8.3m (21 percent) displacement savings, 8.1m (21 percent) wellbeing savings, and 22.9m (58 percent) property savings, thus yielding a 1.21 positive return on investment. Notable though, this return assumes a single severe storm event; the return will markedly increase with each subsequent event. Further, this return does not account for the positive co-benefits of clustered greenspace related to parks and recreation, habitat, and quality of life. If the greenspace is further leveraged as a water retention basin, then this added construction cost of 20.0m dollars to the initial 32.6m dollars acquisition costs, yields a negative return on investment of 0.75. Again, though, this return also assumes a single severe storm event and does not account for reduced flooding in nearby neighborhoods and downstream flooding at the shipyard, both of which may add significant savings.