APPENDIX I: OVERVIEW OF LAND-USE LAW IN NEW YORK STATE

IN NEW YORK, MUNICIPALITIES HAVE specific authority under specific sections of the General City Law, Town and Village Law to adopt comprehensive plans, zoning laws, subdivisions, site plan regulations. They also have general authority under the Municipal Home Rule Law to protect public health, safety and welfare, and the physical environment.

This gives local government the power to control land use, as long as its actions are consistent with a comprehensive plan or a well considered plan, through actions such as:

- Review of subdivision plans and site plans and the adoption of zoning laws.
- Establish overlay districts and special districts under the zoning law enabling legislation. Under zoning overlay districts, special zoning districts or special use permits, the municipality may place conditions on certain uses in a sensitive area. The provisions of special districts and uses may be amended to require special reviews or districts conditions.
- Use of cluster subdivisions or conservation subdivisions. They can be used by municipalities that have subdivisions regulations in place to reduce the percentage of impervious surface and provide open space and natural areas that are useful for managing storm water runoff.
- Adoption of floodplain regulations and wetland and watercourse protection laws to restrict land uses near streams and wetlands to control runoff into water bodies.

When a law is adopted under NYS Home rule (article 2, section 10), rather than as an ordinance under NY General City Town, Village law, it has the same status as an act of legislature. It must be filed with the Secretary of State and can be made effective immediately.

Building construction in New York State is regulated by the Uniform Fire Prevention and Building Code. Each municipality is responsible for administrating and enforcing the Uniform Code. Localities enact legislation to provide for the building permits, construction inspections, and certificates of occupancy to administer the code. Administration and enforcement of the code is performed by the local building inspector or Code Enforcement Officer.

Intermunicipal agreements are allowed under General Municipal Law Article 5-G, which states two or more municipalities may enter into agreement to undertake any activity that is allowed for individual municipalities under general or special laws.

Roles of Local Government

Local governing body:

Authorized to adopt and amend zoning ordinances, subdivision regulations, site plan controls, and special permit provisions, as well as, wetlands ordinances, historic district protections, and open space plans. It may create local boards and agencies and decide what authority to give them. If the boards below are not created by the governing body then the governing body assumes their roles.

Planning boards: Review subdivision and site plans and any special material submitted with plans. If so authorized by local governing board they can review Special Use Permits and place conditions on projects such as requiring storm water management controls as long as they are consistent with comprehensive plan and zoning law.

Zoning Board of Appeals:

The body authorized to grant variances and interpret provisions of the zoning law — its jurisdiction is appellate only and limited by statute to consideration of variance applications and interpretation of the zoning law.

Environmental Review:

SEQR may be conducted by governing board, planning board or ZBA depending on which board has jurisdiction over the permit or funding approval.

Code Enforcement Officer: applies local land use laws, issues building and other permits, and enforces the law.

Country Water Quality Coordinating Committee:

In many counties this body coordinates local storm water management with regional planning councils, watershed groups, and other local groups — and usually includes representation from SWCD staff, USDA NRCS, CCE, EMCs, DEC, and county planning staff. In other counties watershed groups exist in lieu of a coordinating committee.

APPENDIX II: FUTURE CLIMATE IN THE HREW (2030)

HERE WE CHARACTERIZE CLIMATE in the HREW over the next 20 years. Our characterization is based on the scientific consensus around a mid-case (A1B) global emissions scenario developed by hundreds of qualified scientists who participated in the Intergovernmental Panel on Climate Change (IPCC) assessment.[49] Nonetheless, we should keep in mind that we cannot and do not speak with certainty on the future of this, or any other highly complex and dynamic system. We do note though, that the documented changes and trends in historical indicators of climate in the HREW climate over the last 100 years are remarkably consistent with what scientists have predicted for the region as a result of human-induced climate change globally. Furthermore, the international scientific community has reached broad consensus that higher northern latitudes are warming more than the global average, indicating that the HREW could well experience even more dramatic temperature increases and associated effects in the future than are indicated here.

Nancy Kennedy

Climate and Sea-level in 2030

The year is 2030, and the climate in the HREW has undergone significant change in keeping with trends evident today. The region still experiences an annual cycle of four changing seasons, yet the character and timing of seasonal change is noticeably different. Average annual temperatures are now 2º F higher than in 2008 and more than 3º F warmer in winter.[50] Consecutive days over 90º F in the summer endure more often and for longer periods, while in the winter days below 0º F now occur only a handful of times each year.

Generally, the timing and character of the seasons has shifted. Winter is shorter, while spring and summer are longer. The first freeze arrives a day or two later in the fall, and the winter ice-out date comes earlier by a full week. Warmer temperatures in late winter mean that spring arrives earlier — along with the first appearance of robins and Trillium flowers. The first leaf date arrives on average four days earlier,[51] and first bloom date three days earlier.[52] Though the summer season now lasts nearly two weeks longer,[53] and the growing season is now five days longer than it was at the turn of the century (driven primarily by the last frost date in spring arriving six days earlier),[54] spring events are increasingly out of sync. (For example, breeding trout populations in the HREW are in significant decline — not only because stream temperatures are warming beyond their tolerance range, but because critical food resources for hatchling trout, such as caddis and mayfly eggs and larvae, have evolved earlier breeding and emergence schedules in response to the warming environmental conditions faster than trout can evolve in response, and so are no longer available as a food source when trout hatchlings emerge and need them.[55] Or to cite another example, in 2024, the region's Empire Apple crops were destroyed when a particularly warm late winter caused a very early bloom of fruit trees, which were then decimated by a sudden early-spring frost.)

Although traditionally marked by predictable seasonal transitions, in 2030, these transitions are less reliably predictable and routine. The higher temperatures have significantly affected the hydrological system, and in 2030, there is both more annual precipitation, and more of it falls during heavier precipitation events that are less evenly spread out over the course of the seasons.[56] As a result, while there is more total precipitation, there are also some spells of inadequate rainfall and periods of modest, short term drought. There is also more year-over-year variability, with one year featuring frequent floods, and the next dry spells. These seasonal changes in precipitation patterns are especially evident in the winter.

HREW winters are still generally cold and snowy, but significantly less so. Average annual snowfall has declined by 10 inches across the region,[57] even though total winter precipitation (defined as all forms of rain and snowfall) has increased. More precipitation is falling as rain. During the 20th century, rainfall in the region averaged 2-3 inches each month, but now the winter average is 5 inches of rain per month — and so in 2030, the region's winter is now defined as much by heavy rainfall events as it is by snowstorms.[58] The warmer winters also cause snow to melt more quickly, and snow cover in the HREW has decreased by 14-19 days since 2001.[59] Most obvious to residents is that the first major snows melt too quickly or arrive too late for the holiday season. The lack of winter snowfall and snow cover has positive and negative impacts — negative for the skiing industry and skiers, but positive for town snow removal budgets. Also welcome is the noticeable decline in snow-related accidents and fatalities.

Since winter ice and snow melt earlier, the peak river flow arrives four days earlier than it did in 2000.[60] Increases in overall winter precipitation and the frequency and intensity of winter precipitation events also means that the region experiences more frequent and more intense incidents of late winter and spring flooding. Earlier peak spring flows also lead to lower summer flows, and by late July, water levels for the region's lakes and rivers more frequently reach drought-like levels. The water in the Hudson River is generally less clear in the summer, due to lower summer flows and increased shore erosion caused by more frequent and more intense precipitation events year-round. A few native fish species have been put on the endangered list due to low summer flows and the increase of average river temperatures by several degrees. These changed patterns in temperature and precipitation have also enabled new non-native plants and animals to establish themselves in the region, subtly changing the landscape.

True drought is still rare in the HREW, but neighboring regions farther inland and farther northeast now suffer annual dry spells. Since the HREW growing season is nearly a week longer, some traditional plants and crops have a difficult time in late summer when the summer heat evaporates more moisture from the soil.[61] Average Hudson River water temperatures have increased by several degrees Fahrenheit, with important consequences for the river's ecology. Fish species such as Tomcod that were near the southern limits of their distribution have disappeared from the Hudson.[62] When increased needs for irrigation meet a particularly low summer river flow and below average summer rainfall, the region experiences heightened competition for water, and unusual algal blooms in rivers, lakes, and ponds, along with heightened stress on fish populations due to deoxygenation and higher water temperatures.

Many new plant and animal species from southern regions, including kudzu and other invasive species,[63] have appeared in the Valley and some have established permanent populations. Winters are still cold enough to prevent the successful colonization of many others.

Over the previous 25 years, mean sea levels rose another 3 inches,[64] pushing the Hudson's salt water front farther north in general, but especially in the summer months. In contrast, the spring melt pushes the salt front farther south in the late winter and early spring. The continued warming of ocean surface temperatures by another 2º F contributes to more active storm seasons in the Atlantic Ocean,[65] and strong windstorms during hurricane season have affected the HREW's forests and public infrastructure in recent years. The combined rise in sea level and hurricane events heightens worry that a major tidal surge could overwhelm the lower Hudson valley.

Existing trends in regional temperature change continued during the first three decades of the 21st century. The average annual regional temperature increase across the entire 20th century — 1.9º F — doubled again in just two decades (from 2010-2030). The complex feedback effects of a warming earth are transforming the HREW's climate, and by 2030, broad acceptance of these changes has replaced traditional expectations. For the rest of the 21st century and beyond, the extent and rate of further climate change in the HREW will be critically dependent on global actions taken to limit and reduce greenhouse gas concentrations in the atmosphere.

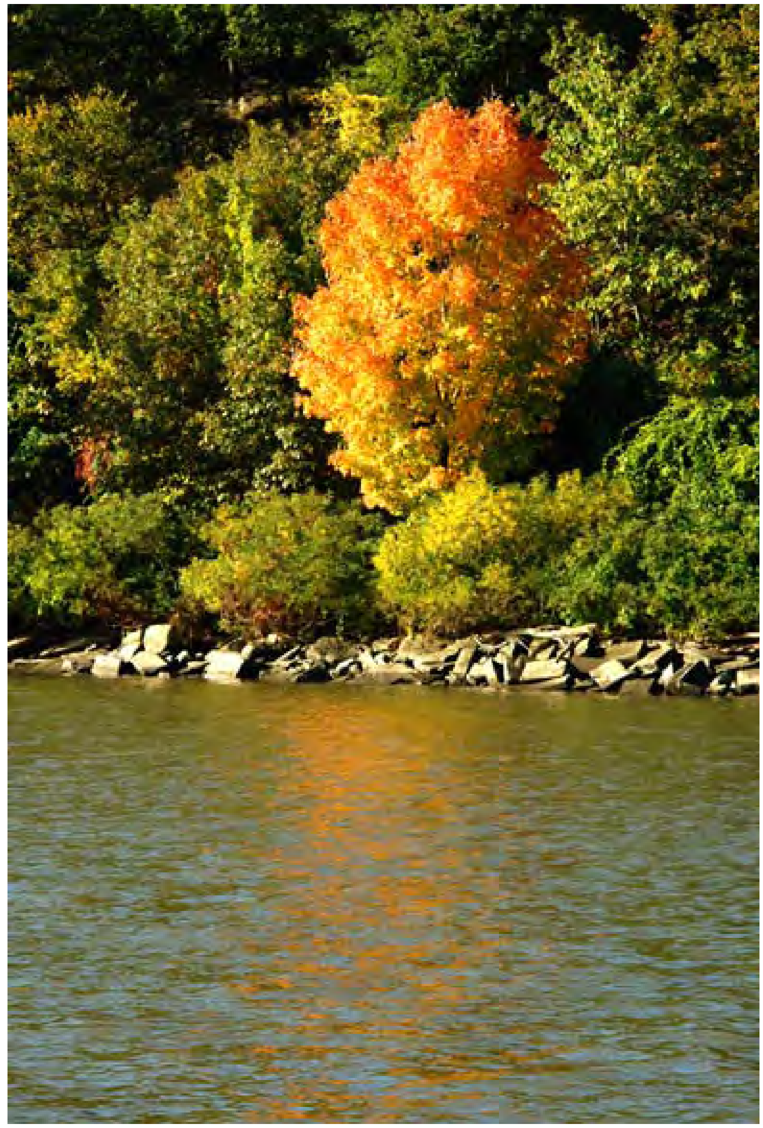
APPENDIX III: FUTURE CLIMATE IN THE HREW (2100)

THE INTERGOVERNMENTAL PANEL on Climate Change (IPCC) produced six scenarios for various emissions levels and subsequent climate change during the 21st century.[66] The IPCC assumptions and scenarios have been reproduced and imbedded in numerous reports on climate change, including the regional study by the Northeast Climate Impacts Assessment (NECIA) in a report, "Climate Change in the U.S. Northeast." In the effort to understand potential climate change specific to the Hudson River Estuary Watershed in 2100, the projections below are the range of figures from the NECIA adaptation of IPCC scenarios, A1F1 and B1, for the Northeast U.S. region. The A1F1 is the high emissions scenario and B1, the low emissions scenario. (When a range is given without reference to the emission scenario, it is the lowest and highest estimates of both scenarios combined.)

The continuing climb in average global temperatures is expected to drive a varied and nuanced set of changes to the global climate. Over the remainder of the 21st century, the increase in global annual mean temperature is expected to increase anywhere from 3.5-12.5º F — depending to a significant extent upon the trajectory of future greenhouse gas emissions. By way of comparison, the Earth's last major ice age experienced average annual temperatures 6-9º F cooler than our contemporary era. In other words, even in a low emissions scenario, the stage appears set for the HREW to experience unprecedented set of changes to its climate within the next 100 years.

For example, from 1961-1990 there were on average only 17 summer days each year above 90º F in NYC, and only 1 or 2 days above 100º F. However, the NECIA estimates that by 2100, cities in the Northeast U.S. could experience more than 30 days above 90º F each year in the lower emissions scenario, and up to 60 or 70 days in a high emissions scenario. Similarly, the NECIA estimates that by 2100, northeast cities may experiences 3-9 days above 100º F in the low emissions scenario, and a startling 14-28 days above 100º F in the high emissions scenario. Compounding the actual rise in temperatures, greater humidity in the future is expected to make summer days feel even hotter. By 2100, summer in the Northeast could feel much more like the today's summer in the Southern United States.

Maureen Plainfield



Average annual winter temperatures in the Northeast are poised to increase 6-10º F by 2070-2099. The warming will cause greater opportunities for winter evaporation, which will energize precipitation patterns significantly. Winter precipitation is expected to increase 25% in the low emissions scenario and 40% in the high emissions scenario by the end of the 21st century. Additionally, the increased intensity of precipitation events could make winter floods a regular concern. Yet in a region with historically abundant water resources, large increases in winter precipitation in the high emissions scenario could happen in parallel with yearly short term droughts (1-3 months). In effect, the hydrological system in the HREW is set to radically transform this century, and the feedback effects on plant, animal and aquatic species are likely to be dramatic. Additionally, the days of snow cover in the HREW could be as few as 5-10 per year, compared to historical averages of up to 45 days per year. A future HREW with little winter snow on the ground will radically alter winter traditions, sports, and tourism.

The earlier ice and snow-melt will cause peak spring flow volumes to course through the HREW region at ever earlier dates. Currently, the center-of-flow date in the Northeast is March 25, but in the last decades of the 21st century, the half-way point of river flow could be more than a week earlier in the low emissions scenario and more than 2 weeks earlier in the high emissions scenario. In both scenarios, the subsequent July through October river flows will be significantly reduced, and will regularly fall well below the United States Fish and Wildlife low-flow threshold mark during the summer and fall. These trends — combined with significantly higher average river temperatures — would indicate that we should expect many aquatic species that currently depend on these waterways to be under severe stress, and that new warm water, less flow-dependent species from outside these waterways may successfully colonize them, with uncertain implications for native biodiversity loss. Moreover, since dissolved oxygen levels decline at higher temperatures, the Hudson River may return to periods of fish kills or at least greater stress in localized areas.

The seasonal shift in 2100 will be remarkably obvious to Hudson River Valley elders. As winter becomes shorter and wetter, the arrival of spring will come 1-3 weeks earlier. However, the welcome warming of spring will be cut short as summer erupts on the scene 1-3 weeks earlier. Summer is set to extend its reign — running longer by 2-3 weeks in the fall. One hundred years from now in a high emissions scenario, summer-like temperatures in the Hudson Valley may extend into the shoulder months by an additional 6 weeks

Maureen Plainfield

each year. The growing season in the region is likely to be 1-3 weeks longer as well, and depending on complex relationships between moisture, heat and storms, the effects on agriculture could be positive or negative, but will undoubtedly be powerful.

The HREW is especially vulnerable to climate change due to the region's proximity to the Atlantic Ocean, as well as the interconnectedness of mean sea levels and the Hudson River. By 2100, the average ocean surface temperature is expected to increase on average 4-5º F in the low emissions scenario and 8.5-10º F in the high emissions scenario. While scientists are divided and uncertain on the climate and weather consequences of rising ocean surface temperatures, if ocean surface temperatures do rise dramatically, at least some scientists think it could result in more frequent and intense ocean storms and hurricanes. If this were to be the case, when combined with a rising sea level, it would mean an expanding threat to the lower HREW via more frequent and severe storm surges, and an increasingly likely possibility that thousands or millions of people might need periodic evacuation from the New York metropolitan area.

While the impact of warmer ocean temperatures on the frequency and severity of storms is not fully understood, it is certain that warmer oceans will result in the thermal expansion of water, and a further rise in sea levels. The low emission scenario suggests that mean sea level in 2100 will be nearly 1 foot higher, while the high emissions scenario expects an increase of nearly 20 inches. These projections are currently under review, as climate scientists assimilate and analyze new evidence that polar ice-melt may be happening much faster than existing models predicted. As a result, the projections for mean sea level rise reflected in current IPCC models could turn out to be overly conservative.

Either way, the projections are dramatic, even in the low emissions scenario. Significantly, the high emissions scenario describes a world in which fossil energy continues to be the dominant source of energy production. In contrast, the low emissions scenario assumes a global economy that undergoes significant technological change towards efficient and low emissions energy production, as well as a radical shift towards a less material and resource intensive global economy during the 21st century. The high emissions scenario is "business as usual," while the low emissions scenario is a world in which global climate change is taken seriously and our economy undergoes a major re-tooling and transformation. The dramatic projections for the HREW in the high emissions scenario — an increase in average temperatures up to 12º F, mean sea level rise up to 2 feet, more than 60 days of above 90º F per year, only 5-10 days of snow cover per year, and an increase in average ocean surface temperatures up to 10º F is, at the least, a profound warning that continuing "business as usual" risks unprecedented disaster for our children and grandchildren. And even with the dramatic changes in global energy resources and use described in the low emissions scenario, the scientific consensus reflected in the IPCC scenarios reflects a degree of climate change that is unprecedented in modern human history.

APPENDIX IV: CLIMATE CHANGE ASSUMPTIONS

THE RISING WATERS CLIMATE WORKGROUP followed the guidelines below in selecting assumptions for future climate in the HREW. A summary table of the changes is included:

A The Intergovernmental Panel on Climate Change (IPCC) mid-case AIB scenario was selected as the global climate scenario.

The A1 story in the IPCC scenarios was selected because the basic framework uses macro assumptions born directly from trends we see in today's world: economic growth especially in emerging markets, increasing global population until mid 21st century, new and more efficient technologies, globalization, and (some) income convergence globally. The other storylines outlined in the IPCC reports offer scenarios where the future diverges more drastically from current trends.

The A1 storyline has three versions, A1Fl, A1T and A1B. Since new, more efficient and non-fossil fuel energy technologies are emerging now, it would be unwise to predict a future only with energy production from fossil fuel sources, as does A1Fl. It is also not reasonable to predict a full energy revolution in the next 20 years (the span of our analysis) in which the global economy fully adopted all non-fossil energy sources, as does scenario A1T. Therefore, "the middle of the road" scenario is A1B, which assumes a balance between fossil and non-fossil energy sources.

Note: All of the IPCC scenarios produce very similar outcomes when projected out over the next 10-20 years. Only in the longer-term future, 40-100 years, do the scenarios diverge dramatically.

B The A1B scenario projections from the NYC DEP report were used for sea level rise, temperature change, and precipitation change because they are specific to southeastern New York and our selected global scenario.

C Figures from the NECIA report were used for changes in winter temperature, snow cover, heat waves, extreme rainfall, drought, and seasonal changes because they are consistent with the Northeast region which was not available from the NYC DEP report. NECIA doesn't project specifically for the A1B scenario so figures roughly at the midpoint (i.e. mid range) of the projected range of the NECIA "high" and "low" emissions scenarios were selected.

Climate scientists have made it clear that regional impacts will be different from globally averaged projections. We decided to use projections from two excellent regional assessments (NYC DEP by Columbia; and NECIA by a variety of scientists). Both have sound, peer-reviewed methodologies and cite specific figures or ranges for the Hudson Valley and Northeastern US. As an added convenience, the NYC DEP report even uses the A1B scenario for its projections.

Note: A1B scenario projections from the NYC DEP report are estimated from graphics.

D Where no figures are cited in either report, qualitative descriptions of change consistent with both NECIA and NYC DEP reports were used.

E Changes described in the table are projected differences from the climate we currently experience today.

The baseline period for the NECIA projections is 1961-1990. The baseline period for the NYC DEP projections is 1970-1999. In their text both reports use their baselines to describe the climate we currently experience today, thus for the purposes of this exercise we've assumed that the effect of the different baselines is minimal and that changes described are projected differences from the climate we currently experience today.

Climate Projections Summary

Report	Average Annual Temperature		Average Annual Temperature	
	2030	2100	2030	2100
Global: IPCC projections (base period 1980-1999)	Est. increase 1.4°F (Increase ≈ 0.72°F/decade for the next 2 decades	Increase 1.98-11.52°F	Warmer	Warmer
North America: IPCC projections	Increase 1.8-5.4°F by 2010 to 2039 "time slice"	Increase 3.6-5.4°F except high latitudes closer to 9°F	Warming greatest in winter at high latitudes	Warming greatest in winter at high latitudes
National or Northeast-specific: US Climate Change Science Program	Est. increase at least ≈ 1.2°F (Avg. temp. for the US risen near 0.6°F/decade in the past few decades	Increase 3.2°F-7.2+°F	Increase in winter temps. Decrease in # of days with frost. Less cold days and nights.	Avg. # of frost days decreases by about one month
Northeast-specific: NE Climate Impacts Assessment (temps relative to 1961-1990	Increase 2.4-2.6°F	Increase 5.0-9.5°F	Increase 3.3-3.4°F	Increase 5.8-9.8°F
NYC and Watershed region: NYC DEP Climate Assessment and Action Plan (base period 1970-1999)	Increase 2.0°F by 2020s. Temps in the city may be higher.	Increase 7.5-8°F by 2080s. Temps in the city may be higher.	Winter temps warming rapidly. Columbia models indicate summer temps likely to increase more than winter temps.	Winter temps warming rapidly. Columbia models indicate summer temps likely to increase more than winter temps.

Climate Projections Summary

Report	Sea Level 2030	Sea Level 2100	Precipitation 2030	Precipitation 2100
Global: IPCC projections (base period 1980-1999)	Est. increase at least 1.6-2.7". (Rate from 1961-2003: 1.8 ± 0.5 mm/yr, 1993-2003: ≈ 3.1 mm (0.12")/yr.) (Does not include rapid change in ice flow.)	Increase 7-23" (Does not include rapid change in ice flow)	Increase. Greater percentage of extreme events.	Increase. Greater percentage of extreme events.
North America: IPCC projections	Increase	13.8"+/- 4.7" global rise in a mid-range scenario (A1B). Eastern US change should be close to the global mean. (Does not include rapid change in ice flow.)	Increase in annual avg. precipitation. Greater changes in extremes than annual average.	Increase in annual avg. precipitation. Greater changes in extremes than annual average.
National or Northeast-specific: US Climate Change Science Program	Est. increase at least 1.8-2.7". (Sea level has been rising 0.08-0.12"/year (2.03-3.1mm) on US Atlantic and Gulf coasts.) (Does not include rapid change in ice flow.)	Uses IPCC projection of 7-23". Sea level in Northeast should rise close to the global mean.	Increase in annual avg. (Annual US precip. totals increased 6-7% in the 20th century. Heaviest precip. increased by ≈ 20%. This increase is most apparent in Eastern US.)	Increase in annual avg. Precip. less frequent but more intense. Increase in autumn and winter precip. in Northern states.
Northeast-specific: NE Climate Impacts Assessment (temps relative to 1961-1990	Increase 1.6-2.4" (Does not include rapid change in ice flow.)	Increase 4-33" (Does not include rapid change in ice flow.)	Increase in winter precip. Max precip. in 5 days increases approx. 10%. Approx. 1 more day of rain > 2"/yr. Precip. intensity increases 7-8%.	4" increase in anual avg. 20-30% increase in winter precip. Max precip. in 5 days increases approx. 20%. Approx 1.5 more days of rain > 2"/yr. Precip. intensity increases 12-13%
NYC and Watershed region: NYC DEP Climate Assessment and Action Plan (base period 1970-1999)	3.2" in 2020s (Does not account for recent research finding increased rates of ice melt.)	16.5" in 2080s (Does not account for recent research finding increased rates of ice melt.)	0.7% increase for 2020s. Greater variability across models for precip. in 2020s. Rainfall events larger and more intense.	8.6% increase for 2080s. Seasonal precip. may be greater in winter than summer. Rainfall events larger and more intense.

Snow		Hurricanes/Strong Storms	
2030	2100	2030	2100
Avg. area of snowcover will contract.	Avg. area of snowcover will contract.	Increase in intensity, possible change in frequency and pole-ward shift.	Increase in intensity, possible change in frequency and pole-ward shift.
Decrease in snow cover, more rain in winter.	Decrease in snow cover, more rain in winter.	Extra tropical storms more intense, perhaps less frequent. Hurricanes have more landfall, stronger winds. More extreme wave heights. No clear trend in hurricane frequency.	Extra tropical storms more intense, perhaps less frequent. Hurricanes have more landfall, stronger winds. More extreme wave heights. No clear trend in hurricane frequency.
Snow cover projected to decrease. Increase in snowstorms in the near-term in Northeast as snowstorm pattern moves northward.	Snow season and snow depth very likely to decrease across entire US.	Increase in storm intensity, rainfall, and ext. wave heights along coasts. For each 1°C (1.8°F) increase in tropical SST, core rainfall rates will increase by 6-18% and surface wind speeds of strongest hurricanes will increase by ≈ 1-8%. No clear trend in hurricane freq.	Increase in storm intensity, rainfall, and ext. wave heights along coasts. For each 1°C (1.8°F) increase in tropical SST, core rainfall rates will increase by 6-18% and surface wind speeds of strongest hurricanes will increase by ≈ 1-8%. No clear trend in hurricane freq.
Area of snowcover will contract. More precip. as rain instead of snow. Denser, slushier snow.	Area of snowcover will contract. More precip. as rain instead of snow. South and western Northeast experience 5-10 snow-covered days in winter, compared with 10-45 days historically. 25-50% shorter snow season.	Increase in intensity. No definitive link between warming and hurricane frequency.	Increase in intensity. Potential for one more strong winter storm per year under A1F1 scenario. No definitive link between warming and hurricane frequency.
More precip. as rain instead of snow.	More precip. as rain instead of snow.	Increased likelihood of strong storms, but not currently well-modeled by GCMs.	Increased likelihood of strong storms, but not currently well-modeled by GCMs.

Climate Projections Summary

Report	Heat Waves 2030	Heat Waves 2100	Drought 2030	Drought 2100
Global: IPCC projections (base period 1980-1999)	More frequent.	More frequent.	Uncertain.	Uncertain.
North America: IPCC projections	Warm extremes more frequent and stronger.	Warm extremes more frequent and stronger.	Increase in risk of drought.	Increase in risk of drought.
National or Northeast-specific: US Climate Change Science Program	Very likely more hot days, nights, and heat waves.	Very likely more hot days, nights, and heat waves.	Droughts increase primarily Southwestern US. Gradual increasing trend in Northeast. (No consistent historical trend across all US.)	Droughts increase primarily Southwestern US.
Northeast-specific: NE Climate Impacts Assessment (temps relative to 1961-1990	On avg. 22-24 days over 90°F, 2-4 days over 100°F (currently ≈ 15 days over 90°F, 2 days over 100°F in NYC).	On avg. 38-70 days over 90°F, ≈ 7-25 days over 100°F (currently ≈ 15 days over 90°, 2 days over 100° in NYC).	Little change. (Currently short-term (1-3 mo.) drought 1 in 2-3 years, medium (3-6 mo.) 1 in 15 years).	Short-term (1-3 mo.) drought up to once a year. Increase in medium term (3-6 mo.) drought frequency.
NYC and Watershed region: NYC DEP Climate Assessment and Action Plan (base period 1970-1999)	Extreme heat is likely to increase in frequency, intensity, and duration.	Extreme heat is likely to increase in frequency, intensity, and duration.	Drought may become more frequent and intense.	Drought may become more frequent and intense.

Timing of Seasons		Water Temps	
2030	2100	2030	2100
Shorter winters and longer growing seasons.	Shorter winters and longer growing seasons.	n/a	n/a
Lengthening growing seasons.	Lengthening growing seasons.	Increase in water temps.	Simulated future surface and bottom water temps of lakes, reservoirs, rivers, and estuaries throughout North America consistently increase from 3.6-12.6°F.
Earlier spring snow-melt.	Earlier spring snow-melt.	Est. increase at least 0.09°F in SST. Est. increase at least 0.16-1.8°F in lakes and rivers. (1961-2003 global ocean temp. from the surface to a depth of 700 m rose by 0.18°F. Water temps have warmed by 0.36-3.6°F in US lakes and rivers since the 1960s.)	Increase in water temps. Unusually high SST episodes likely to become more frequent and widespread.
Spring earlier by 2-4+ days (≈ 1-2 days/decade from 1960-2001). Growing season longer by 5+ days (≈ 2.4 days/decade from 1970-2000).	Spring 1-3 weeks earlier, growing season 4-6 weeks longer, peak streamflow 10 days to 2 weeks earlier.	SST 2+°F warmer (SST riser almost 2°F since 1970 in ME).	SST 4-8°F warmer.
Earlier spring	Earlier spring	Increased water temperatures in Harbor and watershed tributaries downstream of dams.	Increased water temperatures in Harbor and watershed tributaries downstream of dams.

APPENDIX V: COST EFFICIENCY OF SOME SUSTAINABLE METHODS FOR ADAPTING TO CLIMATE CHANGE

WHEN MITIGATING AND ADAPTING to climate change impacts, natural systems and clean, green technologies are often cost efficient. In this article, we examine three ways of looking at the costs of dealing with some of the problems involved in adapting our infrastructure to climate change. First, green approaches, like rain gardens and green roofs, are cost effective at handling rainfall runoff. Second, a decentralized approach to stormwater management fares well when compared to end-of-pipe solutions. And native gardens hold the key to more economical and environmentally friendly landscaping.

Low Impact Development in urban areas

Methods of Low Impact Development (LID) have risen as an alternative to traditional flood and pollution control methods. Traditional stormwater management is based on capturing, transporting, and sometime treating rainfall runoff that is generated on impervious surfaces. When runoff exceeds available conveyance capacity in combined stormwater/sanitary systems, combined sewer overflows (CSOs) occur, resulting in discharge of pollutants to water bodies (Montalto et al. 2007). In contrast, LID is an approach based on distributing works throughout a watershed that handle and treat runoff as locally as possible to reduce the volume of stormwater runoff in developed areas. Examples of LID include rain gardens, green roofs and agri-roofs, rain barrels, redirected downspouts, and impervious paving.

The slowness of LID to catch on among urban planners is partly due to the misperception that LID is costly to retrofit in a densely populated, urban setting. In fact, the installation costs of LID are competitive with conventional practices, and LID can be more cost-effective on a per-volume basis compared to conventional stormwater management methods.

There are some added costs when using LID. For instance, a decentralized CSO abatement system would require municipal inspectors visiting LID measures on private property. Also, buy-in would have to occur on the part of a significant number of citizens as these measures are most effective when applied on private land. However, there are many advantages to LID beyond the basic cost savings. LID supports the reuse of rainwater which reduces the demand for drinking water supplies with all of its associated capital and maintenance costs. Soil erosion is also reduced. Recharging of groundwater resources is increased. Some LID techniques, such as green

Low Impact Development vs. Conventional Costs

Type of land surface	Design Type	Installation cost / unit (US$ 1999)	Storage Cost (US$/liter)
Parking areas	Conventional	0.23	2.43
	LID (porous pavement)	0.25	0.16
Sidewalks	Conventional	0.19	1.96
	LID (porous concrete)	0.19	0.16
Streets	Conventional	0.25	2.58
	LID (porous pavement)	0.26	0.22
Storage	1 million gallon CSO tank	5.00	1.20
	Infiltration/detention basins	5.00	0.26

Source: Heaney et al. 2002

roofs, provide cooling to buildings and reduce the heat island effect. Vegetated LID technologies, such as rain gardens, increase biological activity and support the greening of our cities (Montalto et al. 2007).

Advantages of Distributed Storage

A study conducted in the United Kingdom revealed a general trend of decreasing costs for alleviating flooding the further upstream a control measure is applied within the watershed (Andoh and Declerck 1999). The detailed cost analysis was performed for a 20-hectare subwatershed for both steep and flat catchments. Three general approaches were evaluated: Conventional, involving detention works built at the downstream section of the watershed near the receiving water body ("end of pipe"); Distributed Storage, using many smaller detention facilities scattered throughout the watershed, closer to the source of runoff; and Source Control, involving measures like pervious paving, which decrease the volume of runoff into the stormwater collection system. Of these strategies, Source Control was the least expensive (approx. £300,000) followed by Distributed Storage (approx. £610,000-£700,000) , followed by the Conventional approach (approx. £880,000 - £1,100,000).

Some of the advantages of distributed storage are significant but harder to quantify in financial terms. For instance, most existing systems locate storage at downstream locations which are at lower elevations than upstream locations. As a result, these detention facilities are vulnerable to the effects of sea level rise and may not function as originally designed due to associated higher receiving water elevations. Also, lack of space to build large storage tanks is a common problem in urban areas, which have competing land use needs.

Cost Comparison of Traditional vs. Native Gardens

Landscape design is another area where an approach that honors the guiding principles of sustainability is cost competitive with traditional methods.

In 2003, the City of Santa Anna, California, performed a study of the relative costs of sustainable versus traditional gardening practices (ASLA et al. 2008). The city installed two gardens side by side in adjacent front yards, approximately 1,900 feet in each garden. While the construction costs of the native garden ($16,700) were higher than the traditional garden ($12,400), for a five-year monitoring period water use, green waste, and maintenance labor were significantly lower for the native garden.

Garden Cost Comparison

	Traditional garden	Native garden
Water use (gallons)	283,981	64,396
Green waste (pounds)	647.5	219.0
Maintenance labor (US dollars)	$223.22	$70.44

Twelve benefits (or "ecosystem services") of sustainable site design are (ASLA et al. 2008):

1. **Global climate regulation** — sequester greenhouse gases
2. **Local climate regulation** — reduce heat island effect
3. **Air and water cleansing** — remove pollutants
4. **Water supply and regulation** — store water watersheds and aquifers
5. **Erosion and sediment control** — retain soil
6. **Hazard mitigation** — prevent damage from flooding and other disasters
7. **Pollination** — support reproduction of crops and other plants
8. **Habitat functions** — provide refuge for plants and animals
9. **Waste decomposition and treatment** — perform natural composting
10. **Human and well-being benefits** — enhance physical, mental, and social well-being through interaction with nature
11. **Food and renewable non-food products** — yield items for human use
12. **Cultural benefits** — enhance cultural, educational, aesthetic, and spiritual experiences

These benefits are often overlooked in cost analyses that focus on human-engineered systems.

APPENDIX VI: MORE INFORMATION ON THE SCENARIO ELEMENTS

PREDETERMINED ELEMENTS

IN ADDITION TO CLIMATE CHANGE IMPACTS described above, three other "pre-determined elements" were identified as critically important for future climate change preparedness and adaptation in the Hudson Valley. They include:

Aging Public Infrastructure

Today, human well-being in the HREW is dependent upon complex, interconnected networks of human-constructed infrastructure. Much of this infrastructure was built decades ago, and is now aging and in need of repair or replacement. In the past, design and engineering standards called for much of this infrastructure to be built to withstand a particular standard for extreme weather events such as storms, droughts, and heat waves. Often, the design standard was to build infrastructure to withstand the "100 year event" — i.e., an extreme storm or flood that could be expected to arrive once every 100 years or so. Yet, evidence regarding climate change suggests that what was once a 100-year event may occur more frequently in the future, and that the intensity of true 100-year events in the future may be more extreme. Given this evidence, it is logical that all existing infrastructure repair and replacement standards and timetables should be reconsidered. As a result, there are at least two kinds of impacts of climate change for existing and future infrastructure: on the one hand, climate change in the HREW may have direct impacts on existing infrastructure through extreme weather and rising sea-levels — especially so perhaps, for that infrastructure which is getting old, and in need of repair and replacement; on the other hand, anticipation of climate change could also have significant impacts on design and engineering standards for existing infrastructure repair and replacement, and on the timing of such investments.

The New York City Climate Change Adaptation Task Force identified four types of infrastructure that are especially vulnerable to climate change: transportation infrastructure, water and waste infrastructure, energy infrastructure and communications networks.[67] Those climate change impacts with the greatest potential to adversely affect infrastructure are (1) higher temperatures and heat waves, (2) intense and prolonged storm events, (3) flooding, and (4) droughts.[68] The risk to infrastructure is significantly heightened for coastal or lowland areas.

Transportation

New York is the seventh most densely populated state in the nation, and the transportation network in the HREW is similarly dense and complex. Sea-going vessels enter New York Harbor and carry very large quantities of goods up and down the Hudson River.[69] The highway system in the HREW covers 17,552 highway lane miles,[70] and the NY State Thruway runs snug along the west side of the Hudson River connecting NYC to the HREW and the state capital, Albany. At least eight major airports serve the HREW,[71] and five Metro North rail lines with roughly 70 stations connect the region to New York City.[72] The Amtrak passenger railway line runs directly along the scenic east side of the Hudson River and carries 1.25 million passengers annually through the HREW. The CSXT rail lines run along both sides of the Hudson, carrying 370,000 carloads of freight every year.[73] Additionally, the HREW boasts 1,971 bridges,[74] of which 10 are major crossings over the Hudson River itself. These most important bridges alone carry nearly 600,000 vehicles across the river every day.[75] Indeed, the transportation network in the HREW is critically important to life in the region. Even local and temporary disruptions to the system can have significant effects on regional health, economic productivity, and well-being. Breakdowns of an important hub for any length of time — a major port, a central rail station, a major international airport, or an important bridge — could have major consequences for the regional economy and public well-being.

The Transportation Research Board (TRB) conducted a study, *Potential Impacts of Climate Change on U.S. Transportation*, and concluded that among the various impacts of climate change, "Potentially, the greatest impact of climate change for North America's transportation systems will be the flooding of coastal roads, railways, transit systems, and runways because of global rising sea levels, coupled with storm surges and exacerbated in some locations by land subsidence."[76]

The report noted that the Atlantic coast was especially vulnerable. Although the transportation networks in the HREW are not located directly on the Atlantic Ocean, the low-lying areas of the HREW along the river share an intimate and direct relationship with sea level rise in the Atlantic Ocean. Transportation infrastructure which runs along the river — such as the Amtrak, CSX and Metro North and Hudson railroads; the ships, docks and ports on the Hudson; the NY Thruway; and the on-off ramps of major bridges — are especially vulnerable to flooding, increased erosion and storm surge. The TRB report also warns that extreme temperature increases could cause the misalignment of railroad tracks, as well as the warping, rutting, softening, or migration of paved roads and could compromise bridges through the thermal expansion of bridge joints.

Perhaps the most significant general threat to the region's infrastructure due to climate change arises as conditions emerge which fall outside or beyond design-to-withstand specifications. Most of the bridges on the Hudson River were built 40-80 years ago, and with design-to-withstand criteria associated with 100 or 150 year events. However, climate change is changing the frequency of the 100 year storm. We need to be aware that extreme events that were once very rare are becoming increasingly common, and more extreme — rendering past design-to-withstand criteria inadequate.

Water and Wastewater

The HREW is fortunate to have an abundance of freshwater resources. Nonetheless, the infrastructure required to deliver freshwater, treat wastewater and drain stormwater for 2.7 million residents of the HREW and 9 million residents of NYC[77] is immense and immensely critical. The network of groundwater (wells and springs) and surface water (reservoirs and the Hudson River) supply the demand, which is delivered by pipes or aqueducts. Once these freshwater supplies are distributed and consumed, the wastewater must be treated in order to protect surface and ground water quality. Wastewater is treated either by septic (in ground) systems or wastewater treatment facilities (WWTF). Finally, water infrastructure must capture, treat and drain storm water from heavy precipitation events and spring snow melt. Not surprisingly, the New

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York State Department of Environmental Conservation (NYS DEC) has announced that New York will require a $36 billion investment in municipal wastewater infrastructure over the next 20 years to meet these requirements.[78]

The 1,972 square mile NYC watershed — the area providing 1.3 billion gallons fresh water supplies each day to NYC — includes most of the HREW and three sizeable reservoirs systems: the Delaware System, the Catskills System and the Croton System.[79] Each system contains reservoirs that feed large tunnels and aqueducts carrying the water to NYC residents and neighboring municipalities. These reservoirs hold back water and sediments that would flow to the Hudson and the Delaware and divert the water 100 miles downstream to NYC.

The Hudson River itself drains an area of 13,390 square miles[80] and discharges on average 19,500 cubic feet of water per second at Poughkeepsie.[81] At least nine municipalities take their water directly from the Hudson; Waterford, Stillwater, Halfmoon, Poughkeepsie, Rhinebeck, Hyde Park, Green Island, Highland, Port Ewen, and Esopus. Many more municipalities discharge treated wastewater to the Hudson.[82]

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Some suburban and all urban areas have central water supplies and central sewage treatment. In some areas, the sewage system consists of a combined sanitary and storm water sewer. In those, both sewage and storm water flow through the same pipes to the WWTF. During intense precipitation events many WWTFs cannot handle the high flows, and the treatment plant overflows, sending a mixture of peak storm water runoff and untreated (raw) sewage into the receiving body. This is called "combined sewer overflow" or CSO. Often, for several days after severe storm flood events, poor water quality due to CSOs affects the Hudson River, and public beaches along the river are temporarily unfit for swimming.

The predicted impacts of climate change on the relationships described above are complex. Consequences to water quality and treatment in the scenarios we consider could have severe consequences for human health as well as the health of HREW ecosystems. The NYC Department of Environmental Protection's Climate Change Program, states that the greatest threats to NYC posed by climate change are likely impacts on water supply, drainage and wastewater infrastructure.

Especially important for water supply, drainage and wastewater treatment is the relationship between rising temperatures, sea level, and the hydrologic system. A higher average sea surface temperature causes sea water to expand slightly, resulting in modest increases in sea level. Since these increases can be readily estimated by the scientific community, we should be able to make appropriate shoreline infrastructure adjustments or relocate shoreline infrastructure on a planned basis. However, the impact of even modest incremental sea level rise may be compounded by periodic storm surge events — and further exacerbated by possible increases in the frequency and intensity of extreme storm events in the future due to climate change. As a result, existing infrastructure is vulnerable to periodic extreme storm events.

More significant sea level rise could occur if glacial melt rates increase in the northern hemisphere or if land-based polar ice sheets were to fail abruptly and drop into the ocean. However, current models used for predicting ocean sea level rise do not suggest such an occurrence within our time horizon, and we do not address such possibilities in our scenarios. However, it is worth remembering that while such events may be exceedingly unlikely, should they occur, they would have huge consequences. The rapid loss of Greenland's land-based ice would raise sea levels by tens of feet. Such catastrophic change would permanently inundate transportation, water, wastewater infrastructure, and much of the existing shoreline development throughout the HREW. For these reasons, contemplation of longer-term trends regarding warming and sea-level rise ought to be considered in making adaptive choices.

Higher average temperatures also alter patterns of evaporation and precipitation. More frequent and more intense precipitation events are expected in the future, leading to increased flooding. Characterizations of "10 year" and "100 year" storms are changing, along with our understanding of the implications for the flood plain. Although existing infrastructure designed for the historic 100-year storm may be able to handle a heavy precipitation event or a storm surge with higher sea levels, the infrastructure may be unequipped to handle future larger storm events, or the coincidence of a flood combined with a storm surge, especially in the spring, when high river flow typically occurs. In the aftermath of heavy precipitation events, water supplies may also experience greater threats from contamination due to flooding and storm water runoff, or due to flood plain encroachment closer to existing well intakes.

Although average annual precipitation volumes are predicted to rise slightly over the coming decades, longer rainless periods are predicted between storms. Freshwater is particularly affected by the relationship between temperatures and the hydrological system, with impacts on water quality, supply, and demand. For example, higher temperatures in summer months will increase demand for agricultural irrigation, lawn watering, and recreational use. Furthermore, warmer temperatures will deliver higher evaporative rates from open reservoirs during an extended rainless period. Greater variability in precipitation can also decrease the availability of water during dry spells. Groundwater will be affected by longer periods of drought and by intense rains when larger fractions of rain run off rather than soak in. Historically, some 80 percent of local precipitation falls in rain events of under about an inch per day. With fewer, but more intensive rainfalls, runoff rates are likely to increase with a commensurate loss of aquifer recharge. Water supply wells that rely on proximity to a stream or river may also be affected, because during droughts surface water elevations may be lower, and streams may be at lower base flow conditions. During intense rain events, the water surge will move through the system quickly, rather than slowly soaking into the ground and moving to the stream as base flow.

Energy

Similar to other types of infrastructure in the HREW, the energy supply and distribution networks are vulnerable to the impacts of climate change — especially with respect to extreme weather. Should storm surge disrupt imports to NY Harbor or severely damage oil offload and storage capacity, or prohibit travel up the Hudson to the Albany Port, the region would suffer shortages in energy services and supplies. Extreme storm events also jeopardize electricity transmission lines. And intense heat waves can overwhelm the electricity system's capacity to meet peak demand, causing disruptions in electricity service and potentially widespread power outages, such as the statewide power blackout in August 2003.

Important energy infrastructure includes oil and gas pipelines, ports, storage facilities, electric power generation stations, thousands of motor fueling stations and the web of distribution pipelines and power transmission lines that deliver energy to area homes and businesses. Its position as the gateway to both NYC and NY Harbor renders the HREW a critical region for the supply and distribution of energy.

New York produces only a tiny amount of crude oil — 34,000 barrels of crude from roughly 3,559 wells — and does not have a single refinery.[83] However, NY Harbor is the largest petroleum product hub in the United States, with a storage capacity of over 40 million barrels of refined petroleum products.[84] Needless to say, this makes NY Harbor one of New York's and the nation's most important and strategic sites for energy infrastructure. From the harbor, barges carry petroleum products up the Hudson River to Albany, and from there to the surrounding region. In 2007, the Port at Albany received roughly 28,900 metric tons of petroleum products.[85] Additional pipelines import crude oil and petroleum products into New York via Pennsylvania, the mid-West, and the Gulf Coast. Once the petroleum products are imported, an extensive transportation network distributes gasoline and diesel fuel to 6,700 motor fuel stations,[86] many of which are in the HREW where population densities are often high relative to other parts of the state. Concern over an oil supply disruption that occurred in the winter of 2000 spurred the President to create the Northeast Heating Oil Reserve to hold 10 days of consumption supply in case of future disruptions.[87]

New York consumed 5.2% of total U.S. natural gas consumption in 2007, yet, produced roughly one-third of the gas the state needs.[88] Not surprisingly, seven interstate natural gas pipelines from the north, west and south provide natural gas into the region. The Transcontinental, Tennessee, and Iroquois pipelines converge in Albany and run south to NYC.[89] These major interstate pipelines feed a tangled web of smaller gas distribution lines supplying homes and businesses in the HREW.

Electricity in NY is produced from a wide range of energy sources, including coal, oil, and natural gas, as well as hydroelectric and nuclear power. Niagara Falls with 2,253-megawatt production capacity contributes to the state being one of the largest hydroelectric power producers in the county.[90] The Hudson River itself is a significant source of hydroelectric power generation. Entergy operates two nuclear reactors producing commercial electricity in the HREW — Indian Point 2 and Indian Point 3. Although NY uses less electricity per capita than the country average, NY is still a net importer of electricity from its neighbors.[91]

Communication Technologies

Communication technologies — such as telephone, internet, and cell phones — are fully dependent on the supply of electricity. Should storm events, flooding or periods of high demand shut down the power grid, communication infrastructure would suffer. In an emergency situation, the inability to disseminate critical information for emergency relief and evacuation would multiply consequences. Even discrete, localized disruptions in electricity and communications services could produce relatively large economic and social impacts.

Strong HREW Linkages to New York City

Being so close and directly tied to New York City — one of the world's most densely populated and important economic and cultural hubs — inevitably ties the future fate of the HREW to the fate of the city. In 2005, the estimated Gross Metropolitan Product of NYC was $1.13 trillion,[92] making the city the second largest city economy in the world, as well as the largest regional economy in the United States. In 2006, half of New York State's population lived in New York City, where nearly 9 million people live in an area of only 303 square miles.[93] The scale of the interdependent energy, transportation, water and communications networks required to support such large and dense populations is both immense, and immensely complicated. As climate change occurs in the coming decades, understanding how these networks will be affected will be increasingly important for maintaining the population's ready access to food, water, electricity, heat, transportation, and emergency and medical services.

The existing physiography of New York and the resulting geography of the transportation networks foster an especially strong economic interdependence between NYC and the HREW. Most of what enters or exits NYC to or from other parts of the state does so through the HREW. In 1998, $703 billion worth of freight was transported to, from or within New York on the state's highways, railways, waterways and airways.[94] A significant majority of those goods traveled through the HREW to or from NYC. The value of transported freight in NYS is, by some estimates, expected to grow to $1.38 trillion worth of goods in 2010, and $2.35 trillion in 2020.[95] The economic links between the HREW and NYC arising from simple trade and transportation are significant, and expected to grow stronger in the future.

Although waterway transportation carries far less freight value than highways, airways and railways in NYS, the Hudson River acts as a profound link between the NY Harbor in NYC and the port in Albany. In 2007, the Port of Albany loaded 3.4 million metric tons of exports onto ships, while another 93,000 metric tons of imports were unloaded after traveling up the Hudson River from NY Harbor.[96]

The many HREW residents that commute to work in NYC every day also link the economy of the HREW to NYC. In 2000, 11.7 percent of employed Hudson Valley residents worked in New York City,[97] while 16.7 percent of lower Hudson Valley working residents commuted to New York City in the same year.[98] These commuters and their families depend profoundly on the income that the city provides and the trans-

Xiaoping Liang

portation networks that allow them access to these jobs. The Metro-North rail lines offer service in Rockland, Westchester, Putnam, Orange and Dutchess counties, in which roughly 70 stations directly connect these commuters to NYC. The landscape and lifestyle of the lower HREW is particularly influenced by close proximity to NYC. The southern-most HREW counties — Putnam, Rockland and Westchester — boast larger mean incomes, significantly denser populations and higher average home property values than the rest of the HREW.[99] Notably, however, commuting occurs in both directions and while there are more commuters traveling from the HREW to the city, there is also a trend towards "reverse commuting."

The number of commuters traveling from NYC to jobs in suburbs surrounding the city increased 12% between 2000 and 2005.[100] As in the 1970s, when an economic downturn caused many companies and industries in NYC to seek more cost-effective locations outside of the city, a similar trend to relocate offices in neighboring suburbs, such as the HREW is currently underway.[101] The movement of companies and workers to the HREW leads to local economic growth and supports the value of local property, and the need for expanding public and private infrastructure — and with that, the demand for more HREW development.

While transportation infrastructure underpins and supports the strong economic linkage between NYC and the HREW, other infrastructure networks, such as water, are also critically important. The NYC Watershed region provides all of the water used in NYC, as well as 85% of water in Westchester and 5-10% of water used in Orange, Putnam and Ulster counties. On any given day, 9.2 million people are supplied with an outstanding 1.3 billion gallons of water from the NYC Watershed.[102] Urban life in NYC and the southern counties of the HREW is possible due to this extensive freshwater infrastructure.

The potential for the impacts of climate change to disrupt transportation, water and energy infrastructure in NYC or between NYC and the HREW should be cause for serious concern. While no one can predict the specific timing of coming impacts, the pace of future impacts will be important for the character of the consequences. Any abrupt disruption of the transportation of goods, services, people, water, and energy to and from NYC would certainly have dramatic and immediate social and economic impacts. New York Harbor, the Port of Albany and other low-lying infrastructure along the Hudson River will be especially vulnerable to sudden storm events and flooding. In an emergency event, with large numbers of city residents evacuating to neighboring counties, the HREW could be called upon to house and feed large numbers of displaced persons. On the other hand, a gradual loss of reliability and confidence in the supply chains that city residents depend upon for food, water, heat and emergency services, could — over a course of years — conceivably lead to a steady rise in migration out of the city into HREW counties, with a cascade of consequences for life in the region, from impacts on infrastructure capacity, to job availability, housing, and ultimately the character and culture of the HREW. But while such a scenario may be fanciful, it is certain that reliable functioning infrastructure is critical to the social and economic health of the HREW. This infrastructure is aging and needs renewal and upgrade to meet the changing demands that will certainly be placed upon it due to coming impacts of future climate change. It is worth making special note that accomplishing this will require significant amounts of capital.

DRIVING FORCES

OUR PROCESS IDENTIFIED THE FOLLOWING critical forces shaping the future of climate change adaptation and preparedness in the Hudson Valley:

Land Use in Hudson Valley

Land use decisions are critical in determining the capacity of mixed-use landscapes to withstand and adapt to future climate changes. The impact of extreme weather events can be intensified or mitigated, depending on the character of local land use. Heat island effects, for example, are a well-known feature of urban landscapes, due to the relative paucity of cooling plant cover. Similarly, asphalt paving amplifies the volume and intensity of eroding runoff because the rain falling on asphalt cannot soak into the ground, but flows downhill toward the sea.

The character of a local economy and local trends in the value of alternative land uses are important factors in determining how land is ultimately used. Of special interest and concern are trends affecting the percentage of land capable of contributing to the valley's adaptive capacity. For example, over recent years, the Hudson Valley was witness to a steady influx of industry specific industrial parks, with biopharmaceuticals and microelectronics leading growth in the area. The growing economy also spurred rapid escalation in housing values in the Hudson Valley. Between 2003 and 2007 the average selling price increased from just under $400,000 to more than $550,000,[103] increasing the incentives for existing holders of agricultural or forest lands to sell their lands to developers.

In response to worries about land use and development, the New York State Greenway Act of 1991 established a voluntary regional compact to foster cooperation among 242 communities within 13 counties bordering the Hudson River to facilitate the development of a regional strategy for preserving scenic, natural, historic, cultural, and recreational resources while encouraging compatible economic development and maintaining the tradition of home rule for land use decision-making.[104] As a result, local politicians in the region are already under some pressure to balance land use and economic development with the need to preserve the region's heritage and environment.

In 2007, the Greenway Commission called for the creation of an incentive program that would benefit both economic development and the environment. Approximately 90% of the communities have adopted resolutions in support of the voluntary regional compact. Legislation is also expanding protected areas. In 2007, local efforts led to the expansion of the Greenway Area into bordering Saratoga County and Catskill Park communities in Ulster County.

Oil Prices

Because energy use is fundamental to the global economy, oil prices are a major factor influencing economic conditions. Oil prices have correlated directly with the performance of the economy (see illustration below). Higher oil prices tend to engender slower economic growth in oil-dependent, importing economies like the United States — and in the Hudson region by extension — and lead to slowdowns in oil consumption growth, and increasing utilization of public transportation. This is significant for the large number of commuters that travel to and from the Hudson Valley and NYC. The price of food is also linked to the price of oil, as transportation fuel, food, and feed end-use markets are increasingly competing for access to the same agricultural crops (corn, soybean, and sugarcane), thus increasing the level of integration and pricing feedback effects across these heretofore distinct markets.[105] Increasingly, changes in crude oil prices are flowing through immediately to transportation fuel, soft commodities, food prices, and the value of the US dollar itself. This makes the calculus of how changing oil prices will affect local agriculture complex and difficult to predict. While higher oil prices drive up the price of agricultural products (which is good for local farmers), they also drive up the cost of agricultural inputs that are energy based, such as fertilizer and diesel fuel (which is bad for local farmers). In any event, the future of oil prices will have direct and important repercussions for farmers in the Hudson Valley.

Similarly, the price of oil is an important driver of the use of alternatives. Higher fuel prices, for example, drive more people toward using lower cost, less polluting, and more energy efficient forms of public transportation, while lower fuel prices reduce pressures to increase fuel efficiencies in vehicles and adopt non-oil based alternatives.

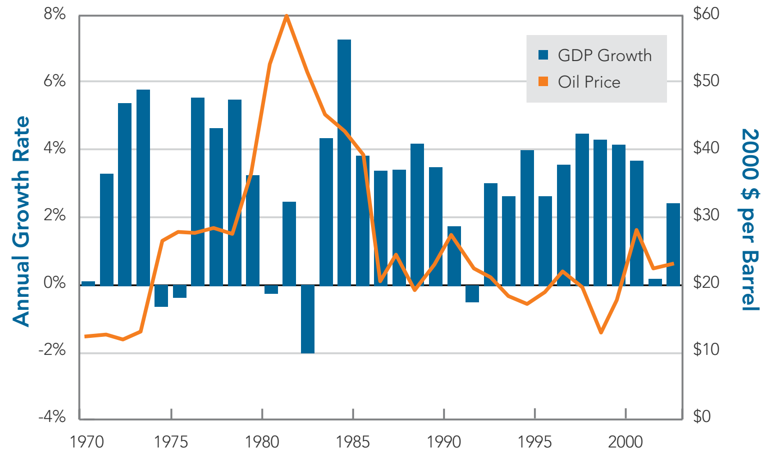
The "Greening" of the Economy

Rising concerns over climate change and energy security are driving growth in "green" solutions throughout the economy. The growth of venture capital investment in the "green" or "cleantech" sector has been very strong in recent years. In 2007, new investment of private capital in sustainable energy in totaled nearly $150 billion.[106] While the largest investments were made in the United States and Europe, emerging economies (China, India, and Brazil) are also investing more heavily in renewable and "greener" energy and technology.[107] Over the time horizon of our scenarios, "green" technologies will have a significant impact on energy use and the resulting character and quality of the future environment.

"Green Building" for example, is a new approach to designing and constructing commercial and residential buildings to reduce environmental impacts, and has been rapidly gaining acceptance — especially in major urban areas. "Green Buildings" focus on efficiently using energy and water, while reducing waste and environmental impacts. The fast growing US Green Building Council has developed a "Leadership in Energy and Environmental Design (LEED)" certification process that requires building designers to meet a rigorous set of criteria for environmentally friendly practices.[108] A Hudson Valley branch of the US Green Building Council's Upstate Chapter formed in 2007, and is offering LEED training.

The HREW is also home to a growing number of "green" companies, including firms active in solar, wind, and geothermal systems, efficient lighting, green roof media and plants, building salvage and deconstruction, sustainably-sourced and recycled-based furniture and interiors, and other "green" areas. In 2007-2008, three solar manufacturing companies announced headquarters or manufacturing locations in the mid-Hudson Valley.

Oil prices vs. GDP growth



Source: U.S. Department of Energy

Rising Tensions between Private Rights and Social Responsibilities

As population and economic growth in the Hudson Valley spur development and land-use changes, they will inevitably lead to increasing tension and conflict around the environmental consequences.

Land use conflicts in the HREW have arisen over new development as well as the rebuilding of infrastructure in environmentally sensitive areas. For example, the recent rebuilding of roads around the Kensico Reservoir, a main way station for the NYC water system surrounded by an industrial park, generated some controversy.[109] In 2000, the State of New York proposed a plan to expand certain roads and rebuild a bridge over the reservoir. This was strongly opposed by environmental advocates who argued that the proposed measures would send more pollution into the reservoir, eat away at woodlands, and increase traffic. Such conflicts, which reflect a balancing of private rights against the rights of a broader commons, can be expected to grow and intensify in concert with the growing impacts of climate change and rising demands to take effective action in response.

PRIME MOVERS

Local Governments

The actions of local government authorities are central to future regulation, taxation, zoning, and development. These same authorities will also decide local policy toward preparing for — and responding to — anticipated climate change impacts. There are 140 separate municipalities in the HREW. Most of these towns and cities have local governments headed by a mayor, an elected council responsible for local ordinances, and a Zoning Board or Code Enforcement Department, responsible for enforcing zoning and land-use regulations.

Media

Media outlets in the HREW will be the principal source of information on local impacts of climate change and extreme weather. As major drivers of public perception and opinion regarding the extent of the problem, they will be a strong influence on future policies and actions. In the HREW, the dominant forms of locally-oriented media are print, radio, TV, and the web. The major players in print media include the *NY Times*, Gannett-owned *Poughkeepsie Journal* and county *Journal News* (separate editions for Westchester, Rockland, Putnam counties), *Albany Times Union* (Hearst Newspapers), *Times Herald Record* (Ottaway Newspapers, a division of News Corporation), *The Journal Register* company (owns the *Independent, Kingston Daily Freeman* and several other local papers). One radio broadcaster, Clear Channel, owns nine music radio and talk radio stations in the region. Local television is popular, but serves a broader area than just the HREW, with most of the local channels also covering lower New York, New Jersey, and Connecticut.

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National outlets like Gannett and Clear Channel reflect the same consistency of brand in the Valley that they do elsewhere. But regional chains such as Ottaway Newspapers, Ulster Publishing and Luminary Publishing bring forth more personalized voices, and cover environmental issues in moderate depth. WAMC Northeast Public Radio has substantial public-affairs programming and covers climate change news such as scientific findings and regional initiatives. Latino publications in Warwick and Newburgh focus mainly on entertainment and culture, but reach a regional audience in Spanish. Several stations have segments of Spanish language programming.

Real Estate Developers

Real estate developers significantly impact land use changes within the HREW — both as a direct result of their development activities and through their influence over land use policies and regulations. The extent to which developers take future climate change impacts into consideration in new development proposals has important consequences for the region's future adaptive capacity.

Hudson Valley Railroads

Large railroad networks run through the HREW and along the Hudson River, connecting large numbers of people, goods and services in New York City with the rest of New York State. The major rail service providers along the Hudson are Amtrak, CSX, and MTA Metro-North. Amtrak carried approximately 1.25 million passengers on 5 separate lines through the Hudson Valley in 2007. MTA Metro North carries approximately 75 - 80 million passengers annually, and is utilized mainly by commuters, with 4 of 5 rail lines running through the Hudson Valley. CSX is the main freight company in the region, operating over 2,800 miles of track (34% of which is shared with Amtrak), and carrying over 370,000 carloads of freight annually. The company invested $80 million to maintain and upgrade tracks in 2007.

Educational Institutions

The HREW is home to over 30 institutes of higher learning. The largest of these schools are The United States Military Academy at WestPoint, Marist College in Poughkeepsie, NY and Vassar College (also in Poughkeepsie).

Religious Institutions

There are over 3,000 religious institutions in the Hudson Valley, representing all faiths. Religious institutions are important influences on public opinion and action on complex social issues. Important interfaith coalitions and efforts are underway in the Hudson Valley to tackle environmental issues such as climate change. Examples include GreenFaith, which works with congregations to green their places of worship and educate them as citizens on environmental stewardship, and the Garrison Institute, which developed the Hudson River Project on interfaith action to combat global climate change.

New York City

The HREW is remarkably connected to NYC economically, culturally, and geographically. As a region near such a large and imposing metropolis, as in HREW, the region's business and policy leaders take cues from the city on many issues. The New York City Department of Environmental Protection (NYCDEP) has made strides in recent years to make climate change adaptation a priority. The work of NYCDEP Climate Change Task Force provides climate change research and analysis that is useful and relevant to the HREW. Even though Hudson Valley communities have expanded and diversified their own economies in recent years, the continued importance of New York City to the communities and businesses of the Hudson Valley can hardly be overstated.

Residents and Workforces[110] — People commute from all over the Hudson Valley into NYC via car, train, and ferry. According to the 2000 U.S. Census, 74.% of Hudson Valley residents work within the region while 12% commute into Manhattan, and 14% commute to the Bronx, Long Island, Northern New Jersey, or Southwestern Connecticut. The lower Hudson Valley has a higher rate of commutation into Manhattan (16.7% in 2000) than the mid-Hudson (4.1%). There is also a significant amount of commuting into the Hudson Valley, with approximately 22% of jobs in the lower Hudson Valley filled by workers outside the area.

Water[111] — NYC is dependent for its fresh drinking water on the Greater Hudson Valley region which contains portions of the Hudson, Mohawk and Delaware River basins and a comprehensive water system comprised of 19 reservoirs and 3 controlled lakes in 3 sub-watersheds: the Croton, the Delaware, and the Catskill. The Croton System is the oldest of the three, and was originally built by damming the Croton River in the mid 19th century. It is comprised of 12 reservoirs and 3 controlled lakes which can store 87 billion gallons; and normally supplies 10% of NYC's water supply. The Catskill System was formed in the early 1900s and is comprised of the Ashokan and Schoharie Reservoirs, west of the Hudson River. This system can store 124 billion gallons and normally supplies 40% of the NYC water supply. The Delaware System was constructed from the 1930s to the 1960s and covers 1,000 square miles over 3 reservoirs (Cannonsville, Neversink, and Pepacton). This system can store 320 billion gallons and normally supplies 50% of the NYC water supply. The total watershed (combination of all 3 sub systems) occupies 2,000 square miles of land in the Hudson Valley and Catskill Mountains and supplies 1.5 billion gallons of unfiltered water per day. There are numerous interconnections that transfer water in between systems that allows for greater flexibility in distribution. The region has a bitter history where the politics of water resources are concerned, dating back at least to the flooding of a cluster of Catskill villages at the beginning of the 20th century to create the Ashokan Reservoir system. The NYC Watershed Agreement, formalized in the 1990s, has provided a challenging but stable framework for source protection and low-impact economic development in the region, administered by the Catskill Watershed Corporation, Watershed Agricultural Council and kindred agencies.

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Waste[112] — The enormous amount of industry in the mid to late 20th century in NYC and the lower Hudson Valley has lead to a large-scale pollution problem in the Hudson River. In 1996, a water protection agreement was formed between NYC, the State of New York, and upstate communities.[113] The agreement forced upstate communities to abide by certain environmental laws, but also mandated that NYC spend $230 million to buy land in the Hudson Valley and another $400 million to support economic development and stop pollution from sewage plants and other sources. Solid waste is also an issue in NYC, with over 50,000 tons of waste and nearly 12,000 tons of recyclables collected weekly. 25% of this waste comes from residents and City institutions, and is managed by the Department of Sanitation (DSNY). The remaining 75% is generated by businesses and construction activities, and is managed privately. Until recently, the majority of this refuse converged at the Fresh Kills Landfill in Staten Island. The landfill closed in 2001, and waste was subsequently shipped by trucks to private transfer stations and landfills in neighboring states. This system has been effective, but is not sustainable economically or environmentally. A comprehensive waste management plan was created in 2006, focusing on a shift from trucking to rail and barge, as well as recycling and collaboration between public and private entities.

Local Governments

The actions of local government authorities are central to future regulation, taxation, zoning, and development. These same authorities will also bear the burden of deciding local policy toward preparing for — and responding to — anticipated climate change impacts. There are 140 separate municipalities in the HREW. Most of these towns and cities have local governments headed by a mayor, an elected council responsible for local ordinances, and a Zoning Board or Code Enforcement Department, responsible for enforcing zoning and land-use regulations.

APPENDIX VII: RESPONSE OPTION SURVEY EXAMPLE

RESPONSE OPTION: Conduct all land-use planning in context of what things will be like in 20 years.

We would like to gather your thoughts on the idea of "Conducting all land-use planning in context of what things will be like in 20 years" as a response option or "strategy" for strengthening the adaptive capacity of the Hudson Valley in response to climate change. Please answer the questions below to the best of your ability. There is space at the bottom for you to provide any comments or questions.

1. How likely do you think it is that if all land-use planning was conducted in the context of what things will be like in 20 years, it would strengthen the adaptive capacity of the HREW to the impacts of climate change?

   Very Low Low Medium High Very High Don't know

2. On a scale of 1-5 (where 1 = immaterial and 5 = extremely material), how material do you think this response option is for strengthening the preparedness and adaptive capacity of the HREW to the impacts of climate change?

3. In your estimation, how significant are the barriers to conducting all land-use planning in the context of what things will be like in 20 years?

   Very Low Low Medium High Very High Don't know

4. If all land-use planning was conducted in the context of what things will be like in 20 years, which of the following choices best reflects how you would characterize the "durability" of such a circumstance?

   Very Low Low Medium High Very High Don't know

5. Which of the following choices best reflects how you would characterize the environmental effects of conducting all land-use planning in the context of what things will be like in 20 years?

   Very Negative Negative Medium Positive Very Positive No Opinion

6. Which of the following choices best reflects your feeling about the "tranformative potential" of "conducting all land-use planning in the context of what things will be like in 20 years" for strengthening the Hudson Valley's capactity to adapt to climate change?

   Very Low Low Medium High Very High Don't know

7. Which of the following choices best reflects how equitable you think the social and economic costs and benefits would be distributed as a consequence of conducting all land-use planning in the context of what things will be like in 20 years?

   Very Low Low Medium High Very High Don't know

8. What is your "best guess" regarding the total cost between now and 2030 of conducting all land-use planning in the HREW in the context of what things will be like in 20 years?

   >$100 million $10 million - $100 million $1 million - $10 million
   $100,000 - $1 million <$100,000 Don't know enough to guess

9. If all land-use planning was conducted in the context of what things would be like in 20 years, what is your "best guess" regarding how much economic benefit would be generated within the Hudson Valley between now and 2030?

   <$100,000 $100,000 - $1 million $1 million - $10 million
   $10 million - $100 million >$100 million Don't know enough to guess

10. Any questions or comments related to this response option?

APPENDIX VIII: RESPONSE OPTION SURVEY DATA

Response Options: Criteria Scoring

Option #	Option Name	Likelihood of Performance	Barriers	Durability	Environmental Effects	Transformative Potential	Equity	Cost	Benefits	Criteria Average	Materiality	Criteria plus Materiality
58	Conduct community outreach campaigns on the local threats posed by climate change, and what can be done in response.	4.3	3.7	3.0	4.0	4.0	4.5	5.0	4.0	**3.9**	4.7	**8.6**
73	Install distributed stormwater systems (rain gardens, etc.)	4.3	3.6	4.1	4.7	4.3	4.0	3.0	3.6	**4.0**	4.4	**8.5**
70	Develop local plans for alerting people of heatwave forecast, and what to do.	4.4	4.0	3.6	3.2	3.5	4.4	4.3	3.0	**3.8**	4.4	**8.2**
80	Hold regular, neighborhood meetings to "listen" to local adaptation needs, and mobilize local resources in response	3.1	3.6	3.3	4.1	3.7	4.3	5.0	3.0	**3.7**	4.2	**7.9**
66	Convene open, regularly scheduled meeting for adaptation planning coordination	4.0	3.8	3.6	4.0	3.9	4.1	4.7	3.8	**3.9**	4.0	**7.9**
37	Create State fund of $50 million to buy floodplain lands	4.1	2.4	4.1	4.6	3.6	3.8	2.0	4.3	**3.7**	4.1	**7.9**
61	Require local community governments to work with the NYS Emergency Management Office (SEMO) to complete and update regional hazard and pre-disaster mitigation plans	3.8	3.3	3.4	3.4	3.2	3.6	3.3	4.0	**3.4**	4.4	**7.8**
63	Develop longterm acquisition and easement plans to conserve floodplains	4.3	2.5	4.0	4.6	3.5	3.4	1.9	4.1	**3.6**	4.2	**7.8**
40	Create a $50 million fund to restore, reconnect and protect riparian corridors	4.0	2.1	3.9	4.5	4.4	3.9	1.9	4.3	**3.7**	4.1	**7.8**
41	Pass $5 billion NYS Green Bond Act in 2009	4.1	1.7	4.1	4.6	4.1	3.8	1.0	4.4	**3.6**	4.2	**7.8**

Response Options: Scenario Screening (continued)

Option #	**Procrastination Blues** Likelihood strategy would be adopted / implemented	**Procrastination Blues** If implemented, how well would strategy perform?	**Stagflation Rules** Likelihood strategy would be adopted / implemented	**Stagflation Rules** If implemented, how well would strategy perform?	**Nature Be Dammed** Likelihood strategy would be adopted / implemented	**Nature Be Dammed** If implemented, how well would strategy perform?	**Give Rivers Room** Likelihood strategy would be adopted / implemented	**Give Rivers Room** If implemented, how well would strategy perform?	**Total Likelihood**	**Total Performance**	**Total**
58	-2	1	2	1	2	-1	1	2	**3**	**4**	**7**
73	-2	2	1	2	1	-1	1	1	**1**	**4**	**5**
70	-1	2	2	2	2	0	1	-1	**4**	**3**	**7**
80	-1	2	2	2	2	-1	2	2	**5**	**5**	**10**
66	-1	1	2	2	2	-1	1	2	**4**	**5**	**9**
37	2	1	-2	1	1	1	-1	1	**0**	**5**	**5**
61	-1	2	1	2	2	0	1	2	**3**	**6**	**9**
63	-1	-1	2	1	2	-1	1	1	**4**	**3**	**7**
40	2	2	-2	1	2	-1	0	1	**2**	**3**	**5**
41	0	0	-1	2	2	0	-1	1	**0**	**5**	**5**

Option #	Option Name	Likelihood of Performance	Barriers	Durability	Environmental Effects	Transformative Potential	Equity	Cost	Benefits	Criteria Average	Materiality	Criteria plus Materiality
65	Become a StormReady community	3.8	3.6	3.8	4.0	3.7	3.7	3.4	4.2	**3.8**	3.9	**7.7**
77	Require surface permeablility for all open surfaces in all new HREW development	4.2	2.3	3.9	4.7	3.9	3.2	2.0	4.0	**3.6**	4.1	**7.7**
15	Enact zoning ordinances that restrict development in the floodplain	3.9	2.6	3.7	4.4	3.8	3.3	2.7	3.8	**3.5**	4.1	**7.6**
12	Increase riparian setbacks and buffers	4.1	2.3	3.6	4.4	4.1	3.1	2.5	3.5	**3.5**	4.1	**7.6**
45	Have NYS require and fund master flood protection plans by local governments	4.0	2.8	3.5	4.0	3.7	3.4	2.1	4.2	**3.4**	4.1	**7.6**
60	Develop and update emergency action plans with community involvement. Coordinate with State Emergency Mgmt Office.	4.0	3.4	3.8	3.6	3.0	3.8	3.0	3.8	**3.6**	4.0	**7.6**
3	Require flood impact assessments and mitigation plans prior to any development	3.9	2.4	3.4	4.3	3.6	3.2	2.7	3.9	**3.5**	4.0	**7.5**
30	Use LIDAR technology to improve on existing FEMA maps	3.7	3.2	4.2	3.8	3.6	3.5	2.4	3.0	**3.5**	4.0	**7.5**
2	Change requirements for all new stormwater permits	3.8	2.6	4.1	4.4	3.6	3.3	2.9	4.4	**3.7**	3.8	**7.5**
56	Require all health and social care facilities to have a "cool room"	4.0	3.0	3.0	3.3	3.3	4.3	3.5	3.0	**3.4**	4.0	**7.4**
51	Undertake "urban area greening programs" in response to more heatwaves	3.8	3.2	3.9	4.5	4.2	4.2	1.9	3.8	**3.7**	3.7	**7.4**
48	Reach out to local officials around best practices and technologies	3.6	3.6	3.8	4.0	3.9	3.8	3.9	3.3	**3.8**	3.6	**7.4**

Option #	Procrastination Blues Likelihood strategy would be adopted / implemented	Procrastination Blues If implemented, how well would strategy perform?	Stagflation Rules Likelihood strategy would be adopted / implemented	Stagflation Rules If implemented, how well would strategy perform?	Nature Be Dammed Likelihood strategy would be adopted / implemented	Nature Be Dammed If implemented, how well would strategy perform?	Give Rivers Room Likelihood strategy would be adopted / implemented	Give Rivers Room If implemented, how well would strategy perform?	Total Likelihood	Total Performance	Total
65	-2	2	2	2	2	-1	1	2	**3**	**5**	**8**
77	-2	2	1	2	1	-2	1	2	**1**	**4**	**5**
15	-2	-1	2	2	1	1	2	2	**3**	**7**	**10**
12	-2	-1	2	2	2	-1	1	2	**3**	**5**	**8**
45	-2	2	1	2	2	-1	1	2	**2**	**5**	**7**
60	-1	2	1	2	2	1	1	2	**3**	**7**	**10**
3	-2	2	1	2	2	-1	1	2	**2**	**5**	**7**
30	0	1	1	1	1	1	1	1	**3**	**5**	**8**
2	-2	1	2	2	1	1	1	2	**2**	**7**	**9**
56	-1	2	1	2	1	1	1	-1	**2**	**4**	**6**
51	-2	2	2	2	2	-1	-1	-1	**1**	**2**	**3**
48	-1	2	1	1	2	-1	1	1	**3**	**3**	**6**

Option #	Option Name	Likelihood of Performance	Barriers	Durability	Environmental Effects	Transformative Potential	Equity	Cost	Benefits	Criteria Average	Materiality	Criteria plus Materiality
22	Require all state agencies to conduct flood audits of critical infrastructure	3.8	3.7	3.5	3.7	3.0	3.7	2.2	4.3	**3.5**	3.8	**7.4**
28	Prepare for tidal wetland migration	3.8	2.7	3.7	4.5	3.6	3.4	2.8	3.6	**3.6**	3.8	**7.3**
29	Create an on-line flood mapping and visualization tool	3.8	3.5	3.7	4.0	3.8	3.5	3.5	3.3	**3.6**	3.7	**7.3**
57	Start a Climate Change Adaptation Fund to build capital for funding future climate change adaptations.	3.3	2.6	3.8	4.2	3.7	3.6	2.0	4.3	**3.5**	3.8	**7.3**
64	Begin an intensive program to restore streams to natural state and revegetate banks	4.0	3.0	3.8	4.6	3.3	3.3	2.6	3.9	**3.6**	3.7	**7.3**
23	Site critical facilities outside of the 500 year floodplain	3.6	2.8	3.4	3.4	3.2	3.4	2.7	3.2	**3.3**	3.9	**7.2**
1	Conduct all landuse planning in the context of what things will be like in 20 years	4.0	2.3	3.4	4.4	3.8	3.3	2.6	3.8	**3.4**	3.8	**7.2**
24	Require municipal staff get flood management training	3.5	4.2	3.0	3.5	3.0	4.0	3.7	3.2	**3.5**	3.7	**7.2**
5	Floodway delineation based on floodwater storage or increases in flow velocity	3.6	2.2	3.4	4.1	3.2	3.3	2.4	3.4	**3.3**	3.9	**7.1**
53	Provide public access to cool buildings during heatwaves	3.6	3.6	3.4	3.3	3.0	4.4	3.7	2.8	**3.5**	3.6	**7.1**
78	Promote smaller, distributed wastewater treatment facilities	3.9	2.7	3.9	4.1	3.6	3.1	2.3	3.5	**3.5**	3.6	**7.0**
50	Intensify enforcement of floodplain zoning, landuse, and building codes	3.9	3.0	3.6	4.1	3.1	2.9	3.0	3.8	**3.4**	3.6	**7.0**

Option #	**Procrastination Blues** Likelihood strategy would be adopted / implemented	**Procrastination Blues** If implemented, how well would strategy perform?	**Stagflation Rules** Likelihood strategy would be adopted / implemented	**Stagflation Rules** If implemented, how well would strategy perform?	**Nature Be Dammed** Likelihood strategy would be adopted / implemented	**Nature Be Dammed** If implemented, how well would strategy perform?	**Give Rivers Room** Likelihood strategy would be adopted / implemented	**Give Rivers Room** If implemented, how well would strategy perform?	**Total Likelihood**	**Total Performance**	**Total**
22	-2	2	1	2	1	2	1	2	**1**	**8**	**9**
28	-2	0	1	1	1	-2	-1	1	**-1**	**2**	**1**
29	-2	-1	1	1	1	-1	1	2	**1**	**4**	**5**
57	2	1	1	-1	2	-1	-1	2	**2**	**2**	**4**
64	-2	-1	2	1	2	-2	1	2	**3**	**3**	**6**
23	-2	2	-1	-1	1	2	-1	1	**-3**	**4**	**1**
1	-2	1	2	2	2	-1	1	2	**3**	**5**	**8**
24	-1	2	1	1	1	-1	1	2	**2**	**4**	**6**
5	-2	-1	1	1	1	-1	1	1	**1**	**3**	**4**
53	-1	2	1	2	2	0	1	-1	**3**	**3**	**6**
78	1	1	-1	-1	1	1	1	2	**2**	**4**	**6**
50	-2	-1	2	2	2	-1	2	2	**4**	**5**	**9**

Option #	Option Name	Likelihood of Performance	Barriers	Durability	Environmental Effects	Transformative Potential	Equity	Cost	Benefits	Criteria Average	Materiality	Criteria plus Materiality
4	Require communities to treat the floodplain as a "no-rise" floodway	3.8	2.3	3.3	4.4	3.2	3.2	2.3	3.3	**3.3**	3.7	**7.0**
55	Develop and publicize local heatwave hazard and warning systems	3.4	3.9	3.9	3.3	3.1	4.1	3.8	2.4	**3.6**	3.4	**7.0**
26	Develop and publicize a flood hazard and warning website	3.4	4.0	3.4	3.8	2.8	4.0	4.0	3.2	**3.6**	3.4	**7.0**
21	Set higher flood standards for new road construction	3.7	2.7	3.5	3.7	3.3	3.7	1.4	4.0	**3.2**	3.7	**6.9**
31	Install green roofs	3.6	2.2	3.9	4.3	3.7	3.0	1.5	4.6	**3.3**	3.6	**6.8**
16	Reduce the minimum size of wetlands regulated by the state	3.8	2.6	3.2	4.6	3.8	3.6	2.7	3.6	**3.5**	3.3	**6.8**
67	Make flood insurance in higher risk areas more expensive	3.8	1.8	3.3	3.8	3.1	2.3	2.0	3.8	**3.0**	3.8	**6.8**
36	Incentivize transfer of development rights programs	3.7	2.4	3.1	3.9	3.6	3.0	2.3	3.5	**3.2**	3.6	**6.8**
38	Assess the impact and value of wetlands for stormwater management	3.5	3.9	3.5	4.1	3.3	3.4	3.0	3.2	**3.5**	3.3	**6.8**
68	Require rainwater harvesting, storage and reuse for all new (or rebuilt/replaced) roof and gutter systems	3.7	2.8	3.6	4.4	3.5	2.4	2.4	3.8	**3.4**	3.4	**6.7**
39	Institute an environmentally sound, drainage system maintenance program	3.4	3.4	3.3	4.2	3.2	3.0	2.3	4.0	**3.3**	3.4	**6.7**
75	Plant trees to strengthen HREW ecosystem resilience (local shade and cooling, soil retention and water uptake and storage)	3.3	3.7	3.9	4.6	3.0	3.6	3.2	2.6	**3.5**	3.1	**6.7**

Option #	**Procrastination Blues** Likelihood strategy would be adopted / implemented	**Procrastination Blues** If implemented, how well would strategy perform?	**Stagflation Rules** Likelihood strategy would be adopted / implemented	**Stagflation Rules** If implemented, how well would strategy perform?	**Nature Be Dammed** Likelihood strategy would be adopted / implemented	**Nature Be Dammed** If implemented, how well would strategy perform?	**Give Rivers Room** Likelihood strategy would be adopted / implemented	**Give Rivers Room** If implemented, how well would strategy perform?	**Total Likelihood**	**Total Performance**	**Total**
4	-2	-2	1	1	1	-1	2	1	**2**	**3**	**5**
55	-2	2	1	2	2	0	1	-1	**2**	**3**	**5**
26	-2	2	1	2	2	2	1	2	**2**	**8**	**10**

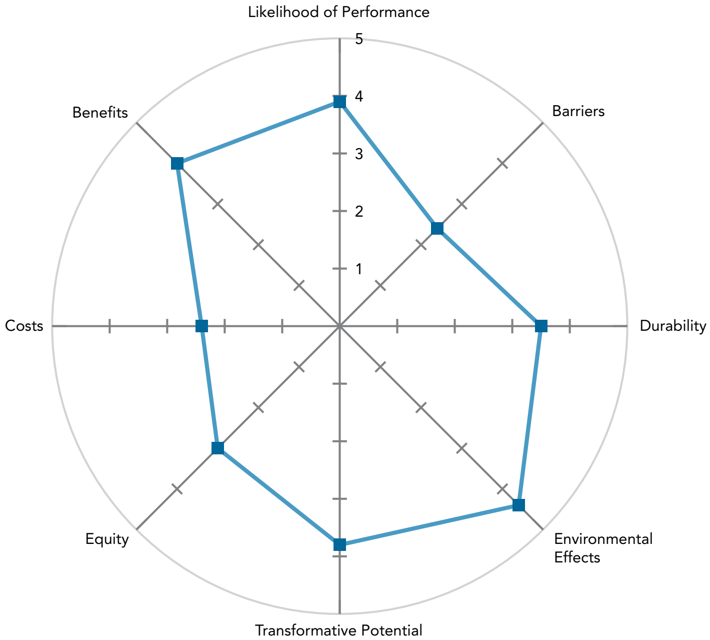
Option #	Option Name	Likelihood of Performance	Barriers	Durability	Environmental Effects	Transformative Potential	Equity	Cost	Benefits	Criteria Average	Materiality	Criteria plus Materiality
47	Extend RW scenarios by developing games and computer simulation tools	3.3	3.6	3.1	3.5	3.5	3.1	4.4	2.5	**3.4**	3.3	**6.6**
76	Require LEED certification for all new buildings in the HREW	3.1	2.1	4.1	4.9	4.3	2.7	1.8	4.0	**3.4**	3.3	**6.6**
59	Prepare post-disaster recovery plans for climate change impact scenarios	4.0	4.0	4.0	3.5	2.0	4.0	3.5	4.0	**3.6**	3.0	**6.6**
27	Require all dam owners to develop emergency action plans	2.8	3.2	3.7	3.3	2.7	3.8	3.3	3.8	**3.3**	3.2	**6.5**
52	Provide design guidance on cooling to architects and engineers	3.3	4.0	3.6	3.7	2.9	2.9	3.0	2.7	**3.3**	3.1	**6.5**
10	Require developers to offset the amount of filling they do	3.2	3.0	3.2	3.5	3.1	3.1	2.4	3.3	**3.2**	3.3	**6.5**
71	Require land bridges, tunnels, and detours for wildlife to cross highways and migrate through developed	3.6	2.3	3.6	4.6	3.2	3.3	1.7	2.8	**3.1**	3.3	**6.4**
25	Raise local property taxes within the floodplain to cover the cost of flood recover	3.6	1.6	2.9	3.7	3.4	2.3	2.4	3.8	**2.9**	3.5	**6.4**
69	Expand funding for better management of HREW ecosystems	3.3	2.0	2.8	4.7	2.8	2.8	2.5	3.2	**3.0**	3.3	**6.4**
8	Change regulations on what is "substantial improvement" to a building	3.1	2.1	2.9	3.6	3.3	2.3	2.2	3.5	**2.9**	3.4	**6.3**
14	Require developers to offset the creation of impermeable surfaces	3.4	2.2	3.7	4.4	3.4	3.0	2.0	3.9	**3.2**	3.1	**6.3**
18	Steadily increase annual flood insurance premiums	2.8	2.1	3.1	3.7	3.3	2.9	2.5	4.0	**3.0**	3.3	**6.3**

Option #	Option Name	Likelihood of Performance	Barriers	Durability	Environmental Effects	Transformative Potential	Equity	Cost	Benefits	Criteria Average	Materiality	Criteria plus Materiality
46	Produce an annual report card of climate change indicators in the HREW	3.0	2.5	3.3	3.8	3.4	3.6	2.1	2.7	**3.0**	3.3	**6.3**
42	Fund and infrastructure monitoring and evaluation program	3.3	2.9	3.4	3.8	2.9	3.2	2.7	3.2	**3.1**	3.1	**6.3**
9	Eliminate filling or buildings that will displace floodwater in the flood fringe	3.3	2.3	3.3	4.1	3.0	2.9	2.5	2.9	**3.1**	3.2	**6.3**
6	Change building standards to require an added 1-4 ft of freeboard	4.0	2.5	3.3	3.3	2.7	2.9	2.2	3.2	**3.0**	3.3	**6.3**
33	Set aside State funds to rebuild bridges and culverts	3.3	2.3	2.8	3.4	2.8	3.5	1.6	3.8	**2.9**	3.3	**6.2**
17	Modify design requirements for transportation infrastructure	3.1	2.4	4.1	3.1	2.7	3.9	1.7	3.6	**3.1**	3.1	**6.2**
54	Aggressively promote cultural adaptations in anticipation of more heatwaves	3.3	2.8	2.8	3.8	3.4	3.1	3.0	3.5	**3.2**	3.0	**6.2**
11	Change subdivision regulations	3.3	2.4	3.3	3.5	3.1	2.8	2.6	3.2	**3.1**	3.1	**6.2**
32	Construct a model community showing adaptations to climate change	2.8	2.0	3.3	4.0	3.6	3.1	2.0	3.6	**3.0**	3.1	**6.2**
34	Move or demolish all structures in the floodplain	3.8	1.0	3.8	3.8	4.2	2.0	1.0	3.8	**2.9**	3.2	**6.1**
35	Elevate all buildings in the floodplain above BFE	3.5	1.2	4.0	2.8	3.3	2.0	1.0	5.0	**2.8**	3.2	**6.0**
49	Double funding for local invasive species management	2.6	2.7	2.3	3.8	2.8	2.9	2.7	3.4	**2.9**	3.0	**5.9**
20	Replace existing culverts with larger diameter culverts	2.9	2.3	3.1	2.7	2.7	2.7	2.0	3.4	**2.7**	3.1	**5.8**

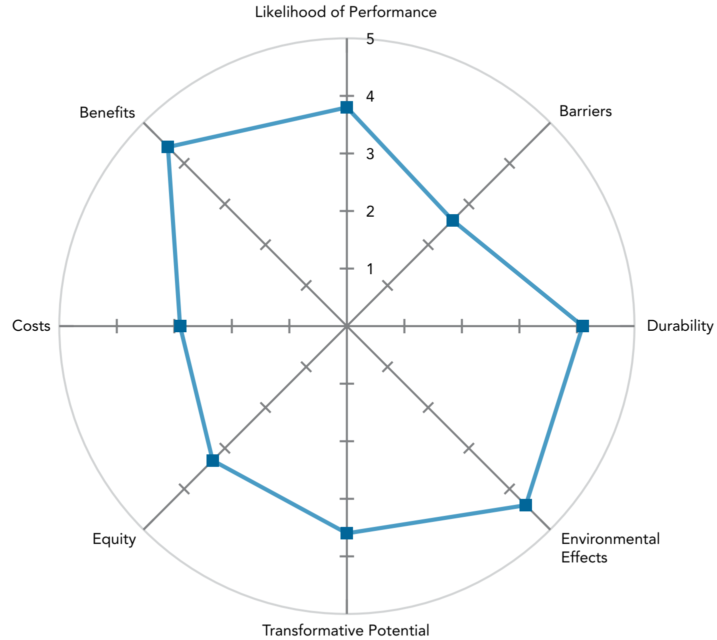
Option #	Option Name	Likelihood of Performance	Barriers	Durability	Environmental Effects	Transformative Potential	Equity	Cost	Benefits	Criteria Average	Materiality	Criteria plus Materiality
74	Disseminate floatation technologies for structures along the waterfront	2.8	2.5	3.2	3.3	2.5	2.5	1.3	3.8	**2.7**	2.8	**5.5**
13	Require flood audits for buildings at high risk	2.9	3.0	2.7	3.2	2.6	2.7	2.8	2.8	**2.8**	2.7	**5.5**
72	Develop technologies to use tidal action in the Hudson to generate electricity	2.3	2.9	3.6	2.9	2.7	3.2	2.0	4.0	**2.9**	2.6	**5.5**
7	Enact state regulations that would count residential improvements cumulatively	2.8	1.9	3.1	3.1	2.8	2.0	1.5	3.6	**2.6**	2.8	**5.4**
79	Move your residence and workplace to low risk areas of the HREW	2.6	1.6	3.7	3.2	2.8	1.5	2.3	2.5	**2.5**	2.7	**5.2**
44	Build floodwalls along shorelines and tributary mouths in urbanized communities	2.3	2.2	2.4	2.0	2.3	2.4	1.5	3.8	**2.3**	2.9	**5.2**
62	Build levees, floodwalls and seawalls	2.2	2.9	2.4	1.7	1.8	2.0	1.5	3.6	**2.2**	2.9	**5.2**
19	Expand capacity of reservoirs for flood control	2.9	2.4	2.8	2.0	1.9	3.0	2.2	3.0	**2.5**	2.4	**4.8**
43	Dredge shallow areas and deepen/widen river and stream channels	1.8	2.2	1.6	1.7	1.7	2.1	1.9	1.9	**1.9**	2.1	**4.0**

APPENDIX IX: RADAR DIAGRAMS OF INDIVIDUAL RESPONSE OPTIONS

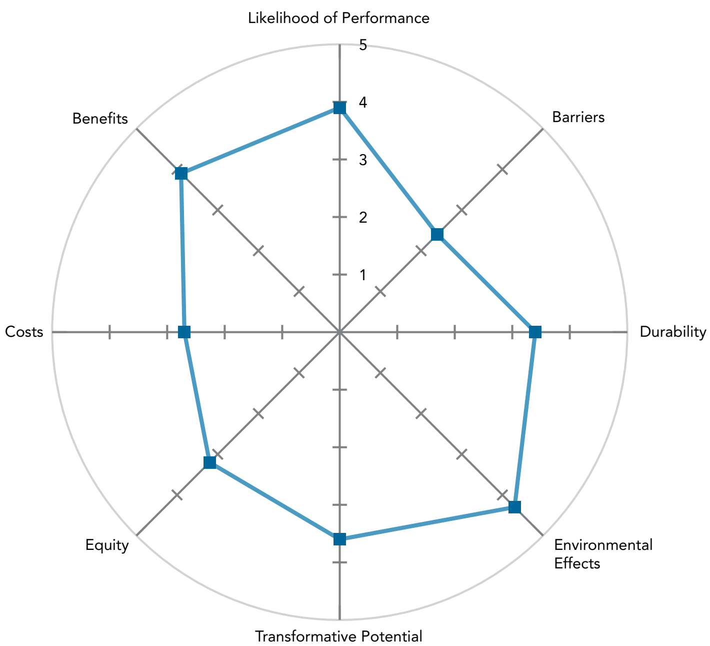
1. Conduct all landuse planning in the context of what things will be like in 20 years



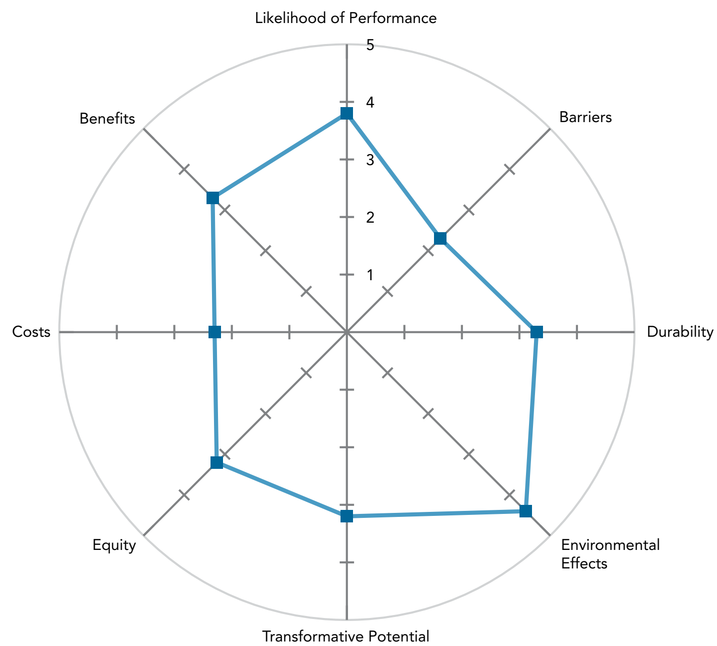
2. Change requirements for all new stormwater permits



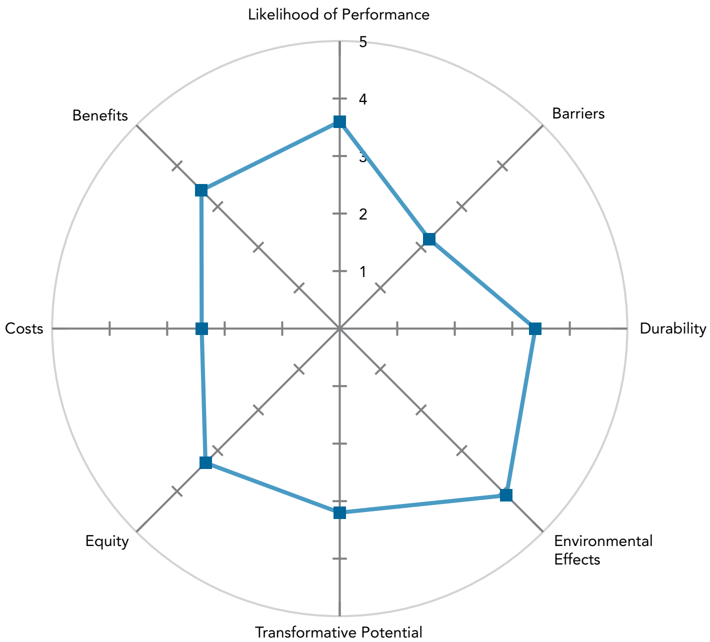
3. Require flood impact assessments and mitigation prior to any development



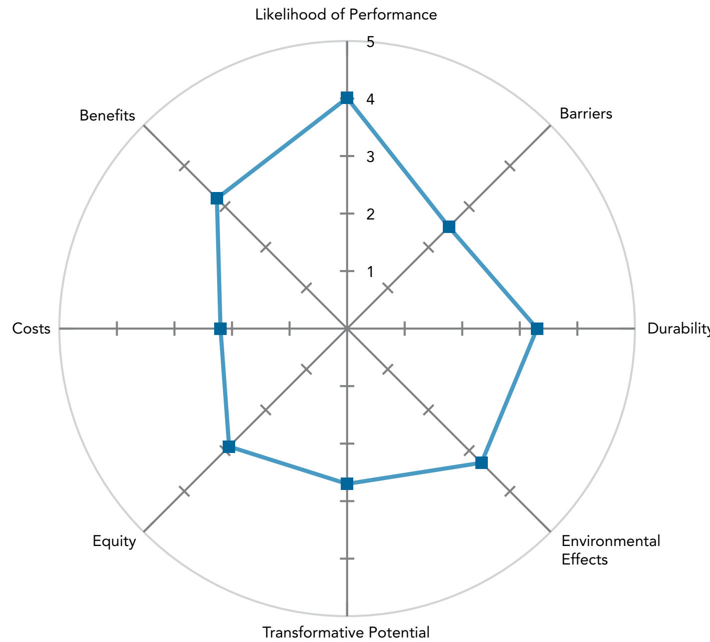
4. Require Communities to treat the floodplain as a "no-rise" floodway



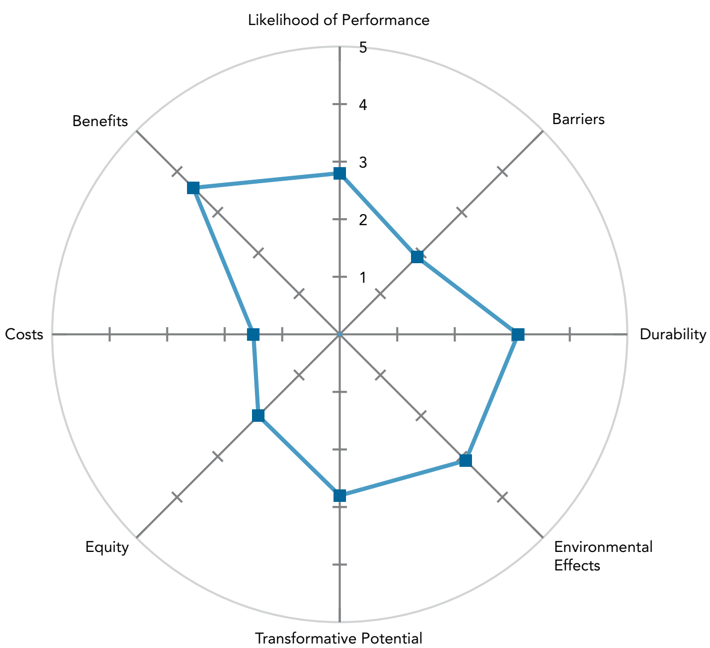
5. Delineate floodway based on floodwater storage or increases in flow velocity



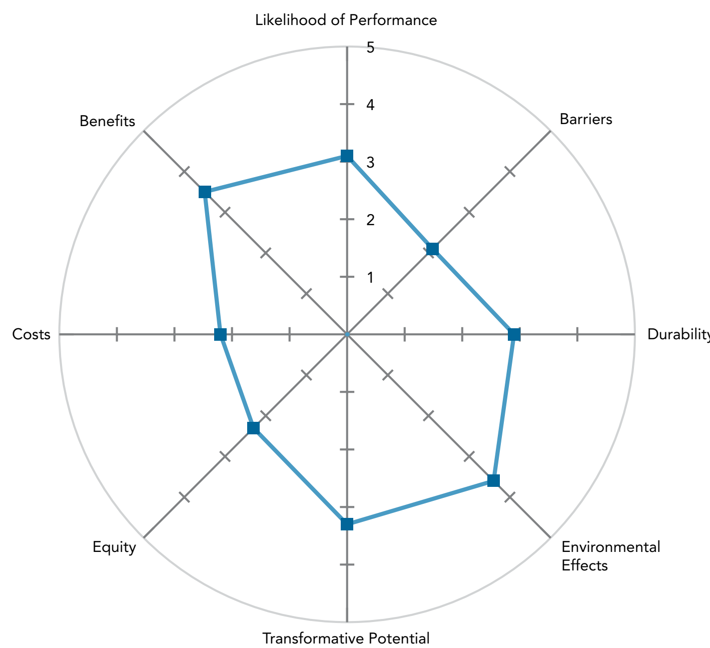
6. Change building standards to require an additional 1 - 4 feet of freeboard



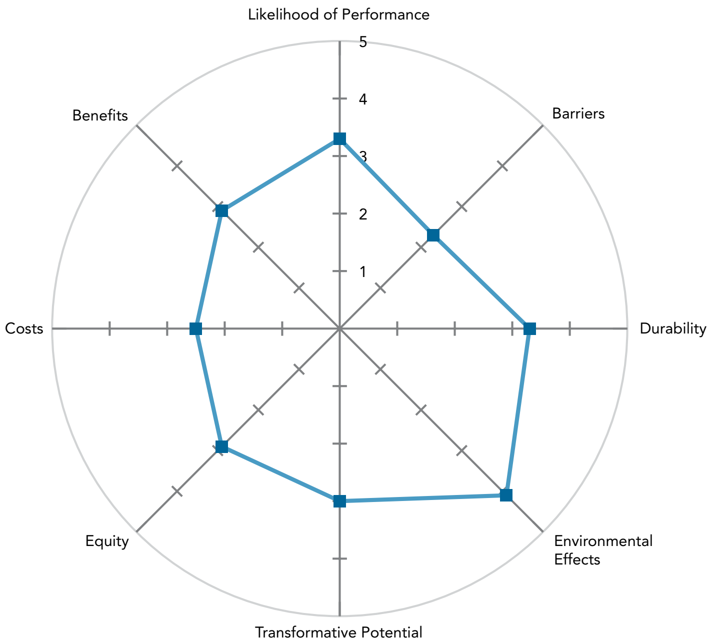
7. Enact State regulations that would count residential improvements cumulatively



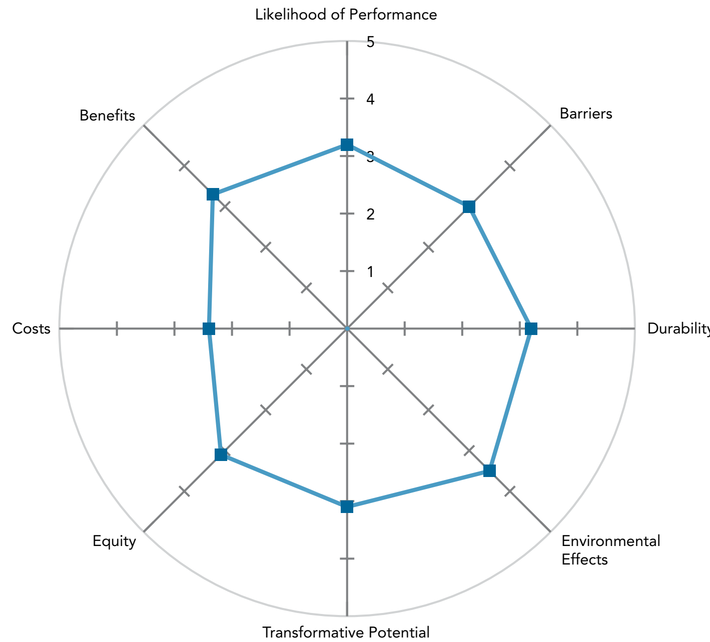
8. Change regulations on what is "substantial improvement" to a building



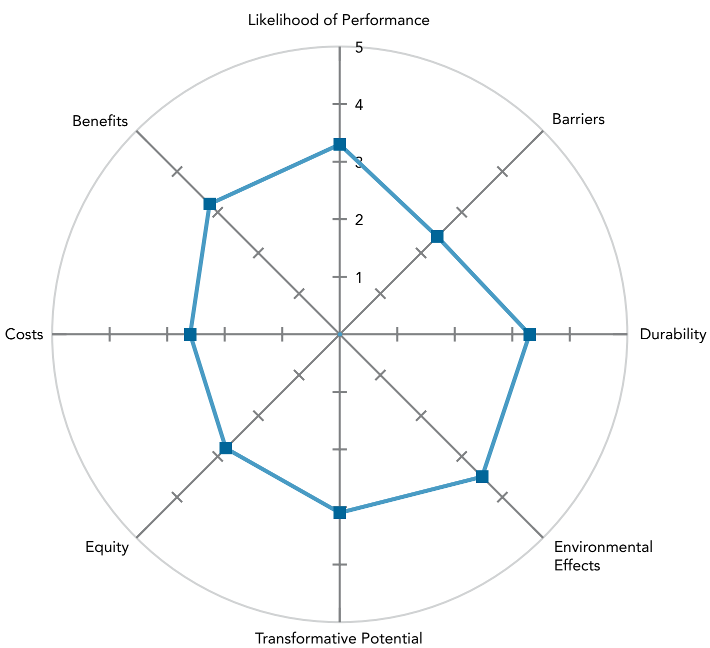
9. Eliminate filling and buildings that will displace flood water in the flood fringe



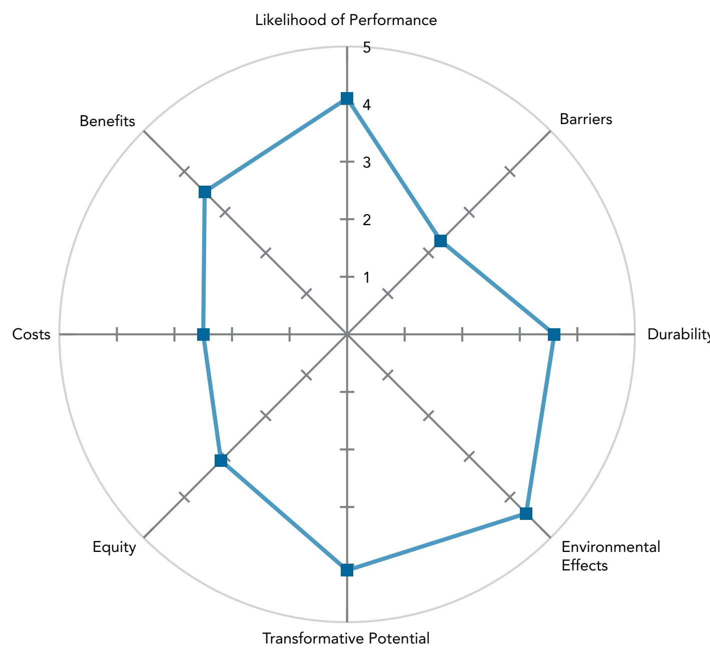
10. Require developers to offset the amount of filling they do



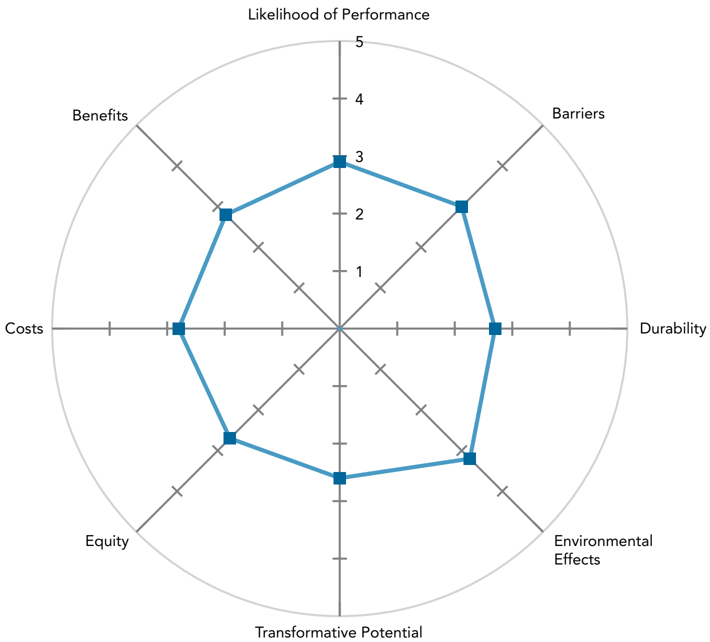
11. Change subdivision regulations



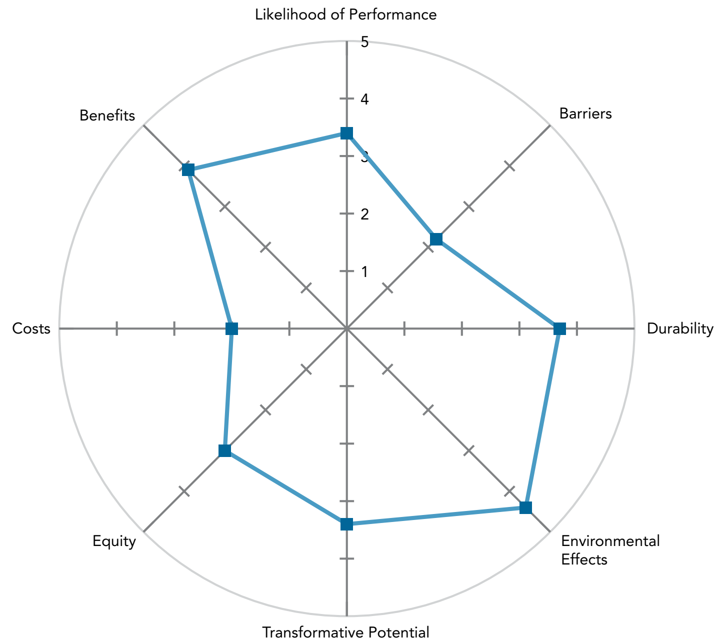
12. Increase riparian setbacks and buffers



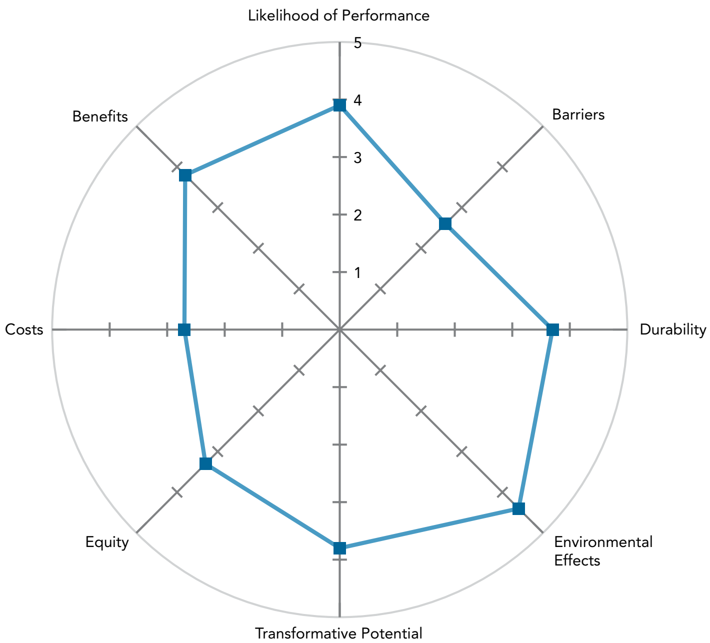
13. Require flood audits for buildings at high risk



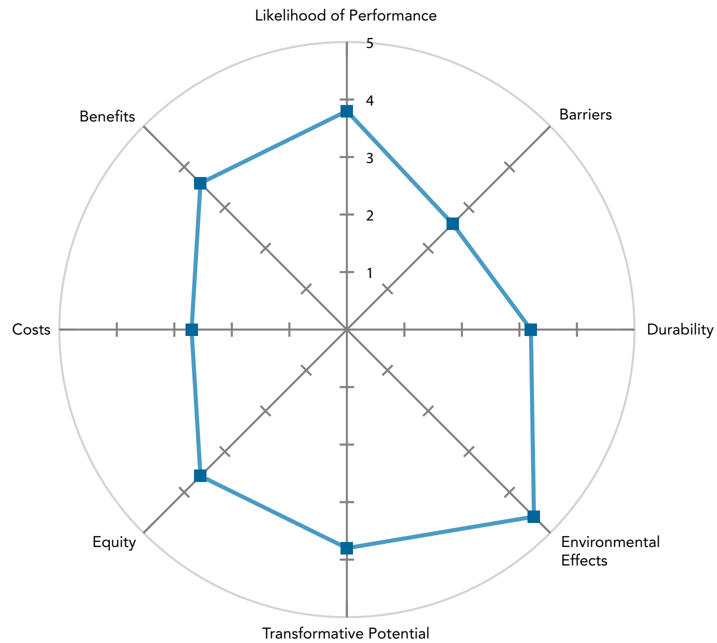
14. Require developers to offset creation of impermeable surfaces



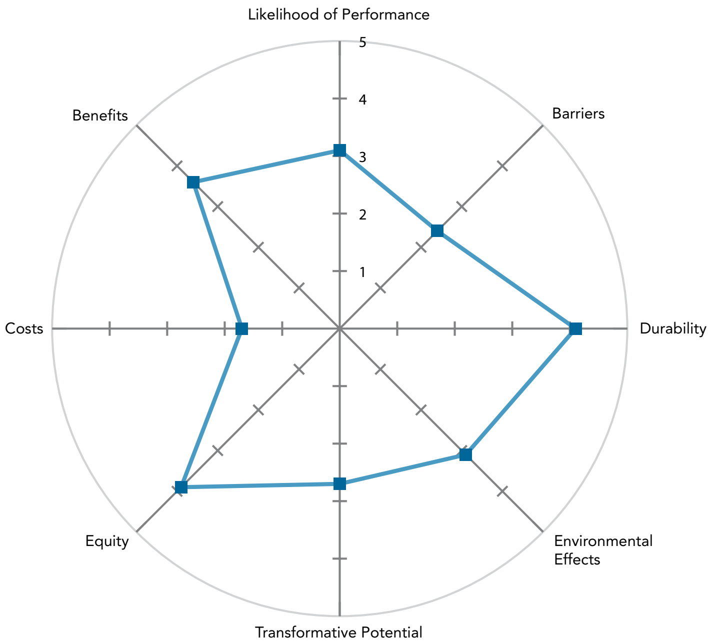
15. Enact zoning ordinances that restrict development in the floodplain



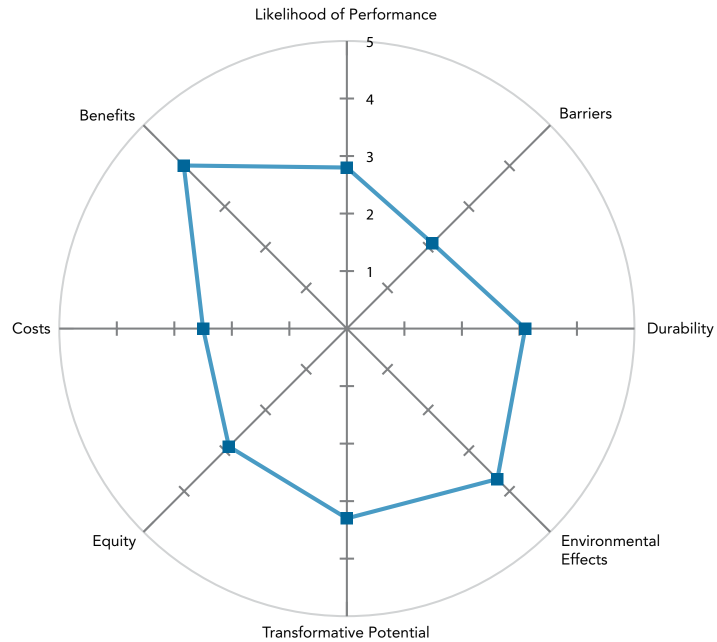
16. Reduce the minimum size of wetlands regulated by the State



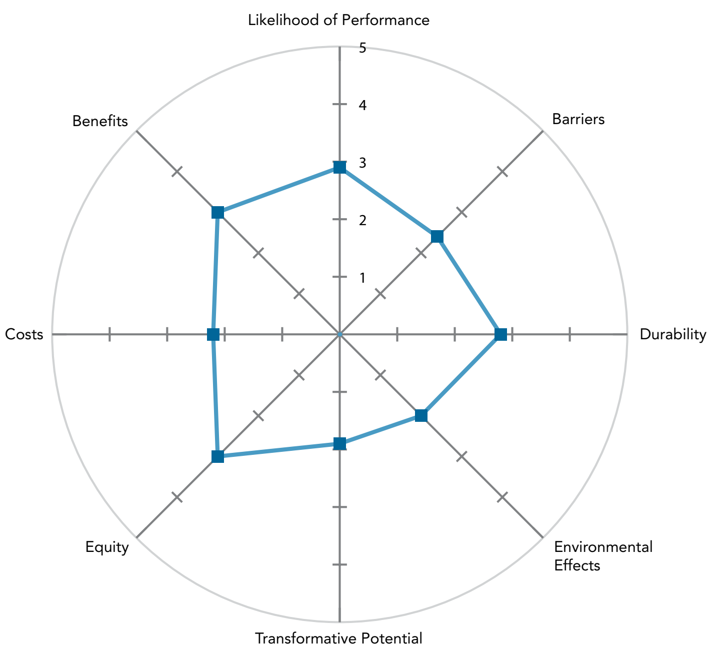
17. Modify design requirements for transportation infrastructure



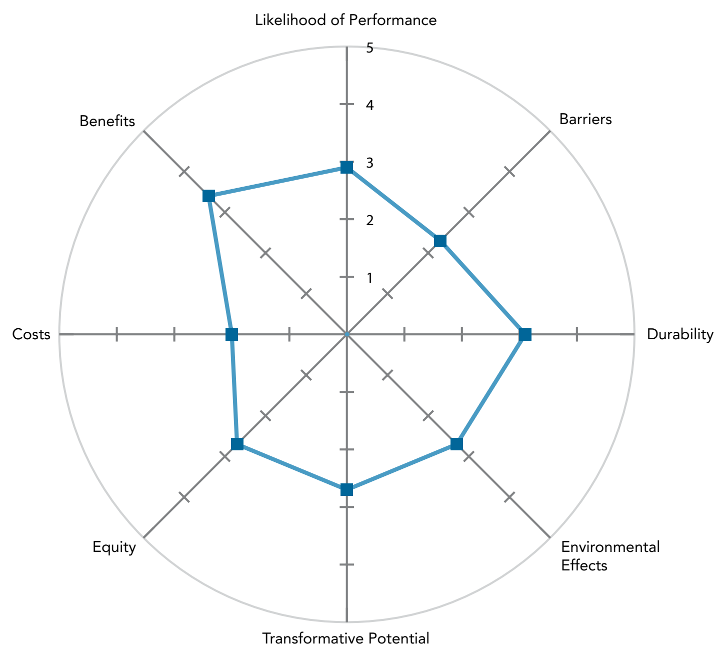
18. Steadily increase annual flood insurance premiums



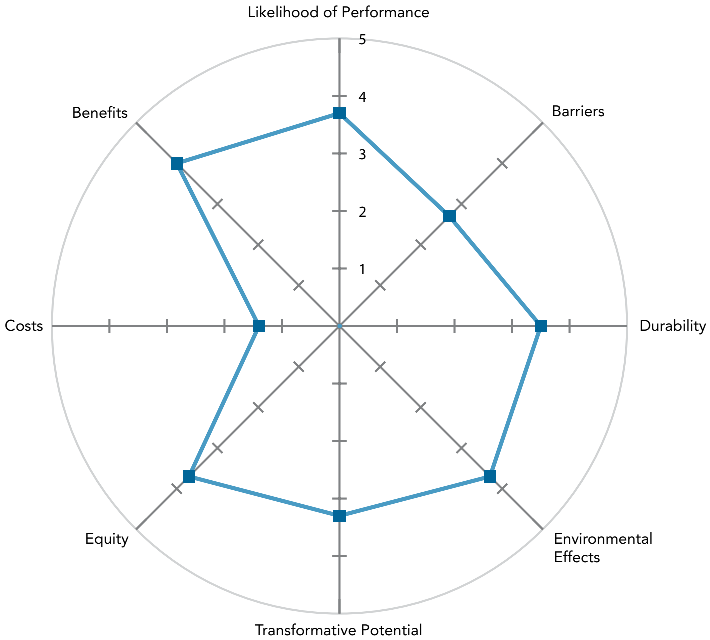
19. Expand capacity of reservoirs for flood control



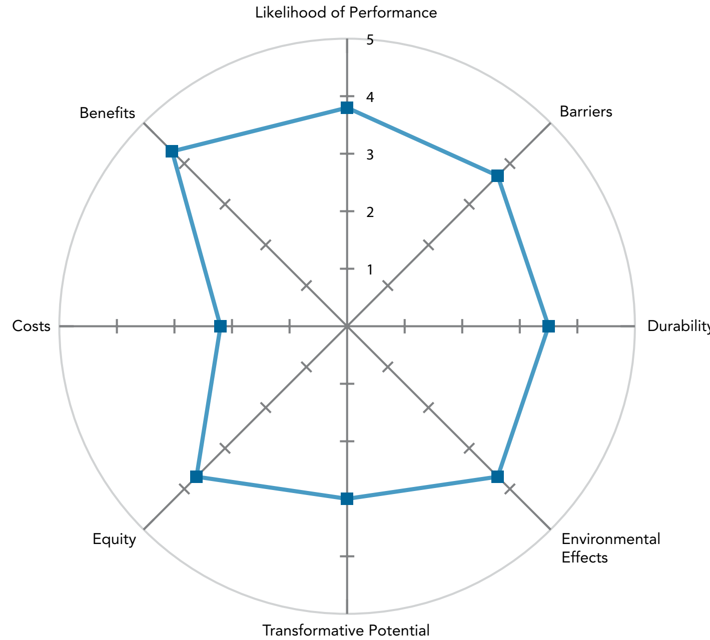
20. Replace existing culverts with larger diameter culverts



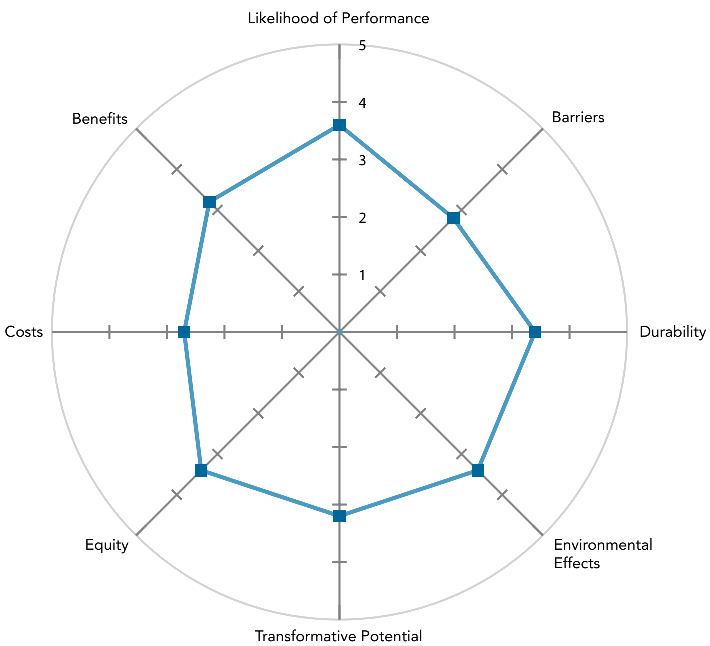
21. Set higher flood standards for new road construction



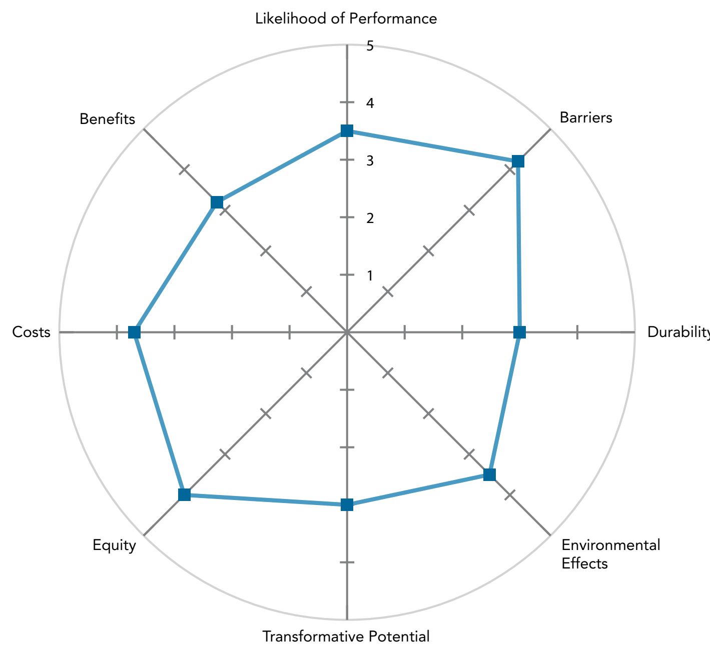
22. Require all State agencies to conduct flood audits of critical infrastructure



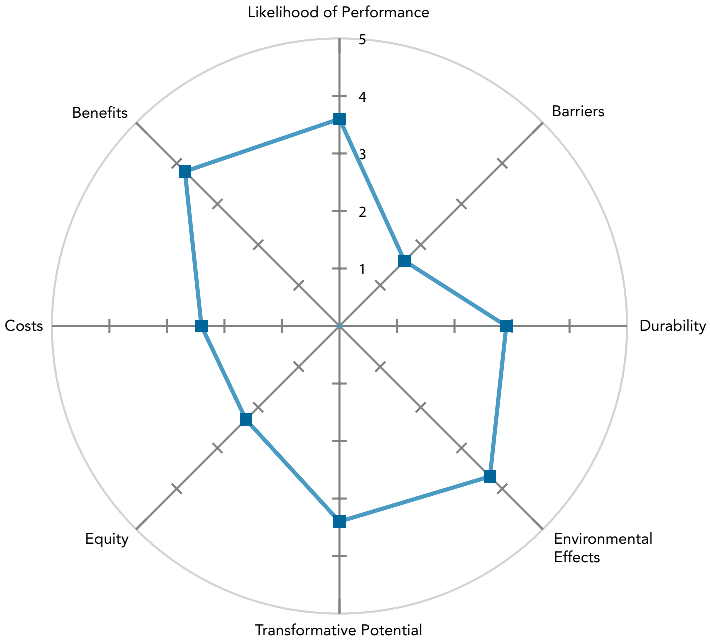
23. Site critical facilities outside the 500 year flood plain



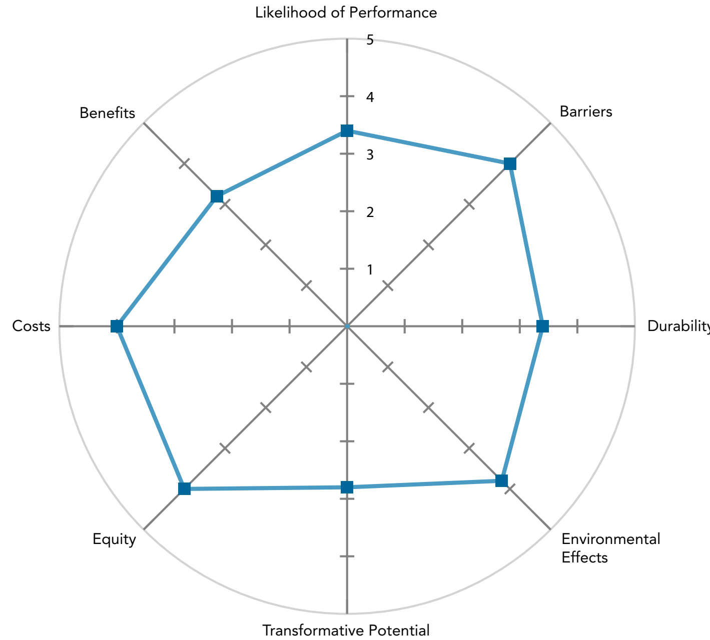
24. Require municipal staff to receive floodplain management training



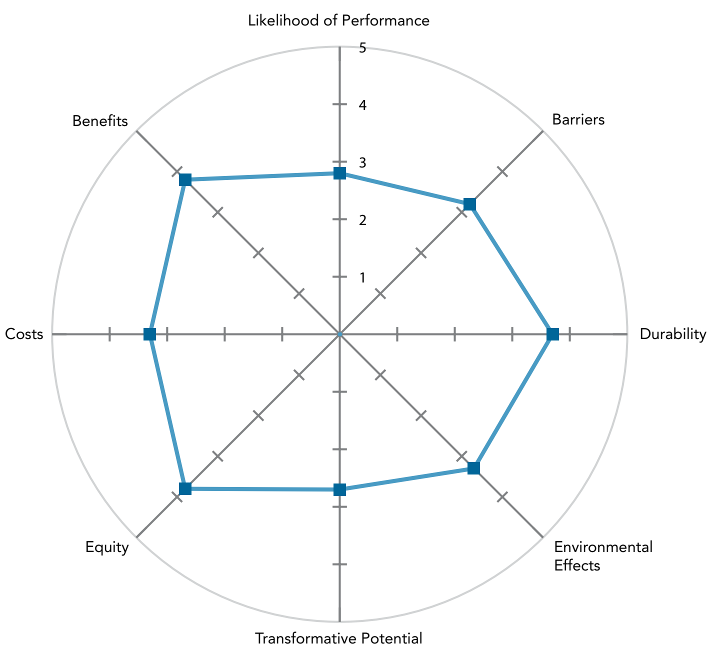
25. Raise local property taxes within the floodplain to cover flood recovery costs



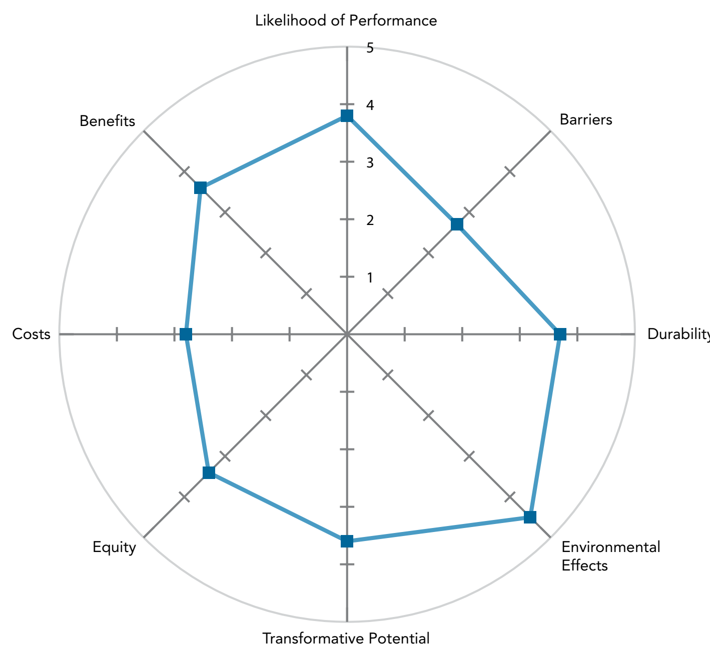
26. Develop and publicize a flood hazard and warning website



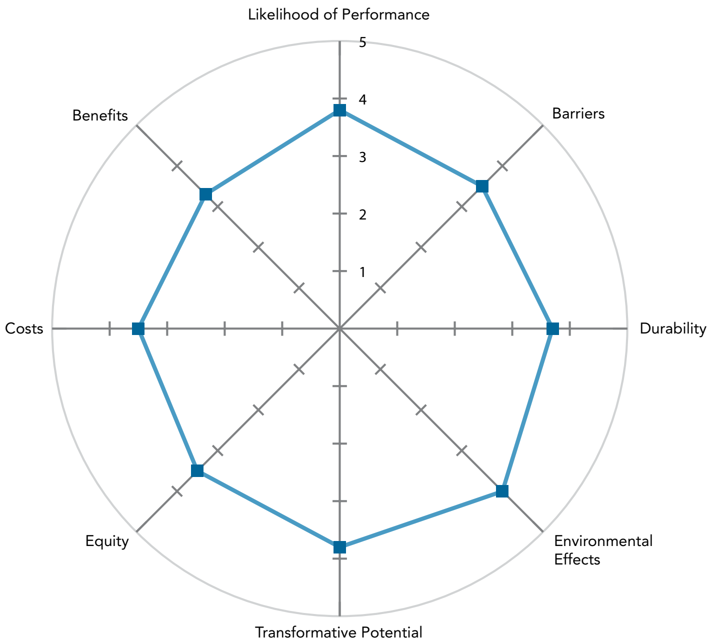
27. Require all dam owners to develop emergency action plans



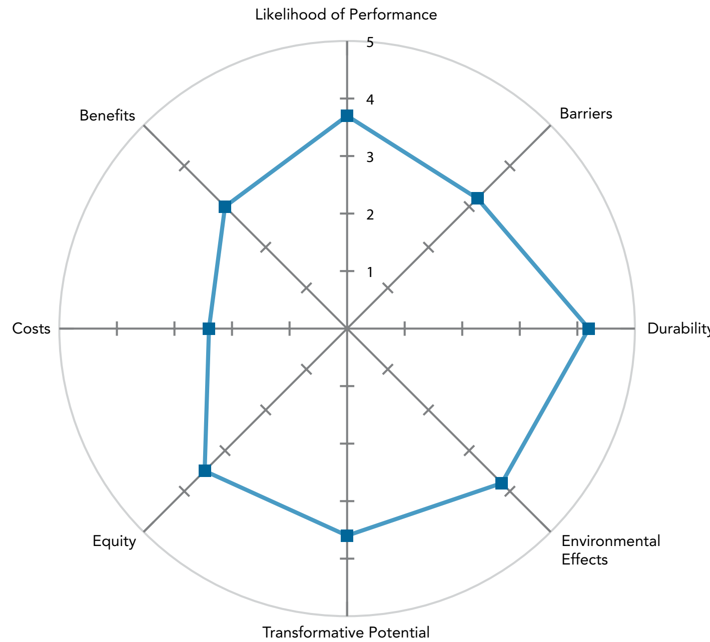
28. Prepare for tidal wetland migration



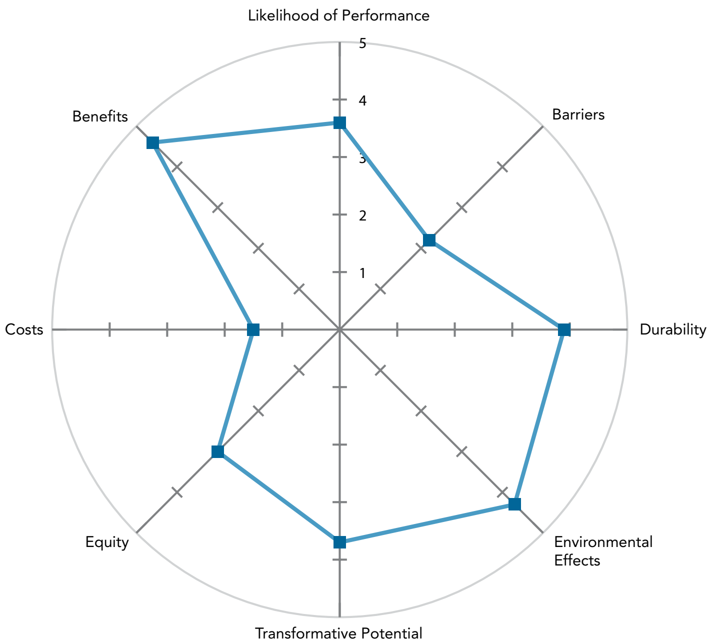
29. Create an on-line flood mapping and visualization tool



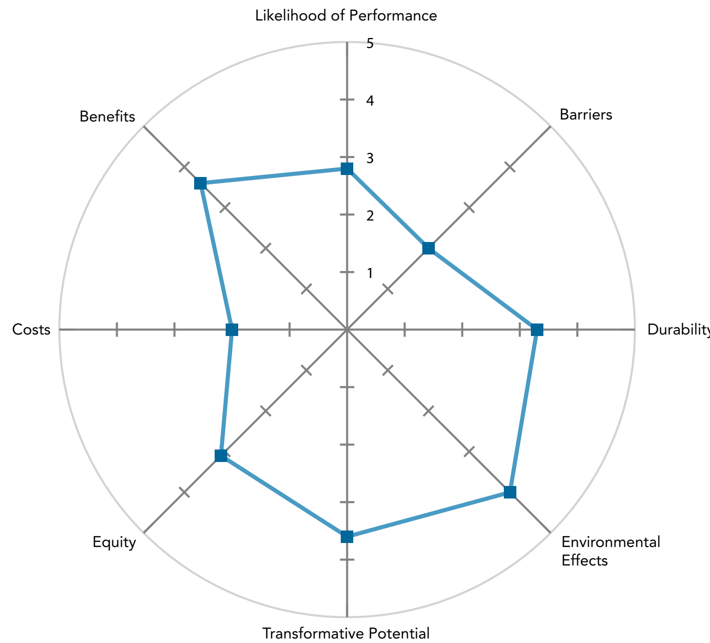
30. Use LIDAR technology to improve on existing FEMA maps



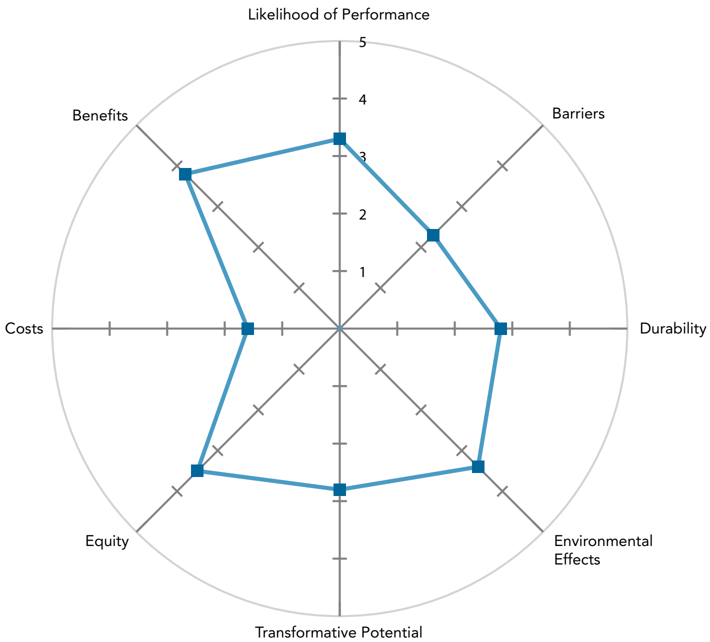
31. Install green roofs



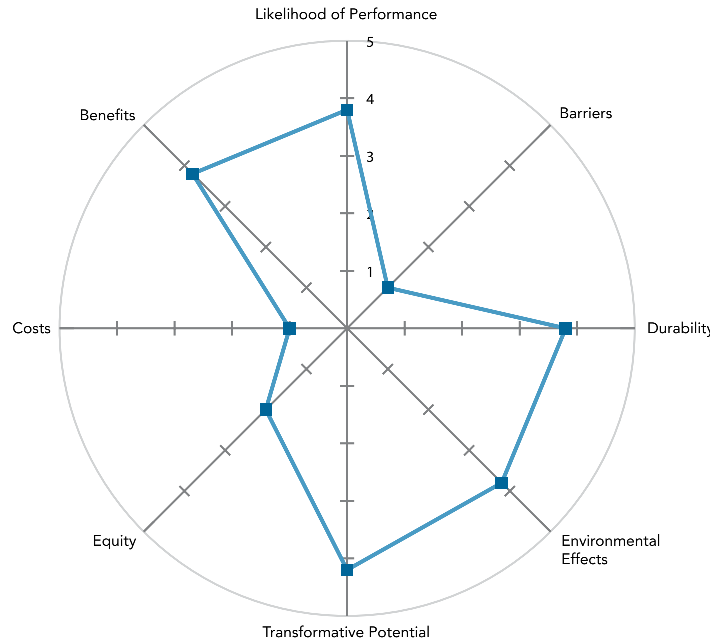
32. Construct a model community showcasing adaptations to climate change



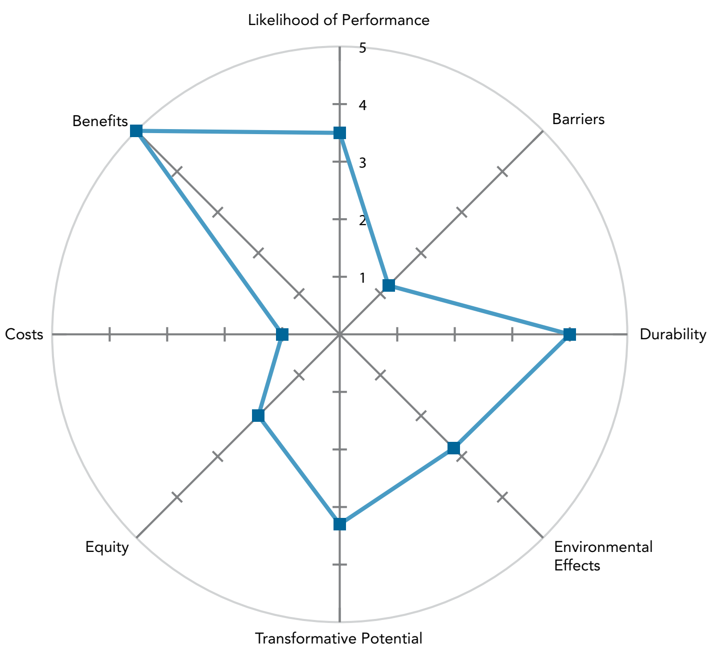
33. Set aside State funds to rebuild bridges and culverts



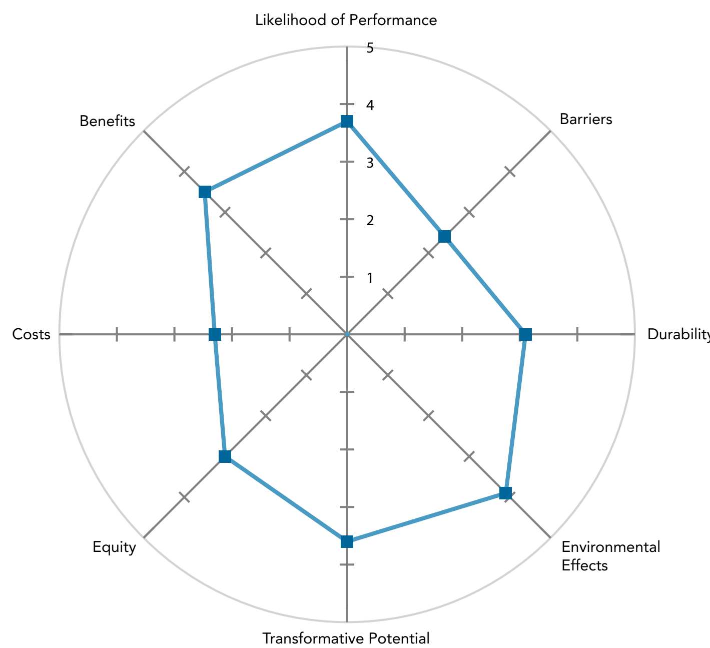
34. Move or demolish all structures in the floodplain



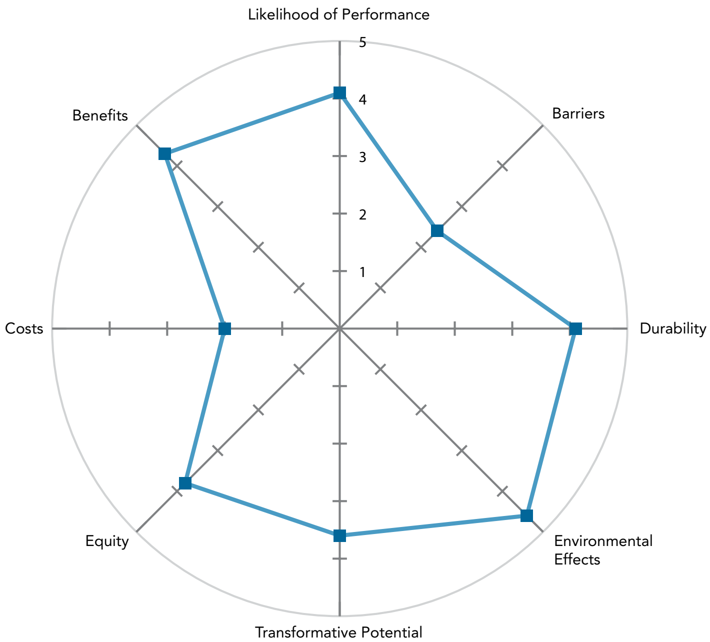
35. Elevate all buildings in the floodplain above BFE



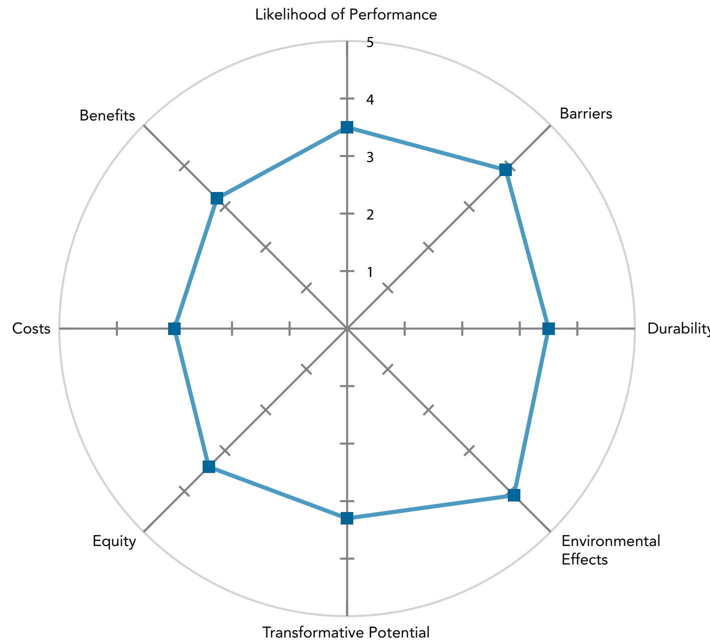
36. Incentivize transfer of development rights programs



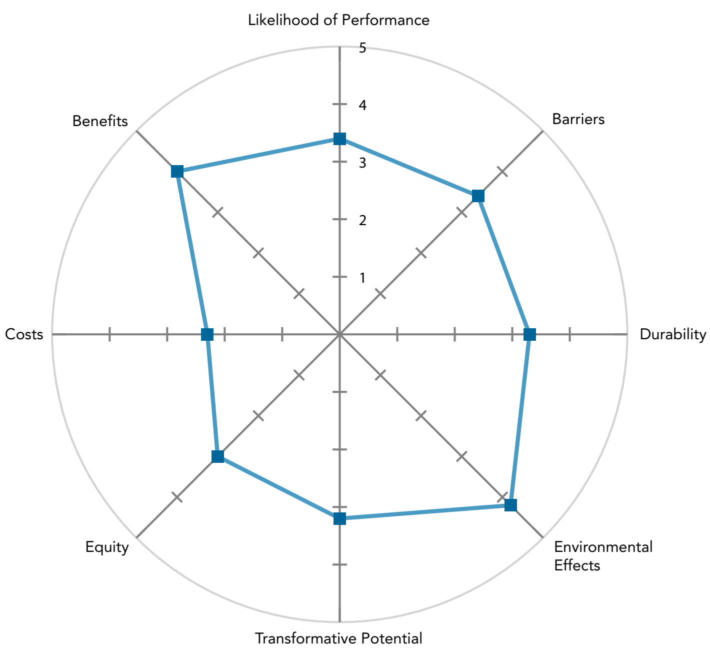
37. Create State fund of $50 million to buy floodplain lands



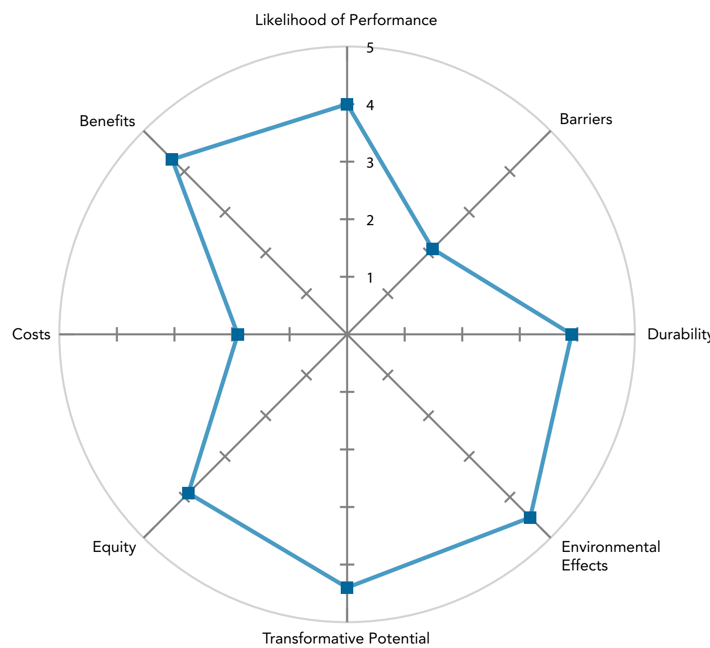
38. Assess the impact and value of wetlands for stormwater management



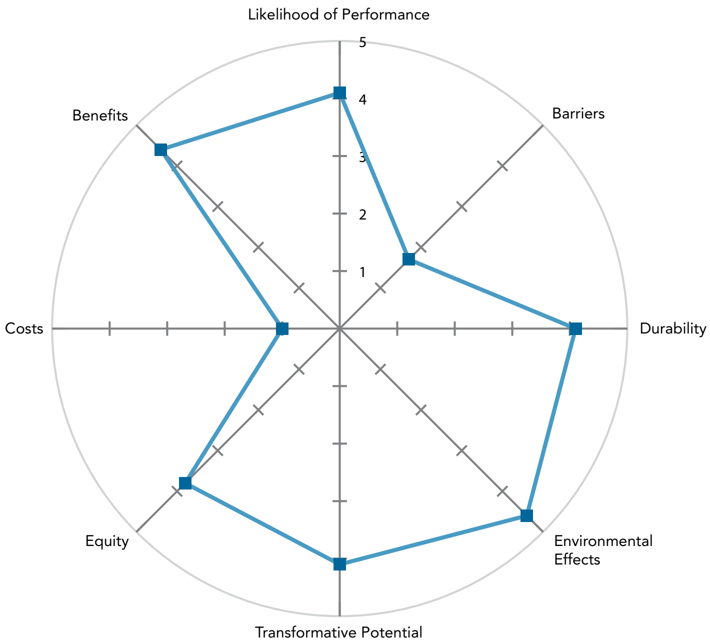
39. Institute an environmentally sound drainage system maintenance program



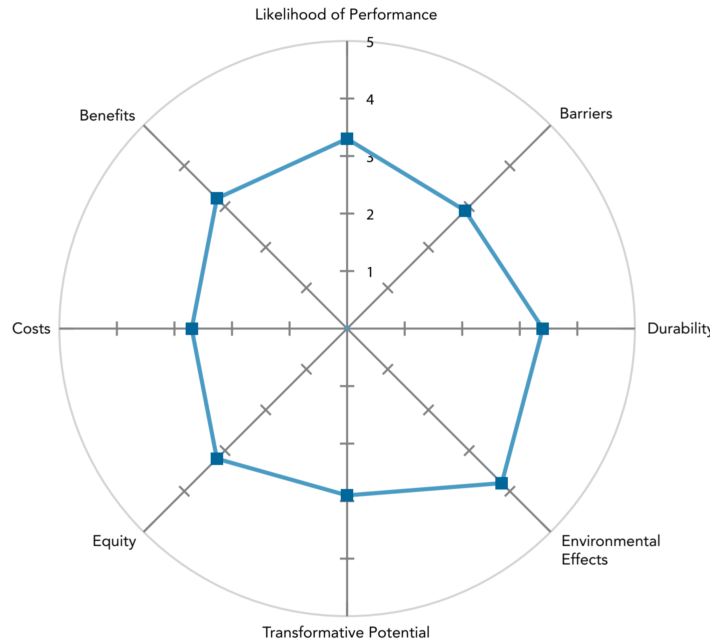
40. Create $50 million fund to restore, reconnect, and protect riparian corridors



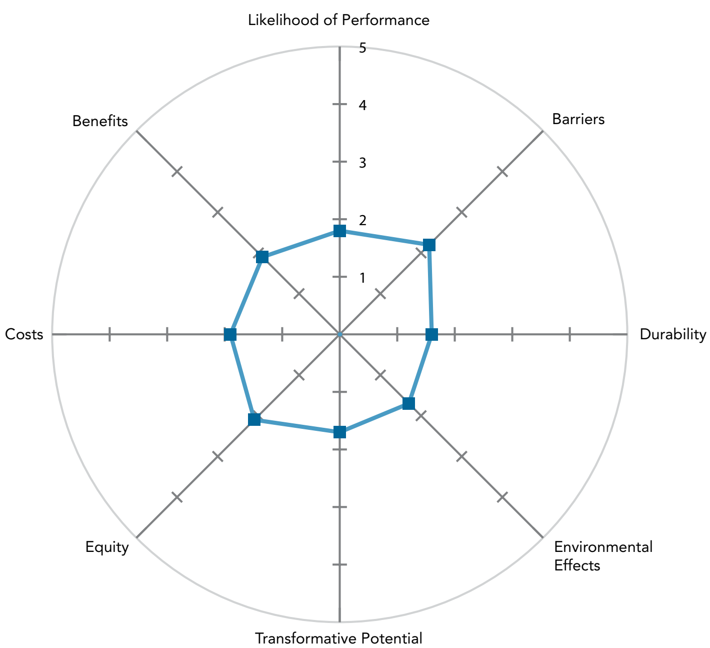
41. Pass $5 billion NYS Green Bond Act in 2009



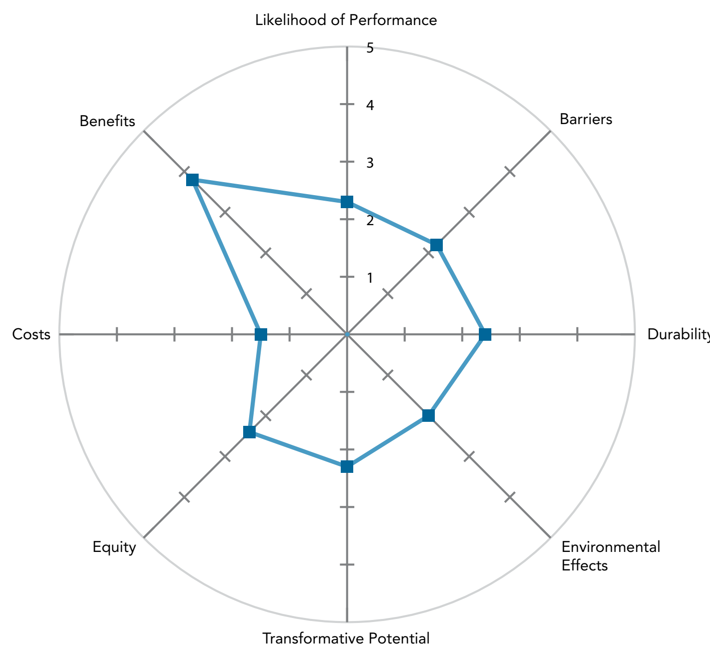
42. Fund an infrastructure monitoring and evaluation program



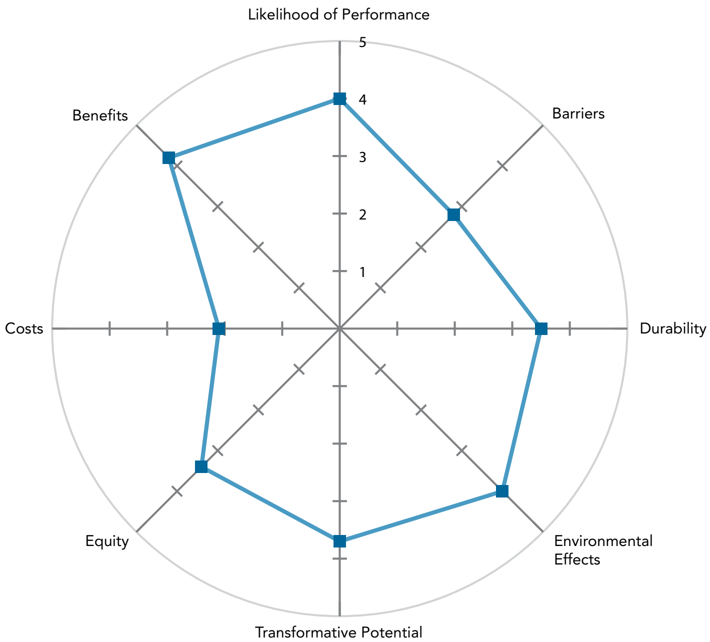
43. Dredge shallow areas and deepen/widen river and stream channels



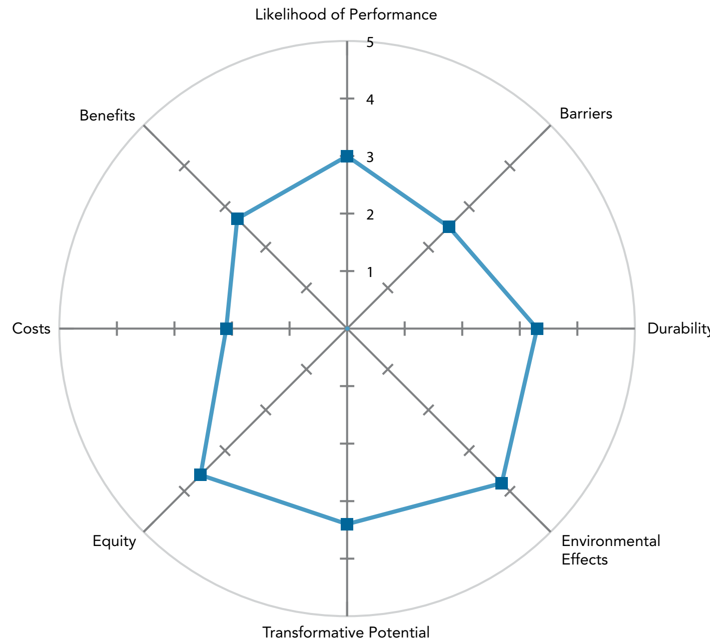
44. Build floodwalls along shorelines and tributary mouths in urbanized communities



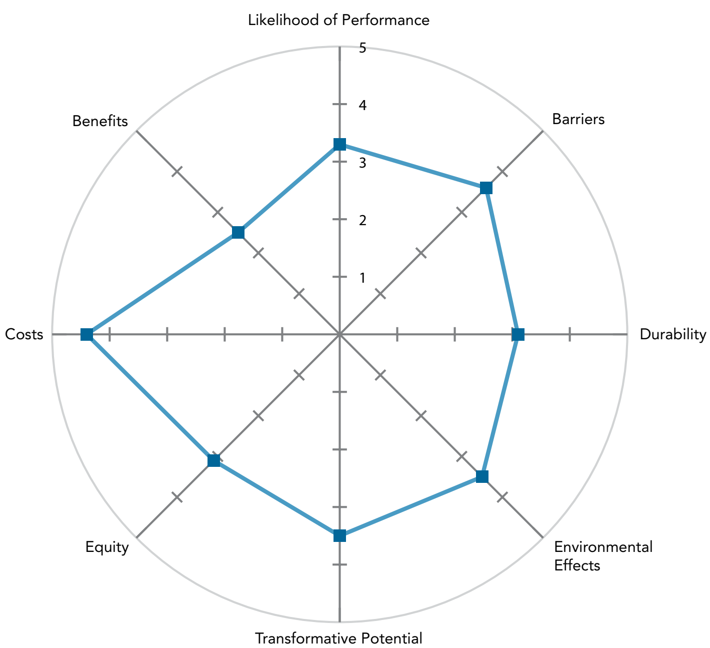
45. Have State require and fund master flood protection plans by local governments



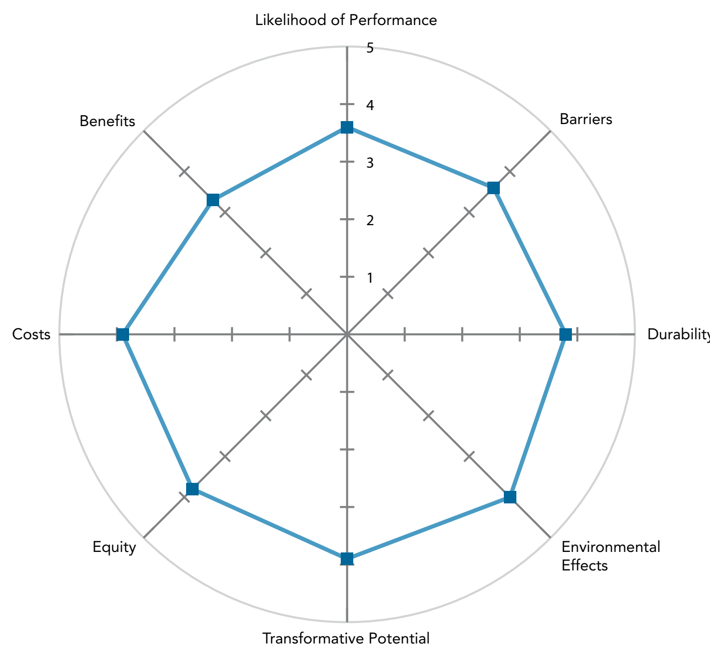
46. Produce an annual report card of climate change indicators in the HREW



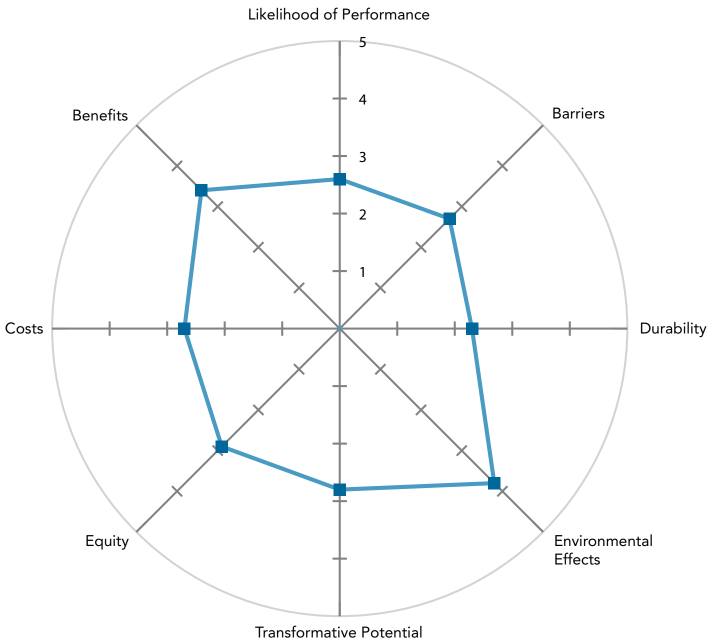
47. Extend Rising Waters scenarios by developing games and computer simulation tools



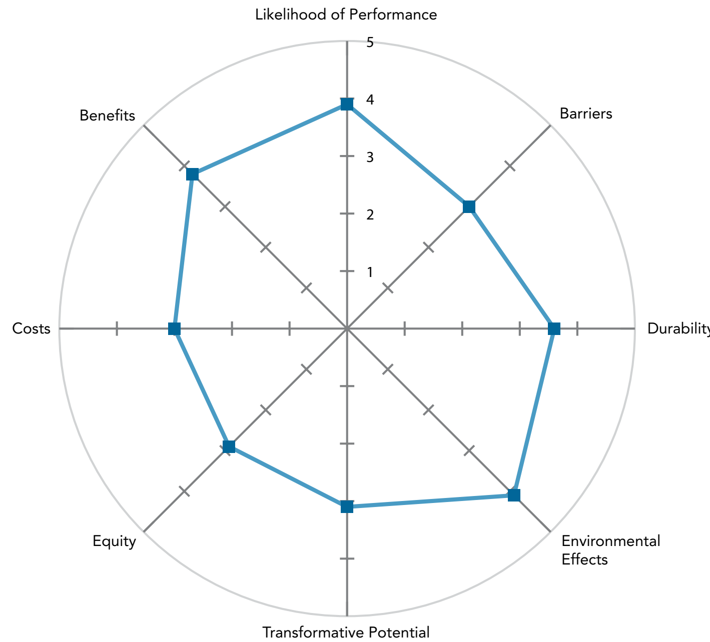
48. Reach out to local officials around best practices and technologies



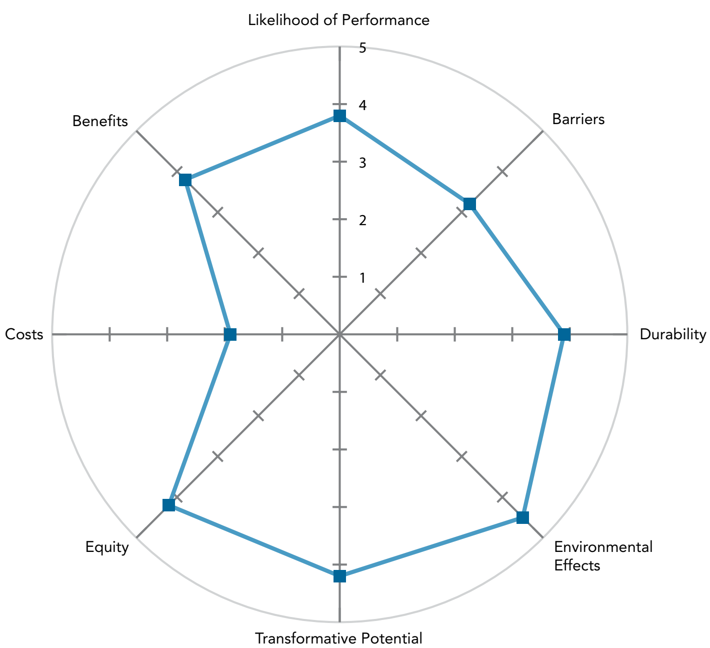
49. Double funding for local invasive species management



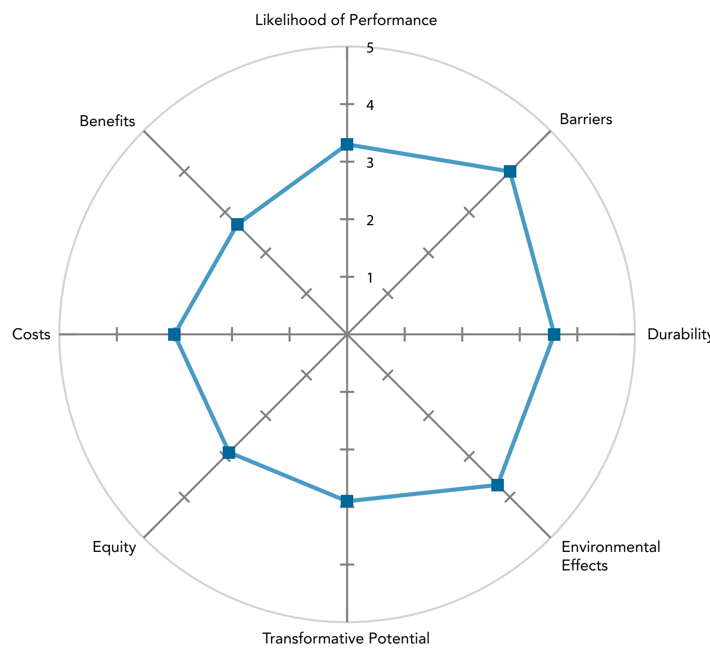
50. Intensify enforcement of floodplain zoning, landuse, & building codes



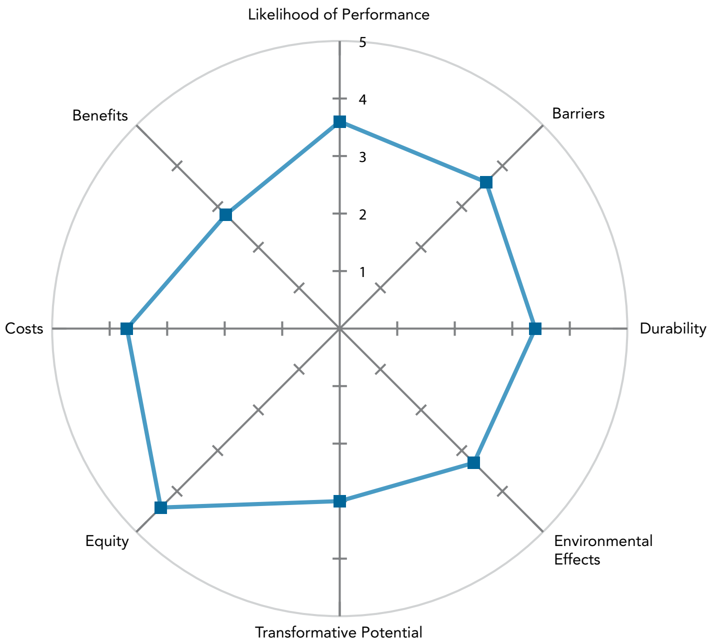
51. Undertake "urban-area greening programs" in response to more heatwaves



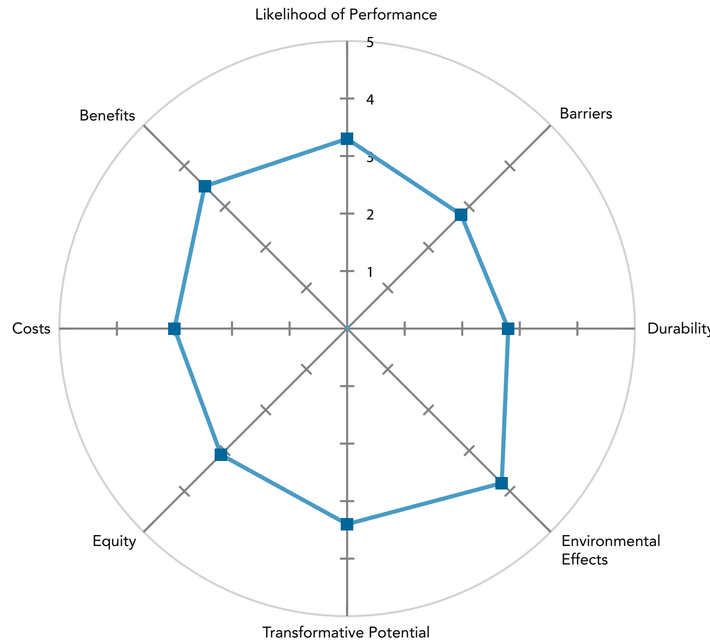
52. Provide design guidance on cooling to architects and engineers



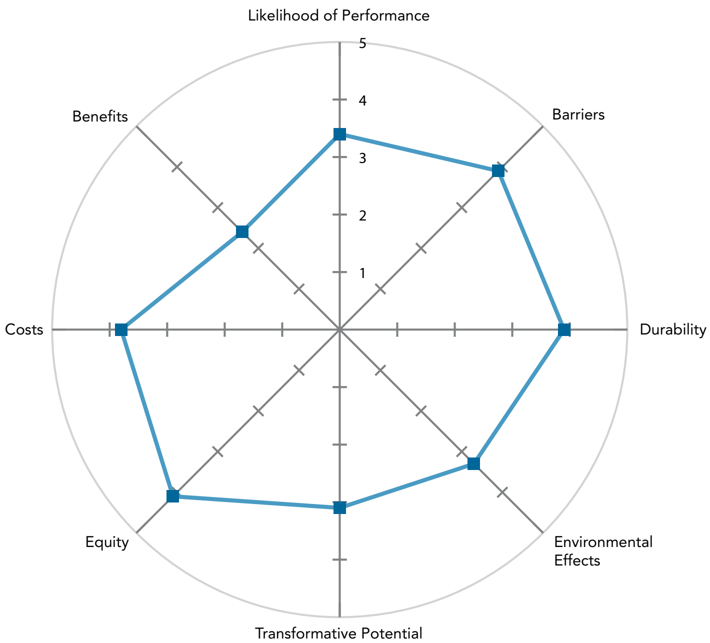
53. Provide public access to cool buildings during heatwaves



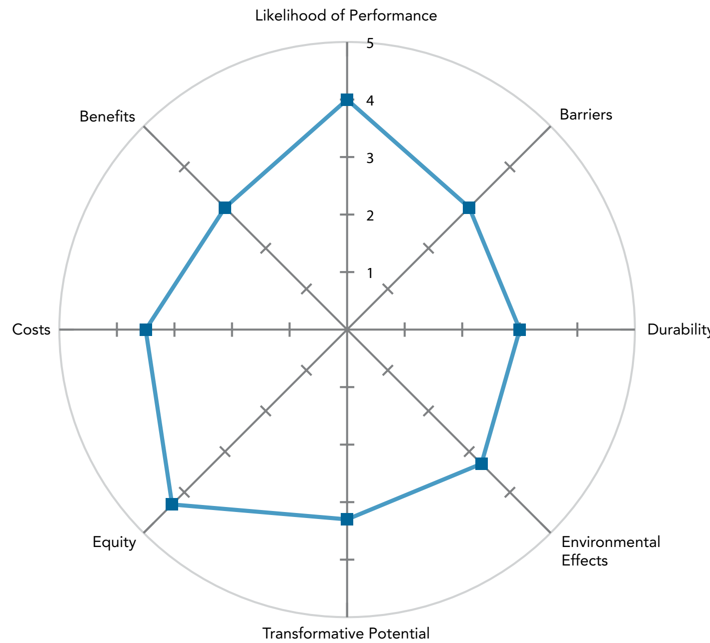
54. Aggressively promote cultural adaptations in anticipation of more heatwaves



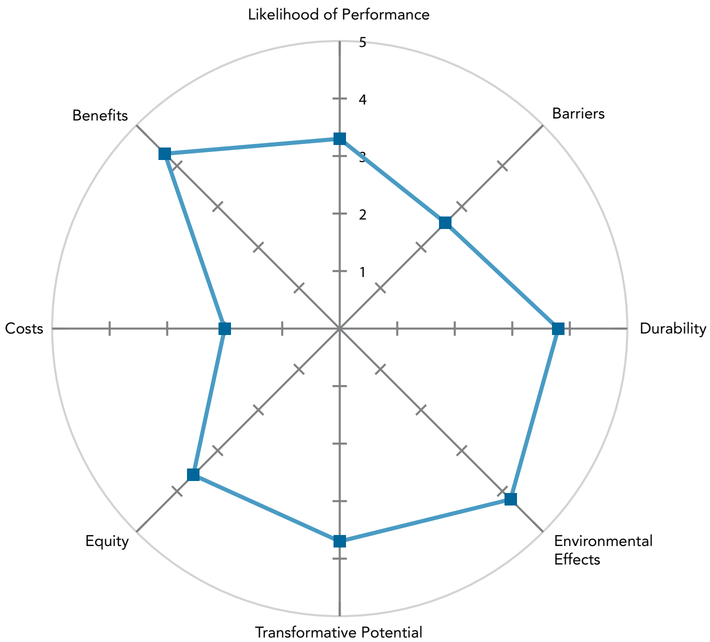
55. Develop and publicize local heatwave hazard and warning systems



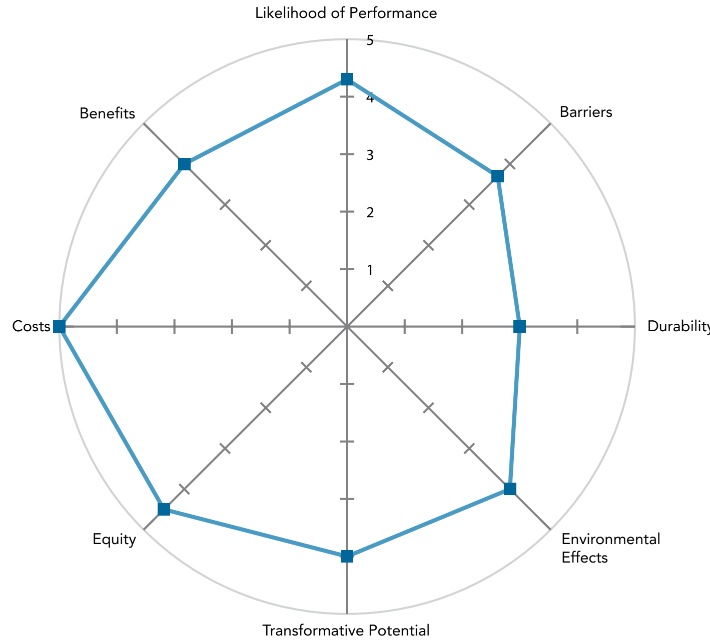
56. Require all health and social care facilities to have a "cool room"



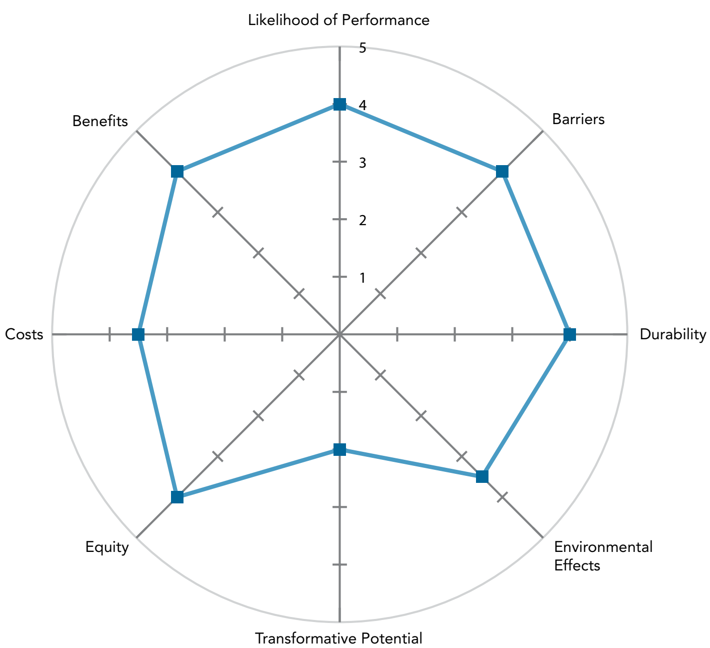
57. Start a climate change adaptation fund to build capital for funding future climate change adaptations



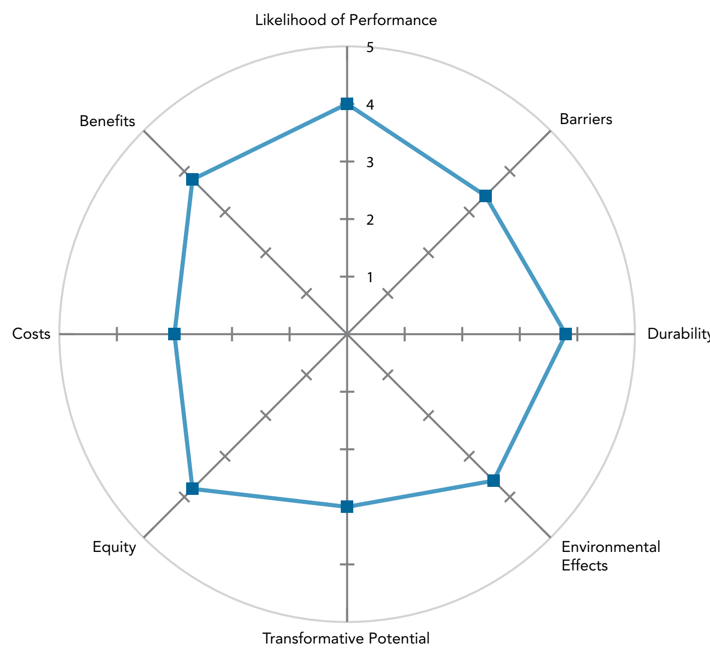
58. Conduct community outreach campaigns on the local threats posed by climate change, and what can be done in response



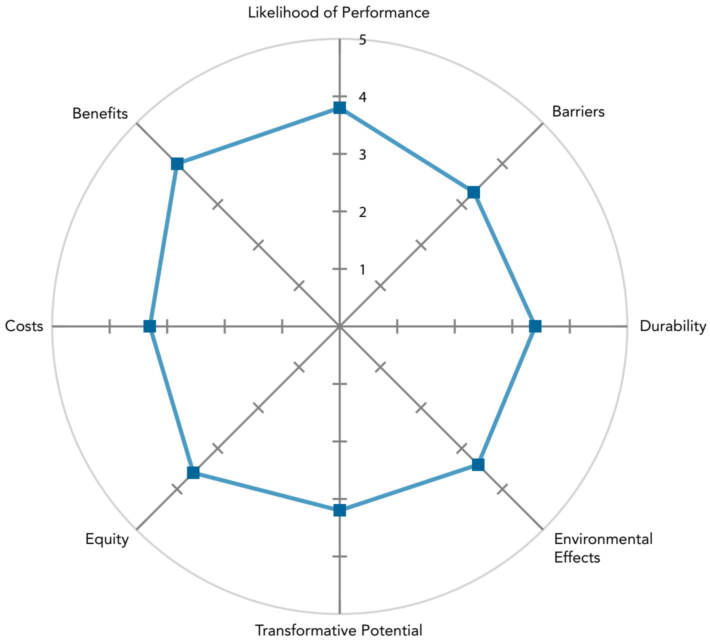
59. Prepare post-disaster recovery plans for climate change impact scenarios



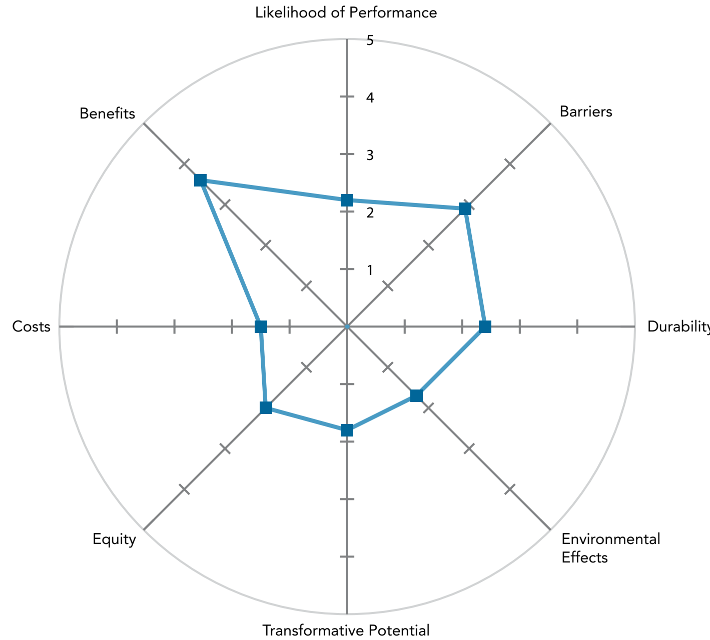
60. Develop and update emergency action plans with community involvement. Coordinate with State emergency management office.



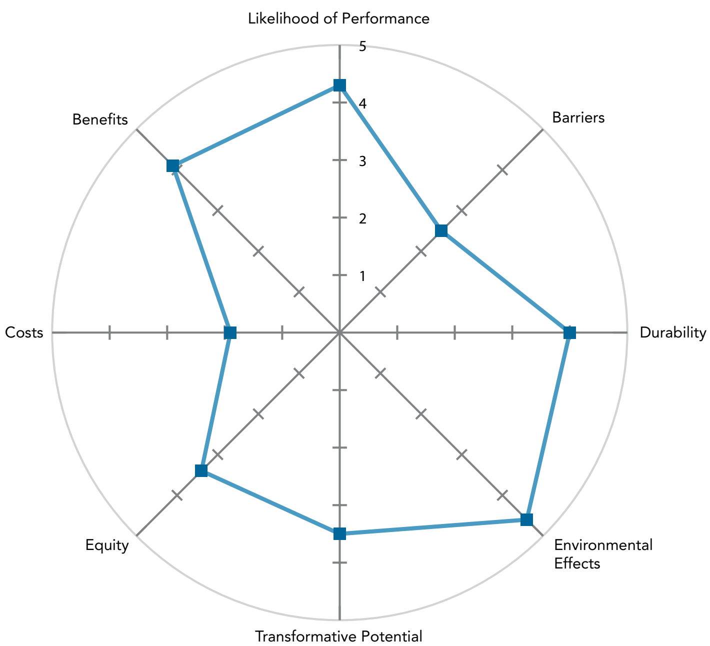
61. Require local community governments to work with the NYS Emergency Management Office (SEMO) to complete and update regional hazard and pre-disaster mitigation plans



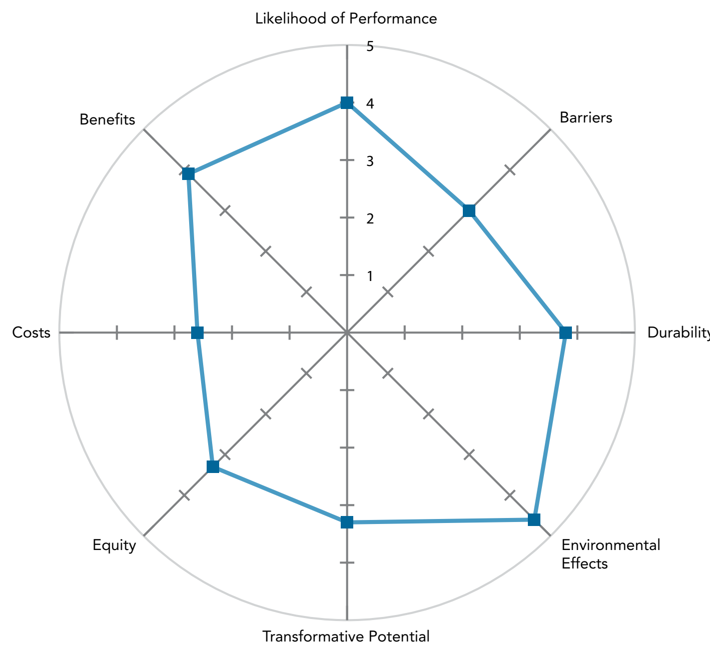
62. Build levees, floodwalls and seawalls



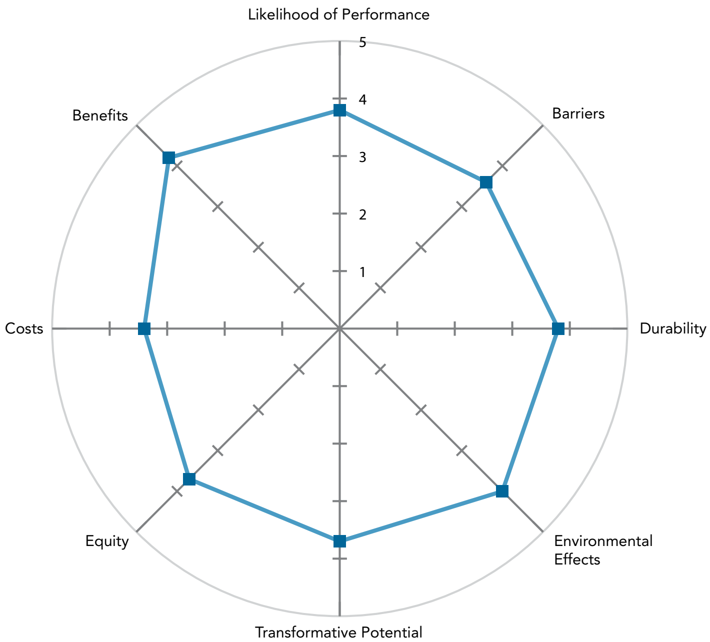
63. Develop longterm acquisition and easement plans to conserve floodplains



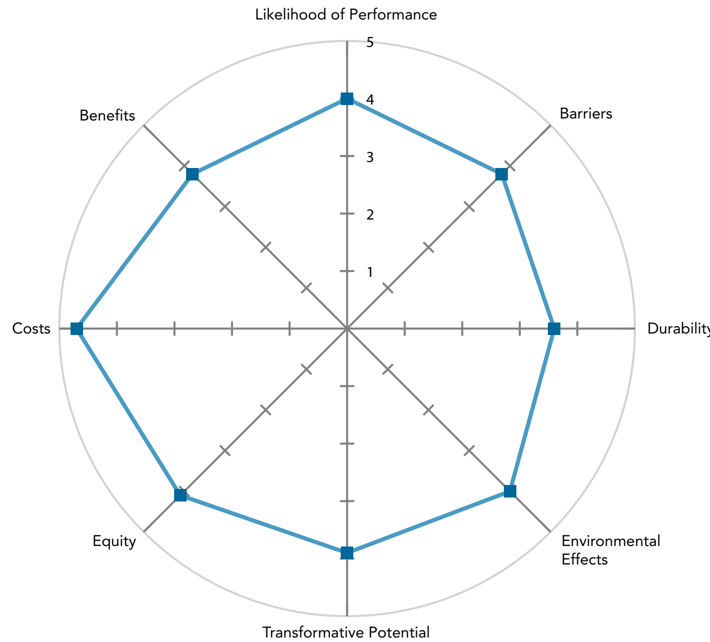
64. Begin an intensive program to restore streams to natural state and revegetate banks



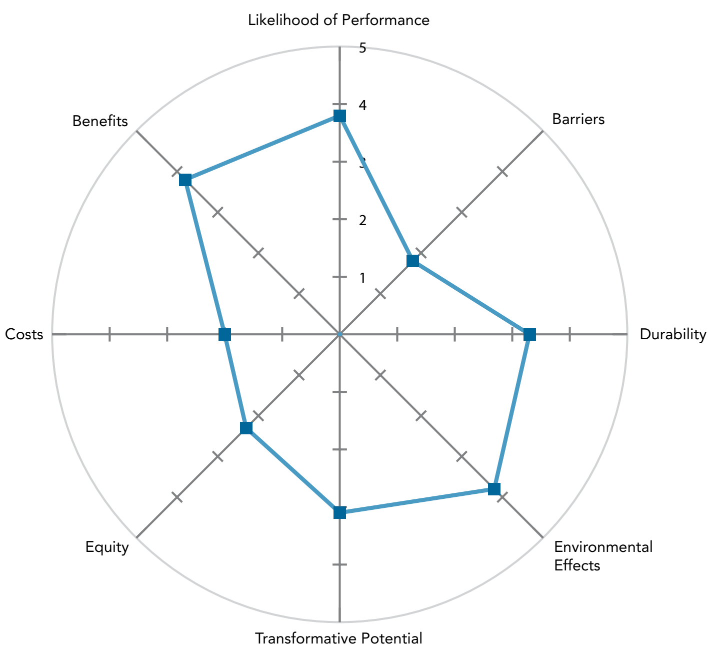
65. Become a StormReady community (NWS program, http://www.stormready.noaa.gov/)



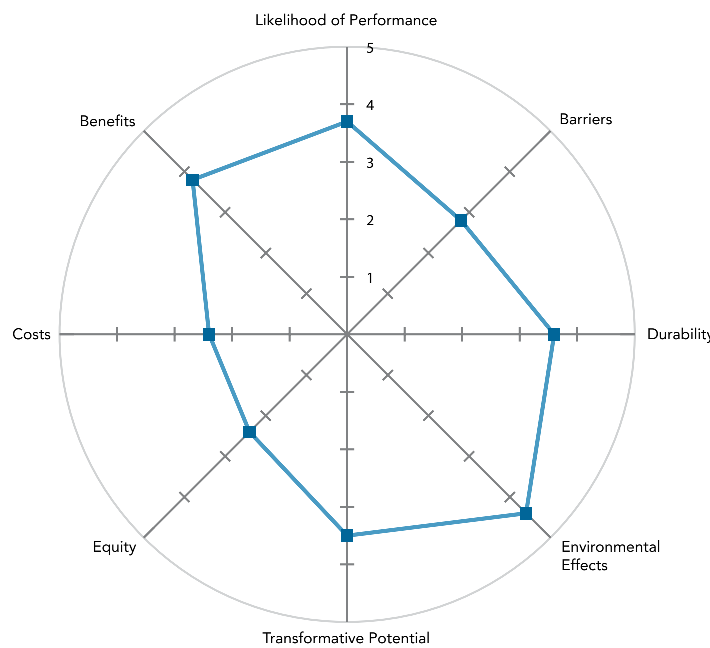
66. Convene open, regularly scheduled meetings for adaptation planning coordination



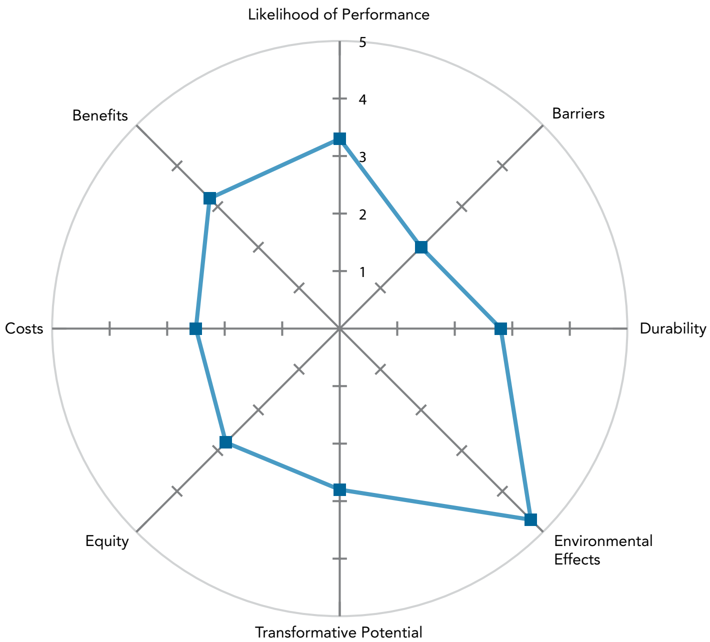
67. Make flood insurance in higher risk areas more expensive



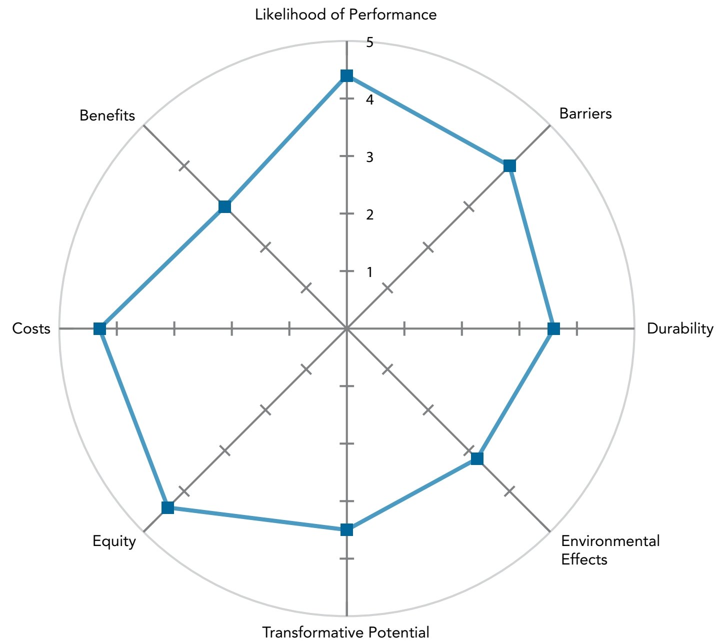
68. Require rainwater harvesting, storage and reuse for all new (or rebuilt/replaced) roof and gutter systems



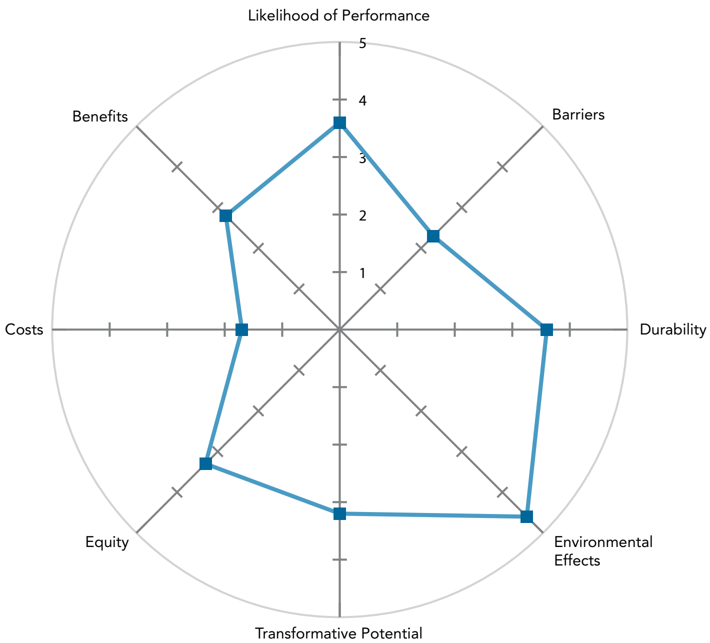
69. Expand funding for better management of HREW ecosystems



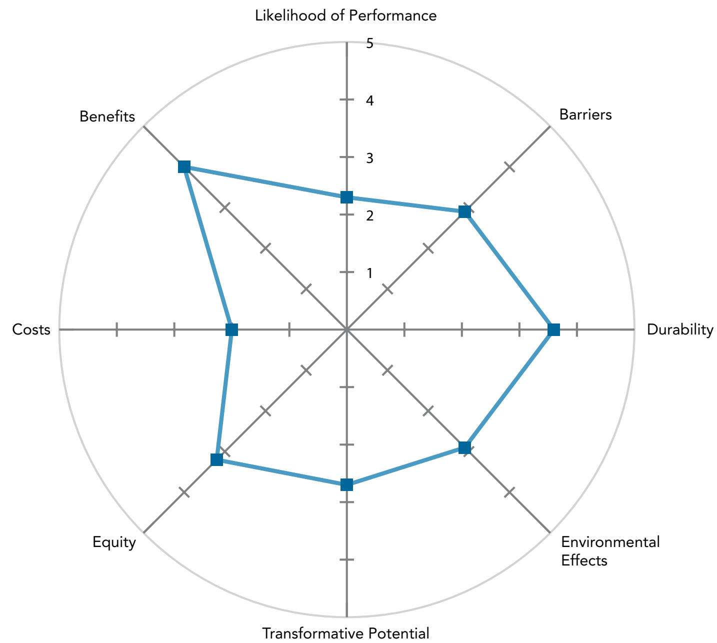
70. Develop local plans for alerting people of heatwave forecast, and what to do



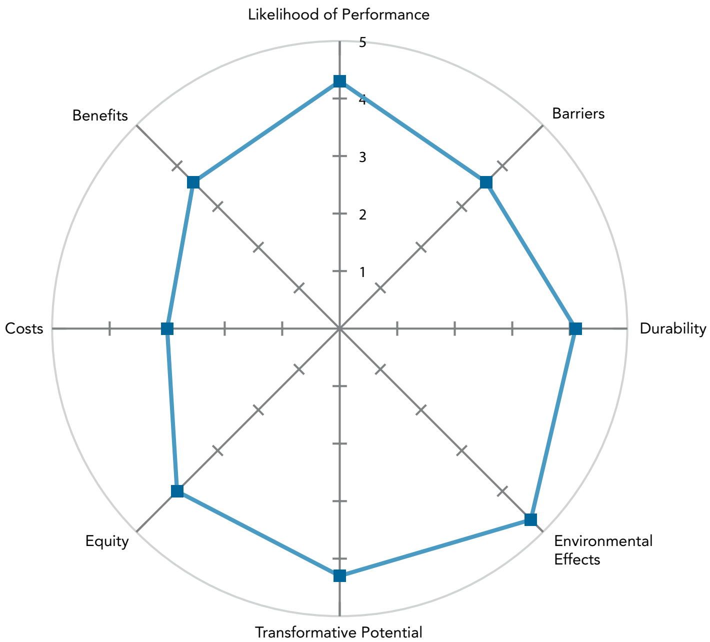
71. Require land bridges, tunnels, and detours for wildlife to cross highways and migrate through developed areas



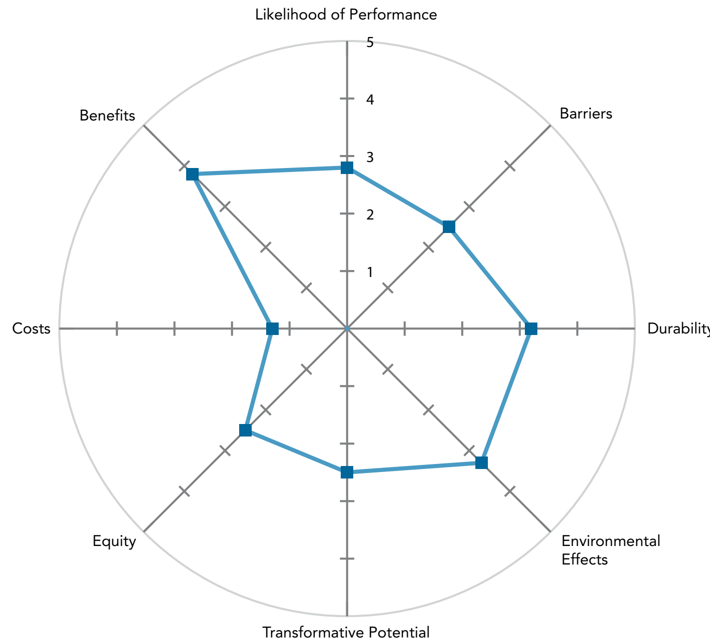
72. Develop technologies to use tidal action in the Hudson to generate electricity



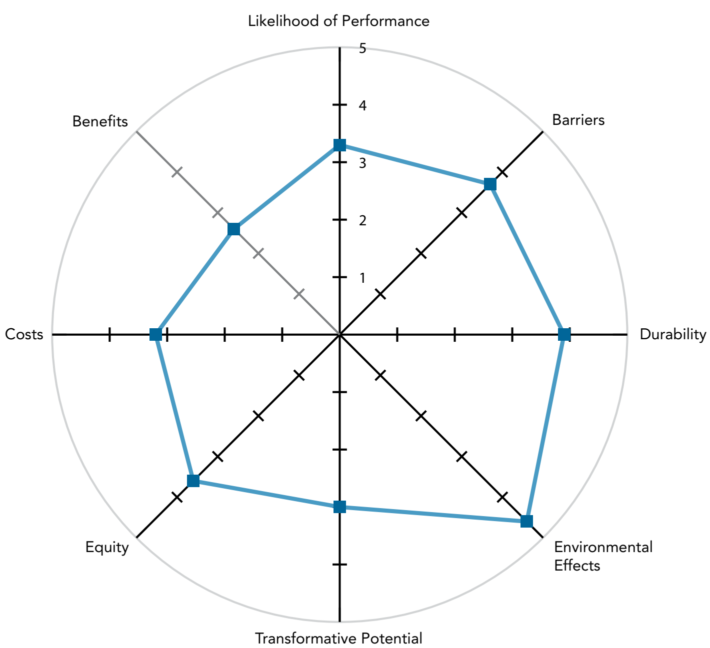
73. Install distributed stormwater systems (rain gardens, etc.)



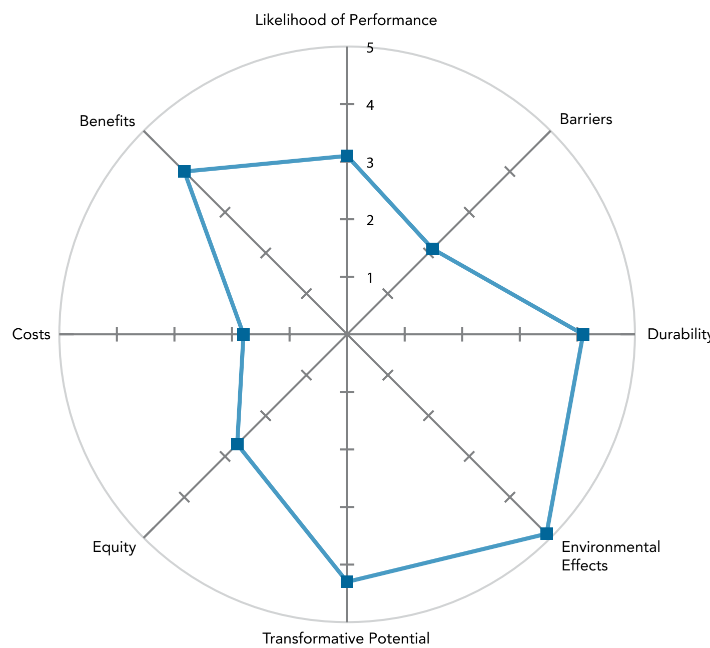
74. Disseminate floatation technologies for structures along the waterfront



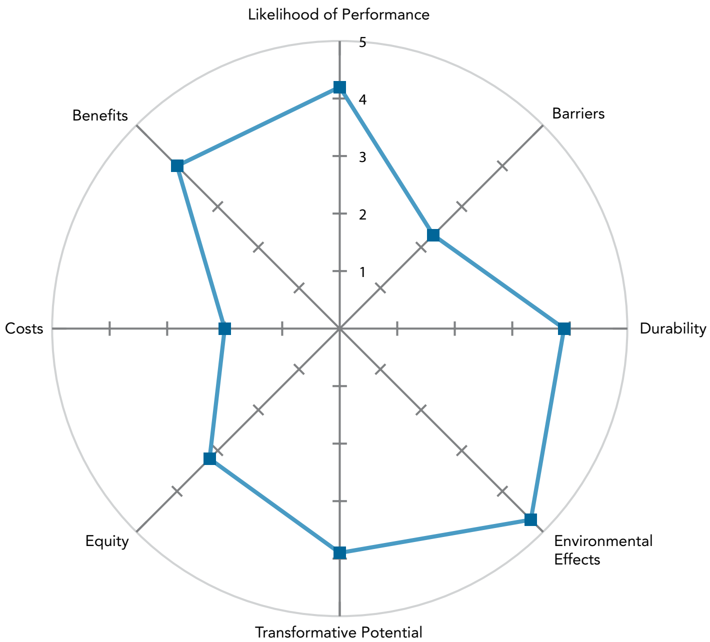
75. Plant trees to strengthen HREW ecosystem resilience (local shade and cooling, soil retention and water uptake and storage)



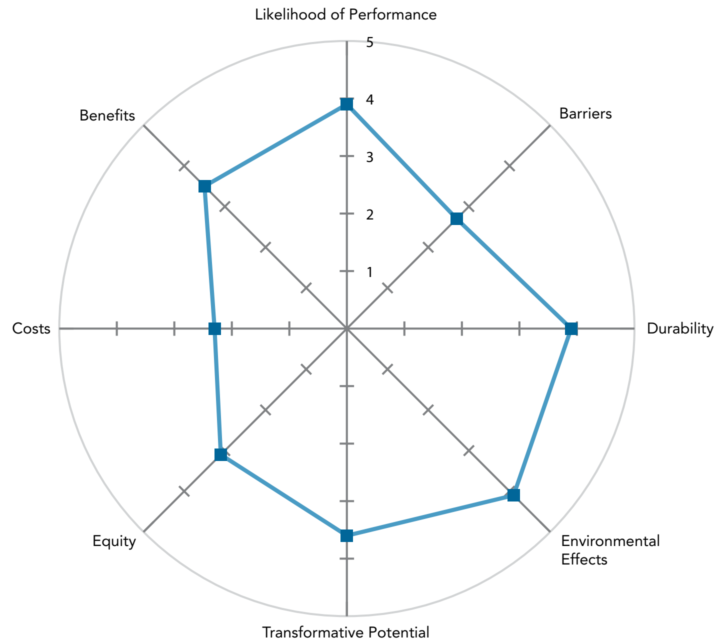
76. Require LEED certification for all new buildings in the HREW



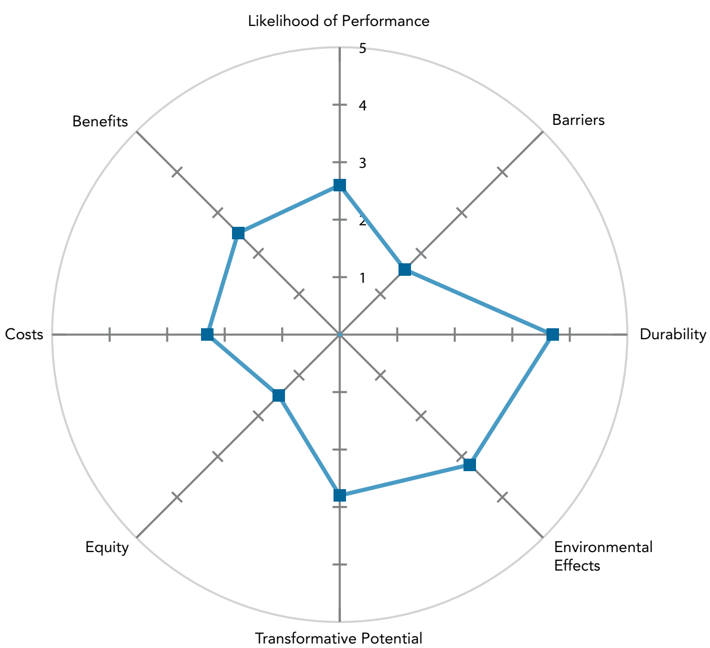
77. Require surface permeablility for all open surfaces in all new HREW development



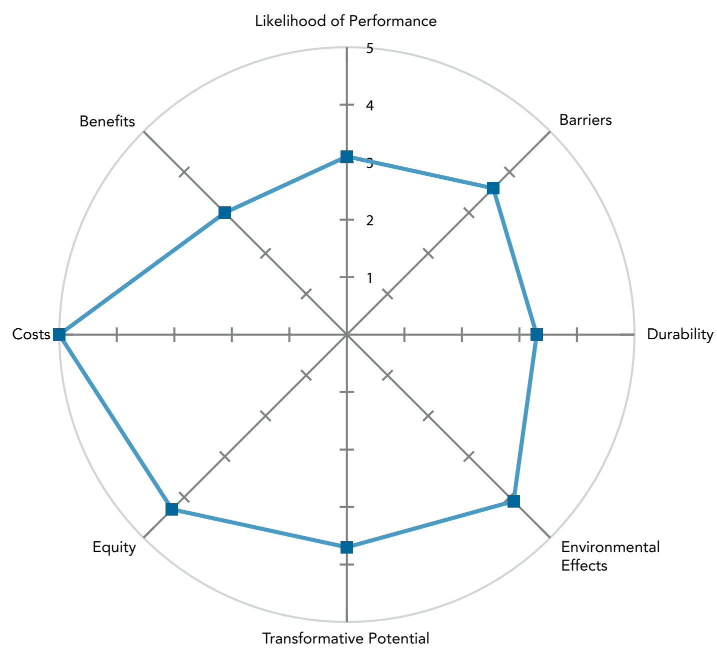
78. Promote smaller, distributed wastewater treatment facilities



79. Move your residence and workplace to low risk areas of the HREW



80. Hold regular, neighborhood meetings to "listen" to local adaptation needs, and mobilize local resources in response



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47 See appendix VI for a full description of the driving forces elements

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Center for Humans and Nature
Central Hudson Energy
Chazen Companies
City of Hudson
City of Kingston, Parks Dept. and Nature Center
Clearwater
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Columbia County Planning Department
Columbia University International Research Institute for Climate and Research
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Cornell Cooperative Extension — Orange County
Cornell Cooperative Extension — Ulster County
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DoRight Enterprises
Dutchess County Legislature
Dutchess County Planning
Dutchess County Water and Wastewater Authority
Earthjustice
Glynwood Center
H2O Conserve
Hastings-on-Hudson Comprehensive Plan Committee
HDR/LMS
Hickory Creek Consulting
Historic Hudson River Towns
Hoguet Newman & Regal
Hudson Highlands Nature Museum
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Hudson River National Estuarine Research Reserve
Hudson River Watershed Alliance
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Hudson Valley Regional Council
Island Press
Jonathan Rose Companies
Malcolm Pirnie, Inc.
Marist College
Metro Countryside Research
National Wildlife Federation
New Paltz & Vicinity for Obama Environmental Committee
New York Interfaith Power & Light
NYC DEP Bureau of Water Supply
NYC DEP Stream Management Program
NYS DEC Climate Change Office
NYS DEC Division of Environmental Permits
NYS DEC Division of Fish, Wildlife & Marine Resources
NYS DEC Division of Water
NYS DEC Hudson River Estuary Program
NYS Department of Agriculture & Markets
NYS Department of Environmental Conservation
NYS DOS Division of Coastal Resources
NYS DOS Division of Local Governments
NYS DOT Water/Ecology Section
NYS DOT, Region 8, Planning & Program Management
NYS Emergency Management Office
NYS Energy Research and Development Authority
Orange County Citizens Foundation
Orange County Planning Department
Orange County Rural Development Advisory Corporation
Orange County Water Authority
Parsons the New School for Design
PennyBridge Marina
Regional Plan Association
Rivers Alive!
Rockland County Executive Office
Sawkill Watershed Alliance
Scenic Hudson
Septon Development Group
Siena College
Skidmore College

Solar Evolution, LLC
Sustainable Hudson Valley
Swiss Re
Teatown Lake Reservation
The Highlands Coalition
The Nature Conservancy
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Ulster County Planning Department
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USGS Water Resources Office
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