Ecological and Socio-Economic Valuation of the Ecosystem Services Provided by a Multifunctional Green Infrastructure for Flood Mitigation

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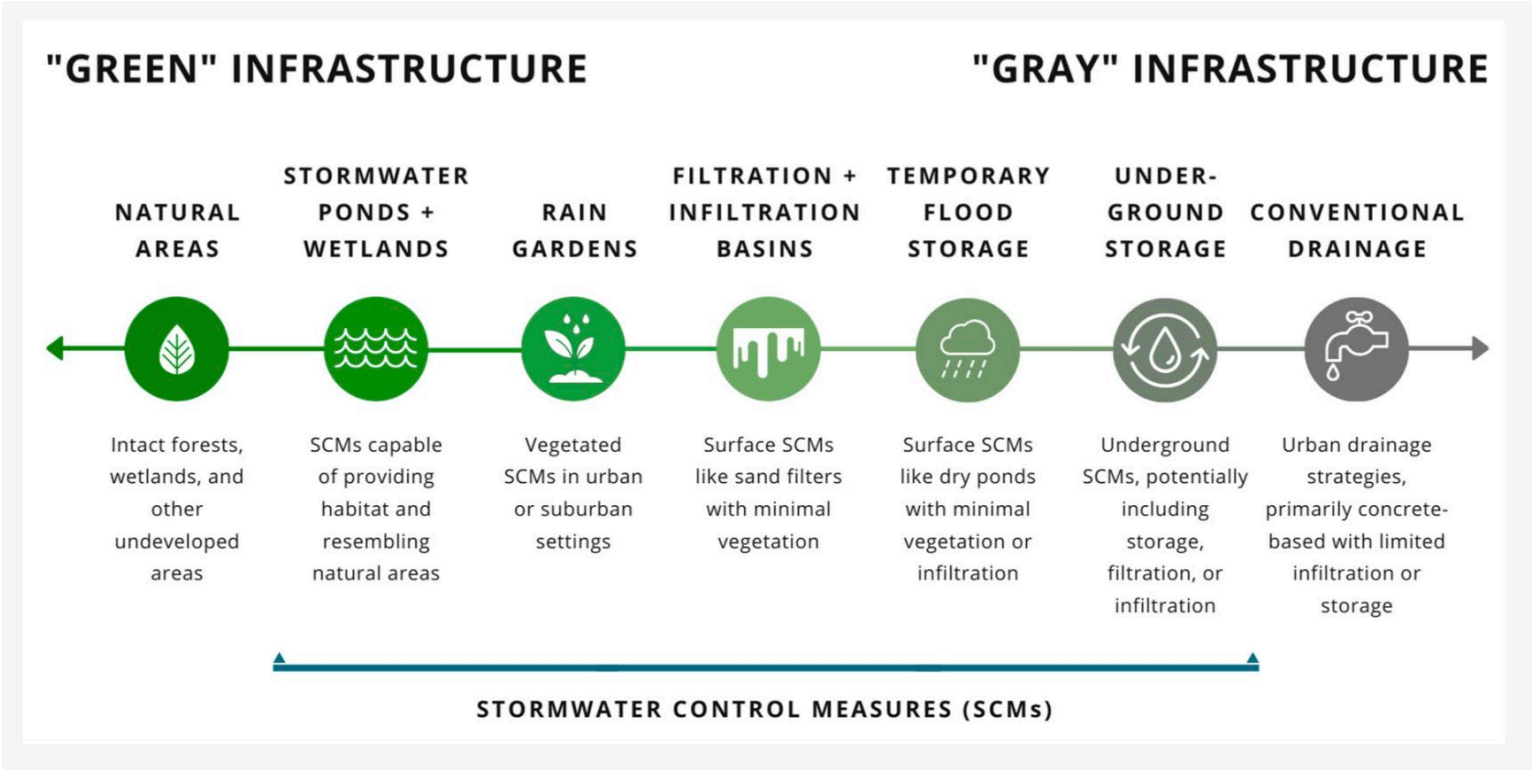
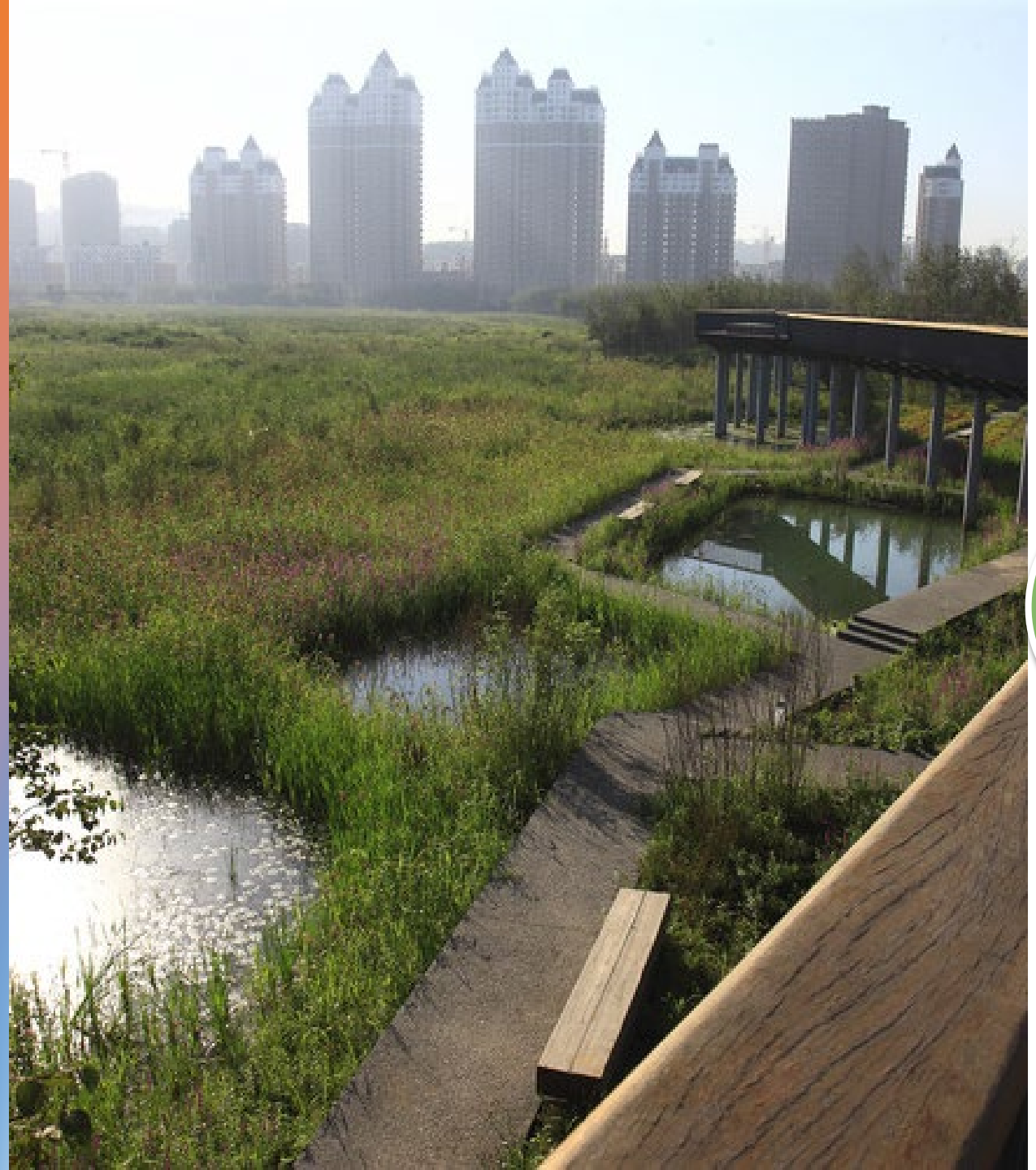
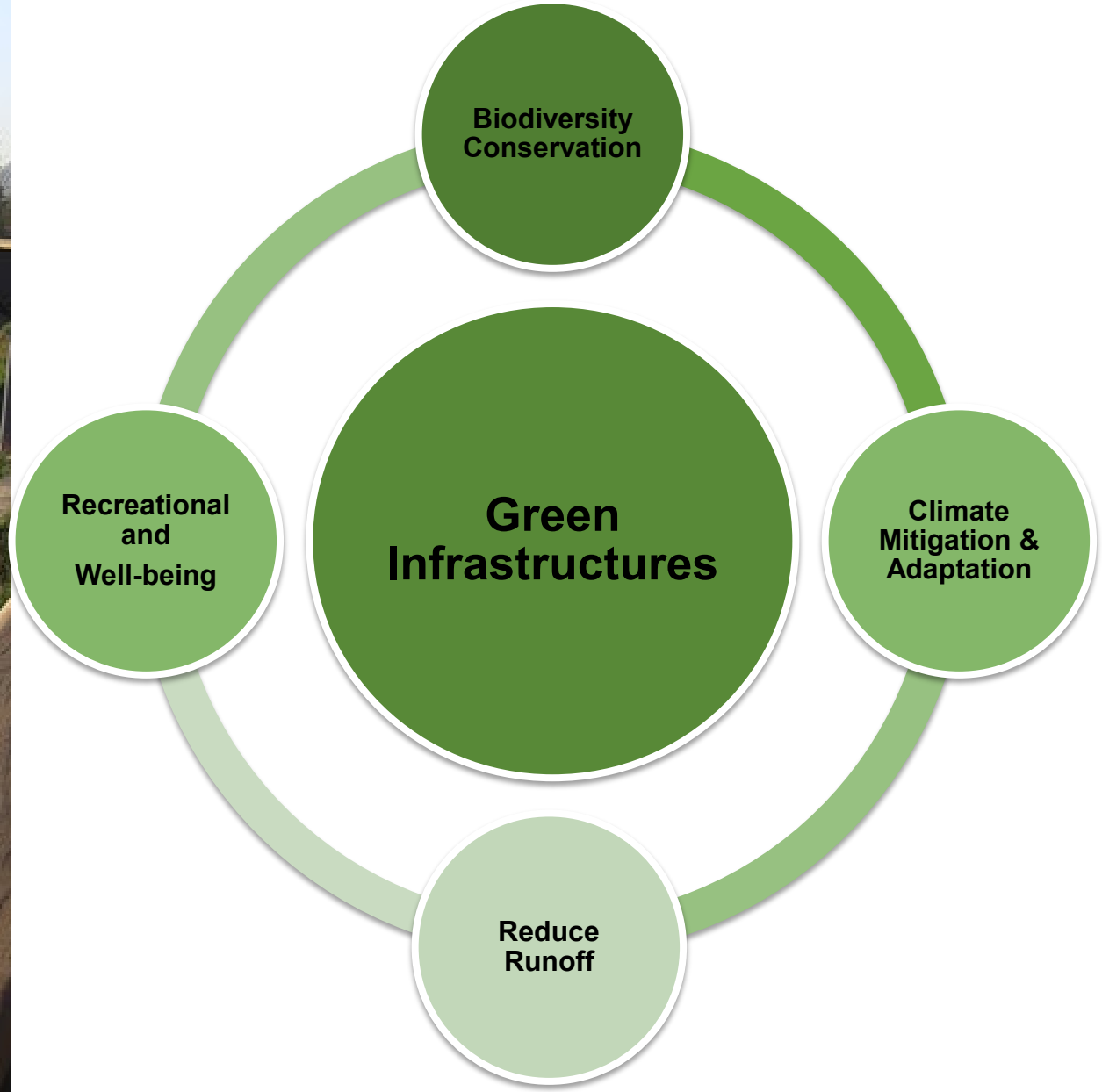
Urban Flooding
A Growing Threat

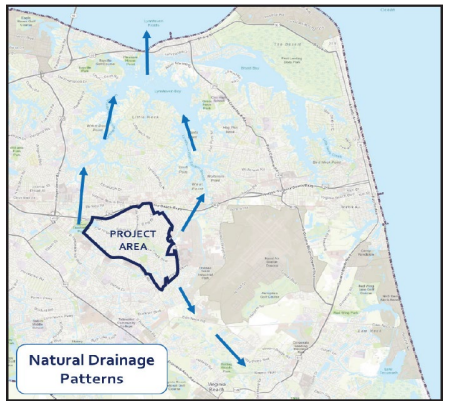
- 75% of U.S. cities are expected to face increasing flood risks due to climate change.
- $9 billion in annual damages (FEMA, 2023).
- In the last decade, flood-related disasters cost over $150 billion in recovery efforts.
- Disproportionate impact on low-income and minority communities.
- Overwhelms urban drainage systems, exacerbating pollution and degrading water quality.

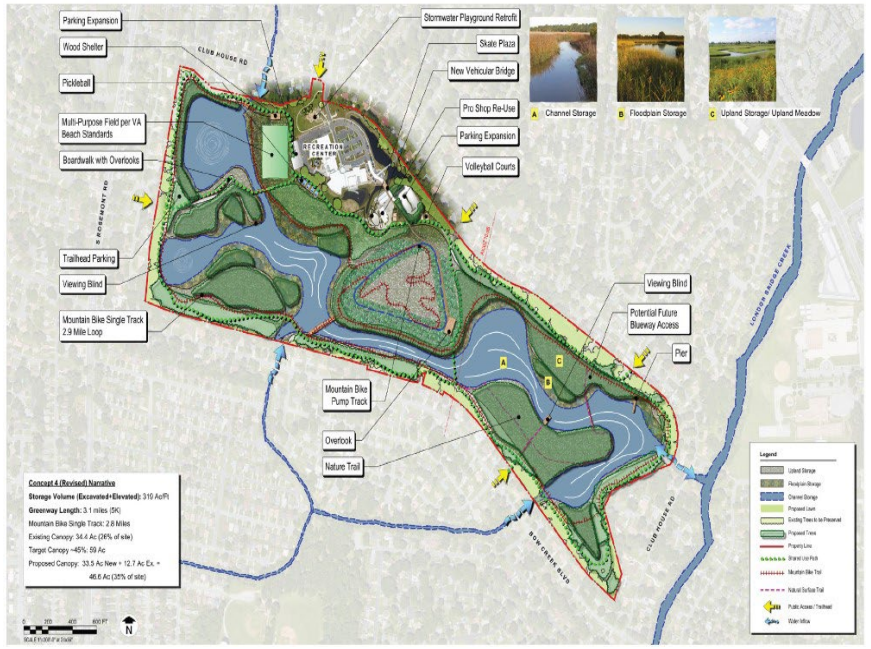


Grey vs Green Infrastructures?




Biodiversity Conservation
Recreational and Well-being
Green Infrastructures
Climate Mitigation & Adaptation
Reduce Runoff





Study Site: Bow Creek Golf Course, Virginia Beach, VA

- The city-owned Bow Creek Golf Course of approximately 55 hectares is located in the City of Virginia Beach
- The golf course is surrounded by neighborhoods characterized by low elevations.
- These areas are impacted by severe flooding due to the compound effect of rainfall and storm tides.

Climate Adaptation Challenges in Coastal VA

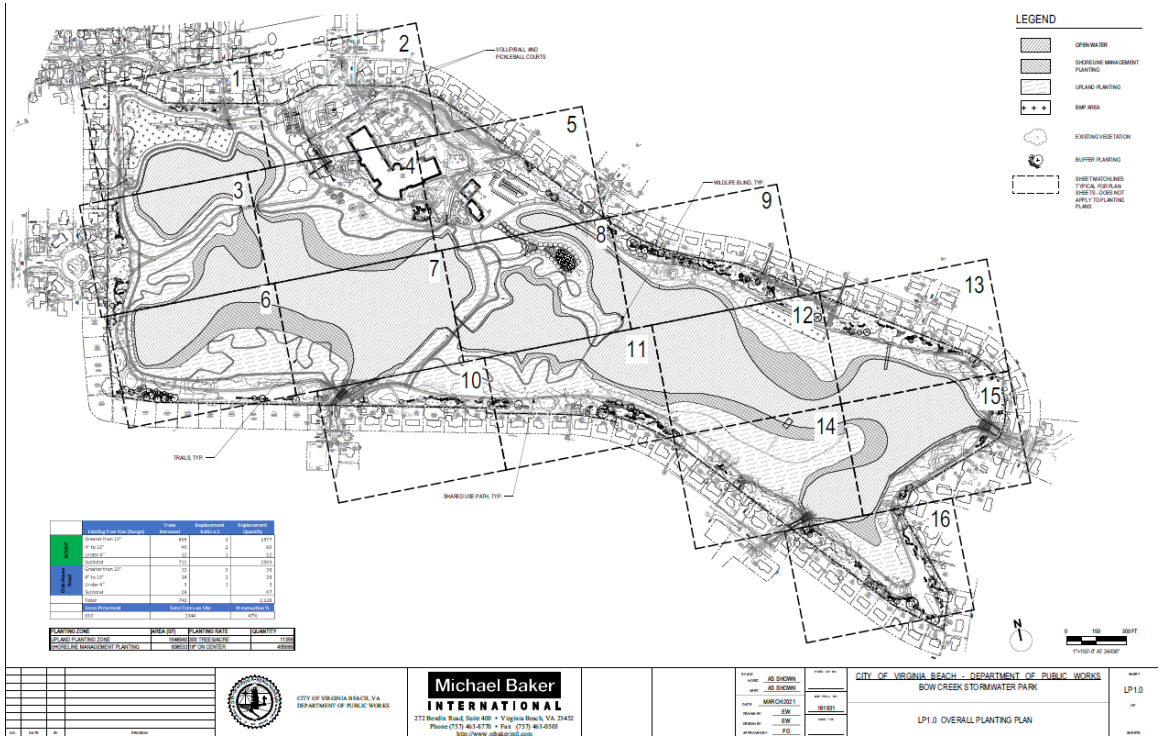
The City of Virginia Beach and the Hampton Roads region (VA, USA) are grappling with significant environmental challenges, primarily driven by the highest rate of sea level rise in the U.S. East Coast.

Sea Level Wise Program: comprehensive initiative aims to enhance the city's resilience to sea level rise and associated flooding.

Proactively integrating nature-based solutions

Ecological and Socio-Economic Valuation of Ecosystem Services

Temperature Mitigation	EnviMET software: three-dimensional software model for simulating complex urban environments
Flood Mitigation	PCSWMM Hydrology and Hydraulic (H&H) model employed iteratively to devise a recommended solution for drainage improvements
Ecological Benefits	Shannon-Wiener and Simpson Indices InVEST Pollination Model
Environmental Quality	Hedonic Price methods



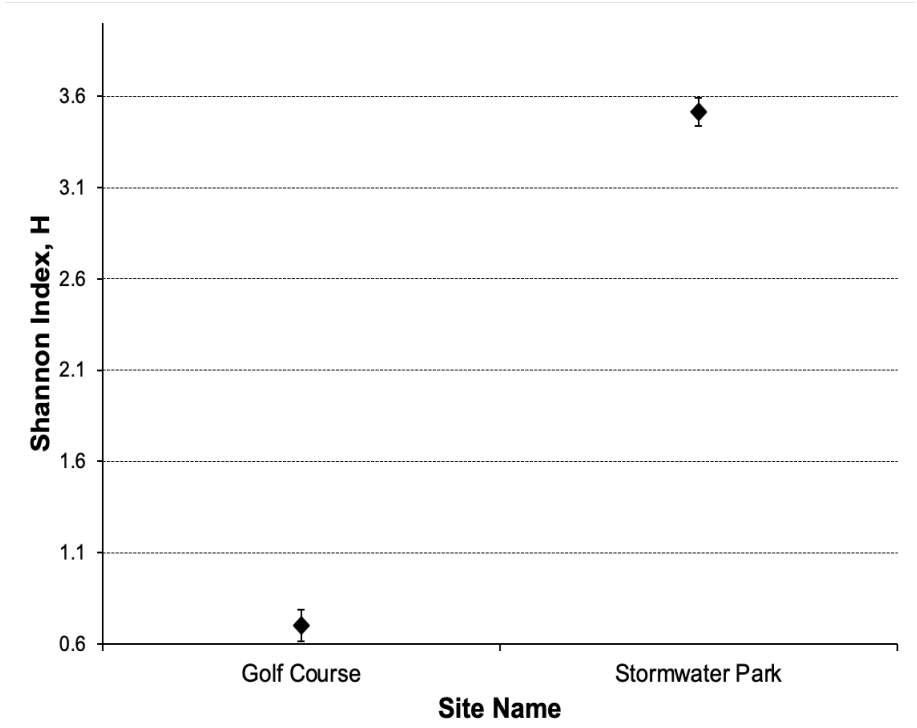
Section	10-year storm			100-year storm		
	Roadway Flooding* (km)	Change From Baseline by Section	Change by Section (%)	Simulated Flooded Structures	Change From Baseline by Section	Change by Section (%)
Baseline	12.7			601		
Section I	10.9	1.8	14%	452	149	25%
Section II	10.3	0.6	5%	306	146	24%
Section III	10.3	0	0%	303	3	0.5%
Total		2.4	19%		298	49.5%

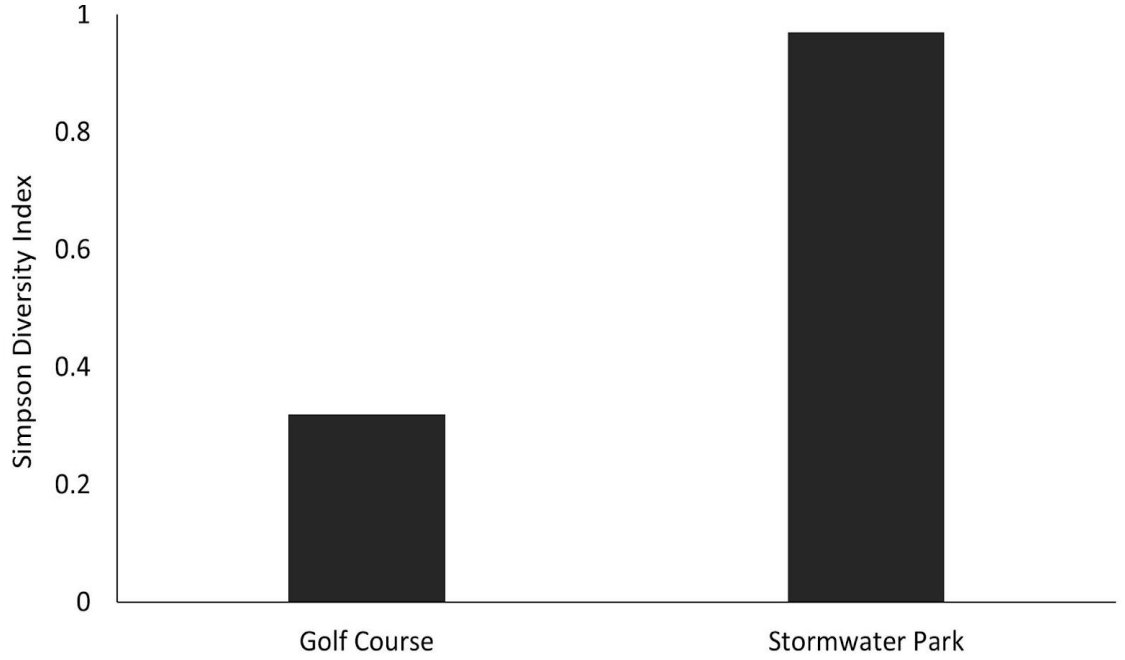
Flood Mitigation Service

- The golf course conversion will create additional water storage
- Predicted structure flooding reduction of approximately 50%
- Roadway flooding reduction of approximately 20%.

Ecological Benefits

The difference of plant diversity between the golf course and stormwater park is highly significant ($\alpha < 0.01$) (Hutcheson t-statistic = -59.207, df = 600.36, p-value < 2.2e-16)



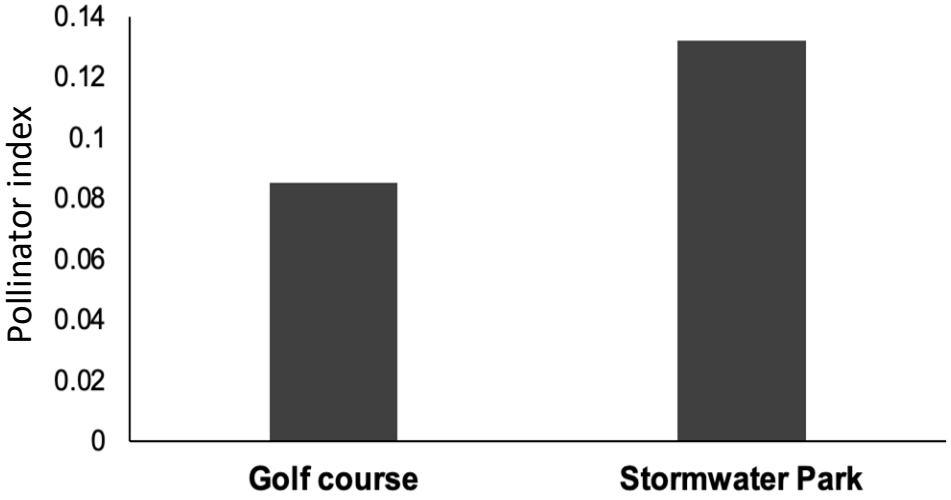


Pollinators abundance

The InVEST model estimates potential pollinator supply based on the availability of nesting and floral resources and relative abundance of different pollinator species.

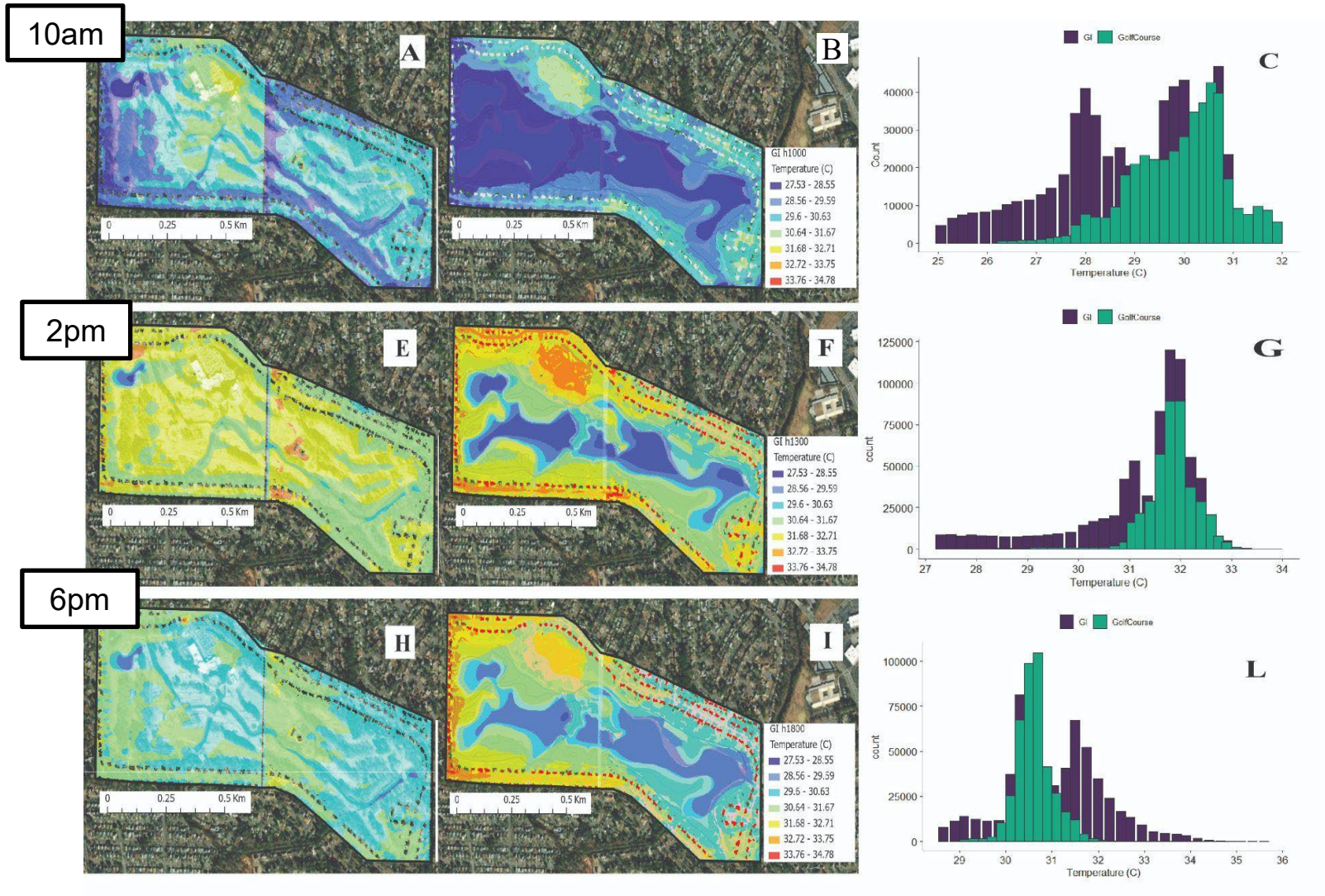
The index of pollinator abundance increased more than 55% in the stormwater park

The stormwater park will serve as a significant hotspot for biodiversity supporting a wide variety of native species and providing crucial habitats for pollinators, birds, and other wildlife.



Temperature Mitigation

- Air temperature was strongly influenced by the ground surface type.
- Areas covered by vegetation and water bodies exhibited lower temperatures compared to impervious surfaces.
- Histograms of temperature distribution show GI scenario consistently exhibiting a broader temperature range and a higher frequency of lower temperatures.



Environmental Quality & Amenities

The average price for houses within the 1500m buffer of the stormwater park is $274,312.4.

Thus a 4.5% increase results in approximately $12,618.37 average increase in housing price for houses within walking distance (1500m) to the park.

Since 2023-01-01, there are 401 houses closed within 1500m buffer of the stormwater park, the total housing appreciation almost 5.1 million dollars.

The tax revenue from the increased property value for local government is 1.0175/100 *5.1 million = $51,892.5

Cost-Benefit Analysis

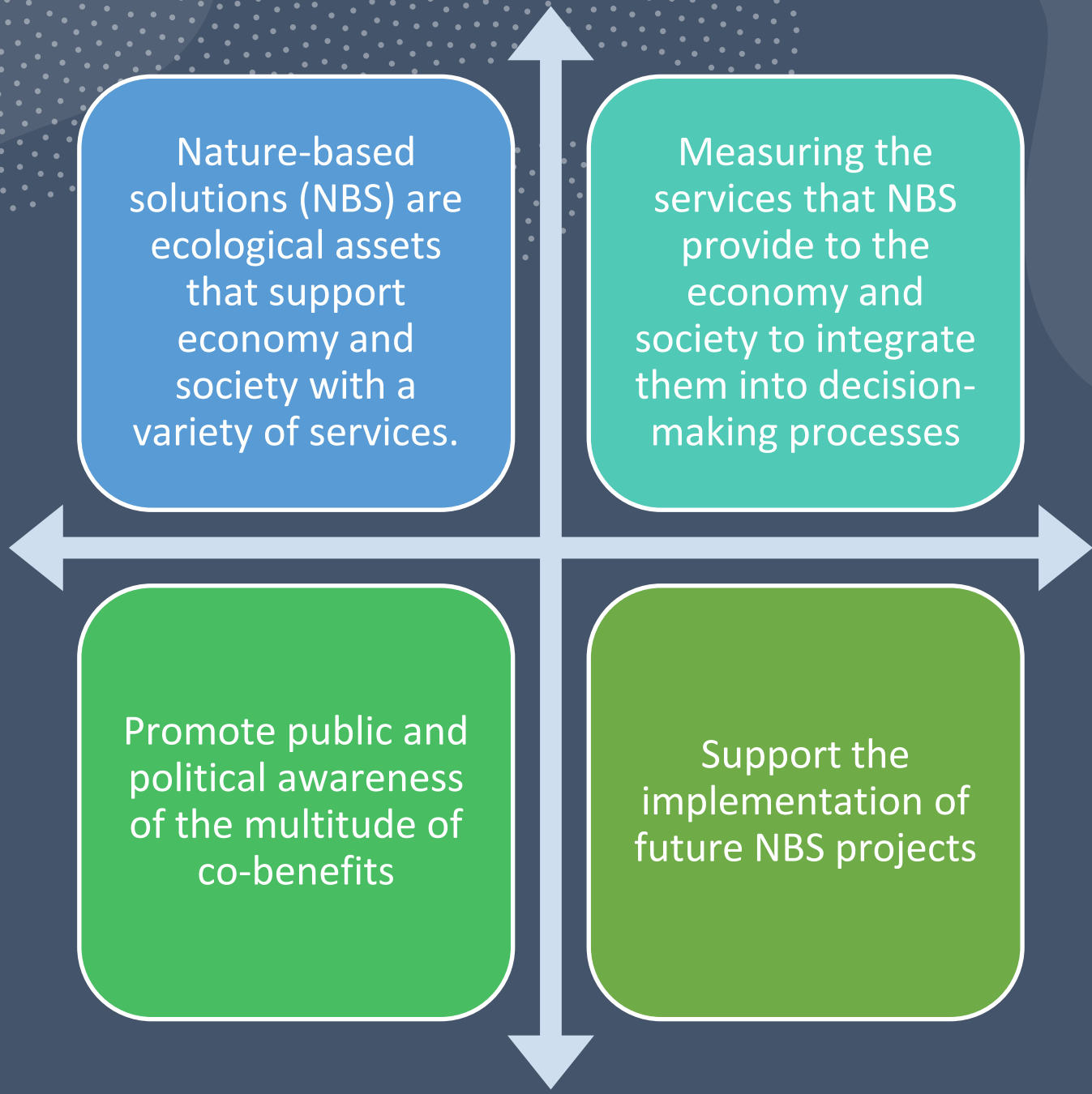
- **Economic Benefits Considered:**
  - Flood mitigation
  - Housing price appreciation
  - Ecosystem services (pollinators abundance)
  - Construction-related revenue
- **Methodology:**
  - Calculated benefit-cost ratio (BCR)
  - Construction benefits: One-time lump sum (3-year period)
  - Annual benefits projected over 10-, 20-, and 30-year periods
- **Discounting Future Benefits:**
  - 5% discount rate applied to project future benefits
  - Reflects conservative estimate for declining interest rates
- **Key Insight:**
  - Present value approach ensures a conservative lower bound for BCR.

Golf Course Conversion

- **Project Cost Source:**
  - Virginia Beach Flood Protection Program Bond Referendum Analysis (2021)-Old Dominion University (ICAR & Dragas Center)
- **Transferred Economic Valuations:**
  - **Pollination Services:**
    - Data from Breeze et al. (2015)
    - UK Willingness to Pay (WTP): £13.4/taxpayer
    - Adjusted for inflation and converted to USD for Virginia Beach
  - **Flood Mitigation:**
    - Data from Bin and Landry (2013)
    - Risk premium on properties post-flood: 5.7%-8.8%

	Current	10 years	20 years	30 years
Cost	$45,344,744	$45,344,744	$45,344,744	$45,344,744
Benefit (Construction)	$66,141,553	$66,141,553	$66,141,553	$66,141,553
Benefit (Flood mitigation)	$6,344,569.87	$6,344,569.87	$6,344,569.87	$6,344,569.87
Benefit (Ecosystem Services)	$34,702,639.34	$72,941,025.83	$115,428,121.93	$157,915,218.03
Benefit-cost ratio (baseline)	1.459	1.459	1.459	1.459
Benefit-cost ratio (including ecosystem services)	2.36	3.21	4.14	5.08
Benefit-cost ratio (Present Value)	2.36	2.59	2.56	2.40

Relevance of this study



Thank you!

- **Evie Zhang (ODU-Economic Department)**
- **City of Virginia Beach**
- **Michael Baker International**

Let’s be in touch!

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