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## Fifty Shades of Gray Infrastructure: Land Use and the Failure to Create Resilient Cities

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# FIFTY SHADES OF GRAY INFRASTRUCTURE: LAND USE AND THE FAILURE TO CREATE RESILIENT CITIES

Jonathan Rosenbloom\*

*Abstract:* Land use laws, such as comprehensive plans, site plan reviews, zoning, and building codes, greatly affect community resilience to climate change. One often-overlooked area of land use law that is essential to community resilience is the regulation of infrastructure on private property. These regulations set standards for infrastructure built by private developers. Such infrastructure is completed in conjunction with millions of commercial and residential projects and is necessary for critical services, including potable water and energy distribution. Throughout the fifty states, these land use laws regulating infrastructure constructed by private developers encourage or compel “gray infrastructure.” Marked by human-made, engineered solutions, including pipes, culverts, and detention basins, gray infrastructure reflects a desire to control, remove, and manipulate ecosystems. Left untouched, these ecosystems often provide critical services that strengthen a community’s resilience to disasters and slow changes. This Article describes the current state of land use laws and their focus on human-engineered, gray infrastructure developed as part of private projects. It explores how that infrastructure is reducing community resilience to change. By creatively combining human-engineered solutions with ecosystem services already available and by incorporating adaptive governance into the regulation of infrastructure erected by private parties, this Article describes how land use laws can enhance community resilience. The Article concludes with several examples where land use laws are relied upon to help build cost-effective, adaptive infrastructure to create more resilient communities.

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## INTRODUCTION

Local communities around the nation risk losing critical services because many of those services rely on deteriorating infrastructure that is not prepared for climate and other changes.<sup>1</sup> The vastness of this

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1. See AM. SOC’Y OF CIVIL ENG’RS, 2017 INFRASTRUCTURE REPORT CARD, (2018), <https://www.infrastructurereportcard.org> [<https://perma.cc/8D3W-6USU>] [hereinafter *Report Card*] (giving U.S. infrastructure a “D+”); JEB BRUGMANN, ICLEI, FINANCING THE RESILIENT CITY: A DEMAND DRIVEN APPROACH TO DEVELOPMENT, DISASTER RISK REDUCTION, AND CLIMATE ADAPTATION 15 (2011), [http://resilient-cities.iclei.org/fileadmin/sites/resilient-cities/files/Frontend\\_user/Report-Financing\\_Resilient\\_City-Final.pdf](http://resilient-cities.iclei.org/fileadmin/sites/resilient-cities/files/Frontend_user/Report-Financing_Resilient_City-Final.pdf) [<https://perma.cc/HGQ7-DNLZ>] [hereinafter BRUGMANN]; ICLEI, LOCAL GOVERNMENTS, EXTREME WEATHER, AND CLIMATE CHANGE 2012 (2012), [http://icleiusa.org/wp-content/uploads/2014/12/ICLEI\\_extreme\\_weather\\_cities\\_fact\\_sheet\\_2012.pdf](http://icleiusa.org/wp-content/uploads/2014/12/ICLEI_extreme_weather_cities_fact_sheet_2012.pdf) [<https://perma.cc/JMN8-TTVA>] (highlighting negative impacts of climate change on numerous local governments’ infrastructure and the actions they have taken in response). See generally Craig Anthony (Tony) Arnold, *Environmental Law, Episode IV: A New Hope? Can Environmental Law Adapt for Resilient Communities and Ecosystems?*, 21 J. ENVTL. & SUSTAINABILITY L. 1, 2 (2015) [hereinafter *Environmental Law, Episode IV*] (“Climate change is threatening communities and ecosystems. The old regimes . . . falter in the face of drought, flood, invasive species, polluted runoff, and land-development pressures.”).

infrastructure is massive, yet often unseen, and includes one million miles of drinking water pipes, almost 15,000 wastewater treatment facilities, and almost 2000 landfills.<sup>2</sup> As aging infrastructure decays and failures occur, communities are at risk of temporarily or permanently losing critical services, including potable water, sewer, stormwater management, waste management, transportation, and the provision and distribution of electricity.<sup>3</sup> Loss of these services, even temporarily, has had and will have profound impacts on communities' health, safety, and economies—a reality some communities have already confronted.<sup>4</sup> Infrastructure challenges may “involve systemic risks in which temporal losses stem from slowly deteriorated infrastructure following repetitive . . . stresses; or catastrophic risks in which losses arise from disastrous climate events.”<sup>5</sup> Whether loss of services stem from catastrophic disasters, such as 2017 Hurricanes Harvey, Irma, and Maria (“destroying much of Puerto Rico’s infrastructure”),<sup>6</sup> or slow-moving changes in the climate and

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2. AM. SOC'Y OF CIVIL ENG'RS, 2017 INFRASTRUCTURE REPORT CARD: DRINKING WATER (2017), <https://www.infrastructurereportcard.org/wp-content/uploads/2017/01/Drinking-Water-Final.pdf> [<https://perma.cc/9K6L-V87K>]; AM. SOC'Y OF CIVIL ENG'RS, 2017 INFRASTRUCTURE REPORT CARD, WASTEWATER, (2017), <https://www.infrastructurereportcard.org/wp-content/uploads/2017/01/Wastewater-Final.pdf> [<https://perma.cc/9R8F-8XFX>]; AM. SOC'Y OF CIVIL ENG'RS, 2017 INFRASTRUCTURE REPORT CARD, SOLID WASTE, (2017), <https://www.infrastructurereportcard.org/wp-content/uploads/2017/01/Solid-Waste-Final.pdf> [<https://perma.cc/RG46-JQE5>].

3. See *Report Card*, *supra* note 1; Sarah Adams-Schoen & Edward Thomas, *A Three-Legged Stool on Two Legs: Recent Federal Law Related to Local Climate Resilience Planning and Zoning*, 47 URB. LAW. 525, 526–27 (2015) (“Indeed, many communities are already experiencing climate change related threats, including eroding shores, more massive storm surges, more severe storms, salt water intrusion, loss of land, heat waves, droughts, and other extreme weather conditions.”).

4. See NAT'L INFRASTRUCTURE ADVISORY COUNCIL, WATER SECTOR RESILIENCE FINAL REPORT AND RECOMMENDATIONS: DRAFT/PRE-DECISIONAL 1, 18 (2016) [hereinafter WATER SECTOR RESILIENCE FINAL REPORT], <https://www.dhs.gov/sites/default/files/publications/niac-water-resilience-study-draft-06-09-16-508.pdf> [<https://perma.cc/MNQ9-564K>] (“Secure and resilient water and wastewater infrastructure is essential to daily life, ensuring the economic vitality of the Nation and maintaining public confidence in utility services.”); Adams-Schoen & Thomas, *supra* note 3, at 526–27; Jonathan Rosenbloom, *Funding Adaptation*, 47 J. MARSHALL L. REV. 657, 658 (citing BRUGMANN, *supra* note 1, at 14 (citing several examples of cities facing economic, environmental, and social disasters)); see, e.g., Emma G. Fitzsimmons, *Tap Water Ban for Toledo Residents*, N.Y. TIMES (Aug. 3, 2014), <https://www.nytimes.com/2014/08/04/us/toledo-faces-second-day-of-water-ban.html> [<https://perma.cc/59BT-AR25>]; *Flint Water Crisis*, DETROIT NEWS, <http://www.detroitnews.com/news/flint-water-crisis/> [<https://perma.cc/EMV6-E9BR>] (compilation of The Detroit News' stories covering Flint potable water crisis); Emma Penrod, *Torrey Declares State of Emergency After Town Runs Out of Water*, SALT LAKE TRIB. (June 20, 2017), <http://www.sltrib.com/home/5424247-155/torrey-declares-state-of-emergency-after#sthash.2vh5kbU0.dpuf> [<https://perma.cc/R6HZ-E8TD>] (noting the town of Torrey, Utah is without potable water following a water main break).

5. Rosenbloom, *supra* note 4, at 662, 667.

6. Victor B. Flatt & Rob Verchick, *Burying Our Head in Sand on Climate Change No Longer an Option*, HOUS. CHRON. (Sept. 28, 2017), <http://www.houstonchronicle.com/opinion/outlook/article/>

ecosystems, or a combination of the two, infrastructure and the laws that influence infrastructure development are not prepared.

The citizens of Houston, Texas; Puerto Rico; Flint, Michigan; Toledo, Ohio; Torrey, Utah; and many, many others have experienced great hardship from the loss of critical services that require infrastructure.<sup>7</sup> On average, water infrastructure alone suffers 240,000 main breaks per year and six billion gallons of treated water lost per day.<sup>8</sup> When disaster strikes, it does not take much to lead to tragic results because a weakened infrastructure is vulnerable to a changing climate. For example, in September 2017, after Hurricane Irma significantly damaged water and energy infrastructure, eight patients at a rehabilitation center in Hollywood, Florida, died from heat-related causes.<sup>9</sup> As the reality of these risks become clearer, it is necessary to create more resilient infrastructure systems that can adapt to known and unknown threats to help protect the health and safety of communities.

Land use laws are among the most powerful tools local governments have to create resilient infrastructure that can adapt to climate change and other uncertainties.<sup>10</sup> While land use laws provide an opportunity for local governments to prepare for changes, they have traditionally been drafted and implemented in a way that creates and exacerbates vulnerabilities.<sup>11</sup>

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Burying-our-head-in-sand-on-climate-change-no-12238961.php [https://perma.cc/MD7M-T477]. Hurricane Maria has also been called “the most ferocious storm to strike the island in at least 85 years . . . [It] obliterated electric grid that cut power to every one of the island’s 3.4 million people.” Patricia Mazzei & David Ovalle, *Hurricane Maria’s Rampage Demolishes Puerto Rico*, MIAMI HERALD (Sept. 21, 2017), <http://www.miamiherald.com/news/weather/hurricane/article174488726.html> [https://perma.cc/U2YS-C62X].

7. Fitzsimmons, *supra* note 4; *Flint Water Crisis*, *supra* note 4; Penrod, *supra* note 4.

8. WATER SECTOR RESILIENCE FINAL REPORT, *supra* note 4, at 3.

9. See Amy Davidson Sorkin, *In the Dark*, NEW YORKER, Sept. 25, 2017, at 37. Before Hurricane Irma hit the Florida Keys as a Category Four hurricane it decimated the Caribbean Island of Barbuda, which suffered damages to 95% of its structures and required all 1,800 residents to evacuate, leaving the island uninhabited for the first time in 300 years. T.J. Raphael, ‘For First Time in 300 Years, There’s Not a Single Living Person on the Island of Barbuda,’ USA TODAY (Sept. 14, 2017), <https://www.usatoday.com/story/news/world/2017/09/14/barbuda-hurricane-irama-devastation/665950001/> [https://perma.cc/3N62-Z2TB].

10. For purposes of this Article, “land use laws” refer to building, zoning, and development codes. While some private development infrastructure is required and negotiated through development agreements, those requirements and agreements are typically rooted in land use laws.

11. See Sarah J. Adams-Schoen, *Sink or Swim: In Search of a Model for Coastal City Climate Resilience*, 40 COLUM. J. ENVTL. L. 433, 446–47 (2015) (“Municipal regulation of the form and placement of building stock in particular offers an opportunity to create more resilient infrastructure and patterns of development . . . . Because we can anticipate the addition of substantial new building stock and infrastructure over the next few decades, local governments that regulate the placement and, in some respects, design aspects of building stock certainly have an opportunity to avoid locking in

This is particularly true for land use regulations governing infrastructure for millions of private projects.<sup>12</sup> Only a portion of the infrastructure system is designed, built, and paid for by the public sector. A critical part of the system is designed, built, and paid for by the private sector.<sup>13</sup> From single-family homes to large scale commercial skyscrapers, most private developments require the installation of infrastructure. Developers seeking to construct these projects are subject to local land use laws.<sup>14</sup> Those laws often address a broad range of infrastructure needs, including streets, bike paths, parking, sidewalks, energy distribution, street lighting, stormwater run-off, potable water, waste management, tree removal, and access to nature.<sup>15</sup> Further, these laws may be applicable at a variety of stages, including site plan reviews, zoning amendments, and planned unit development approvals.<sup>16</sup> As such, an essential part of any local resilience plan must include a close look at land use laws and how they regulate infrastructure that is required for private development.<sup>17</sup>

The predominant land use narrative governing infrastructure on private properties encourages, if not compels, the construction of “gray infrastructure.” Made of concrete, metal, pipes, tunnels, tanks, and “other materials with high embedded energy necessary in their construction,” gray infrastructure is often static.<sup>18</sup> It is designed to manipulate or resist

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infrastructure that increases flood and other climate-related risks.”); *infra* Part III (reviewing land use provisions that strain community resilience).

12. See *infra* Part III (reviewing land use provisions that encourage gray infrastructure and increase vulnerabilities).

13. See *id.* (reviewing land use provisions that regulate infrastructure).

14. See, e.g., COOPER TOWNSHIP, PA., § 120.430 (2017), <http://www.coopertwp.org/wp-content/uploads/2017/01/430.pdf> [<https://perma.cc/E7XX-CYJQ>] (requiring all industrial and commercial development to comply with site plan review); CORNELIUS, OR., MUN. CODE. ch. 18.110 (2017), <http://www.codepublishing.com/OR/Cornelius/html/Cornelius18/Cornelius18110.html> [<https://perma.cc/5N6L-3JGB>] (same); FERNDALÉ, WASH., MUN. CODE § 18.69.020 (2017), <http://www.codepublishing.com/WA/Ferndale/html/Ferndale18/Ferndale1869.html#18.69.020> [<https://perma.cc/2EZD-FXM3>] (same, but for Planned Unit Development provisions); MESA, ARIZ., MESA ZONING ORDINANCE ch. 69 (2017), <http://www.mesaaz.gov/home/showdocument?id=12516> [<https://perma.cc/67VM-8K9L>] (same); WATERTOWN, Wis., APPLICATION FOR SITE PLAN REVIEW COMMITTEE, <http://www.ci.watertown.wi.us/SITE%20PLAN%20REVIEW%20application-March%202016.pdf> [<https://perma.cc/HA92-Y6P2>] (describing properties subject to site plan review).

15. See, e.g., *infra* sections IV.B–C (setting forth specific provisions).

16. See, e.g., *infra* ordinances cited in sections III.A–B.

17. See Alice Kaswan, *Climate Adaptation and Land Use Governance: The Vertical Axis*, 39 COLUM. J. ENVTL. L. 390, 405–07 (2014) (“Land-use law plays a critical role in efforts to accommodate risk by increasing resilience.”).

18. Caswell F. Holloway et al., *Solving the CSO Conundrum: Green Infrastructure and the Unfulfilled Promise of Federal-Municipal Cooperation*, 38 HARV. ENVTL. L. REV. 335, 359–60 (2014); John Talberth & Craig Hanson, *Green vs. Gray Infrastructure: When Nature Is Better than Concrete*, WORLD RESOURCES INST. (June 19, 2012), <http://www.wri.org/blog/2012/06/green-vs->

ecosystems and remain steadfast to changes.<sup>19</sup> Gray infrastructure is typically designed to meet a predetermined set of criteria or maintain a fixed level of performance established at a single point in time. If that level is breached or if the circumstances change such that the infrastructure is directed at resisting an event outside of the predetermined criteria, public services are at risk.

Most gray infrastructure presents at least two challenges to community resilience. It is decaying and it is not prepared to adjust or modify to changes.<sup>20</sup> Both of these challenges to community resilience are affected by rapid and intense disturbances, such as hurricanes and floods, and relatively slower-moving ecosystem changes, such as climate change. In terms of rapid and intense disturbances, we can expect stronger and more frequent weather events.<sup>21</sup> For example, September 2017 was the

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gray-infrastructure-when-nature-better-concrete [<https://perma.cc/X8FR-R895>] (describing gray infrastructure as “human-engineered solutions that often involved concrete and steel”).

19. In the context of environmental and natural resources law, this approach has been called a “Humans as Controlling Engineers” narrative. See Robin Kundis Craig, *Learning to Live with the Trickster: Narrating Climate Change and the Value of Resilience Thinking*, 33 PACE ENVTL. L. REV. 351, 359 (2016) [hereinafter *Learning to Live with the Trickster*]. The content and development of how Americans subscribed to the idea that we could and should re-engineer nature in order to control it has a fascinating history that is beyond the purview of this Article. The narrative is manifested in public policies, programs, norms, and perspectives, including in areas of disaster preparedness and response planning. See generally WALLACE S. BROECKER, *HOW TO BUILD A HABITABLE PLANET*, ch. 20 (1985); EDWARD O. WILSON, *HALF-EARTH—OUR PLANET’S FIGHT FOR LIFE* (2016); Will Steffen et al., *The Anthropocene: Conceptual and Historical Perspectives*, 369 PHIL. TRANSACTIONS ROYAL SOC’Y A 842–67 (2011); Jan Zalasiewicz et al., *When Did the Anthropocene Begin? A Mid-Twentieth Century Boundary Level Is Stratigraphically Optimal*, 383 Q. INT’L. 196–203 (2015). My focus in this Article is to highlight that land use law is an unexplored area where this narrative is manifested and is having dire consequences for communities.

20. See NELL GREEN NYLEN & MICHAEL KIPARSKY, *ACCELERATING COST-EFFECTIVE GREEN STORMWATER INFRASTRUCTURE: LEARNING FROM LOCAL IMPLEMENTATION* (2015), [https://www.law.berkeley.edu/files/CLEE/GSI\\_Report\\_Full\\_2015-02-25.pdf](https://www.law.berkeley.edu/files/CLEE/GSI_Report_Full_2015-02-25.pdf) [<https://perma.cc/TQ7A-8UCY>]; Leda Zimmerman, *Greening Gray Infrastructure*, MIT SPECTRUM (2014), <http://spectrum.mit.edu/winter-2014/greening-gray-infrastructure/> [<https://perma.cc/TXN9-UU7W>] (“As urban development escalates, and climate change brings rising seas and monster storms, current water management systems are failing . . .”).

21. See Flatt, *supra* note 6 (“Houston has now had 500-year storms—storms with a 0.2 percent chance of occurring in a given year—in each of the last three years.”); Dan Frosch, *After Hurricane Harvey, Texas County Rethinks Flood-Prevention Efforts*, WALL ST. J. (Oct. 2, 2017), <https://www.wsj.com/articles/after-hurricane-harvey-texas-county-rethinks-flood-prevention-efforts-1506936602> [<https://perma.cc/HS4J-54XJ>] (“‘We’ve had three 500-year floods or above in the last two years. So there is a new normal,’ said Judge Ed Emmett, Harris County’s chief executive.”); Daniel C. Vock, *As Disasters Grow More Frequent, How Should States and Cities Prepare?*, GOVERNING (Sept. 25, 2017), <http://www.governing.com/topics/transportation-infrastructure/gov-disaster-haryey-irma-madhu-berawal-interview.html> [<https://perma.cc/5UTG-2EBQ>] (noting “we have seen five flood events in the last 18 to 24 months that have been either 500-year or 1,000-year events. We’ve seen two Category 4 storms strike in the same year. So we are seeing an increased propensity for these very large flood events”).

strongest hurricane month ever in terms of accumulated cyclone energy.<sup>22</sup> September had the most major hurricane days in a single month, two Category 5 storms (wind speeds exceeding 157 miles per hour), which had only occurred in five other years, and had multiple Category 5 storms making landfall in North America, which only occurred once before in recorded history (2007).<sup>23</sup> As one commentator stated, Hurricanes Irma and Harvey “are reminders that we live in an era of standardized disaster, with cities sprawling across what are now, effectively, floodplains. . . . [I]n other areas, too, relating to infrastructure . . . Irma provided a case study in precariousness.”<sup>24</sup> Similarly, as slow-moving changes occur in ecosystems, the stationarity<sup>25</sup> of infrastructure and the laws governing infrastructure leaves communities vulnerable because they are unable to quickly adapt to changes.<sup>26</sup> If communities are to protect themselves they must adopt a new land use narrative for the regulation of infrastructure on private property—one that no longer focuses primarily on gray infrastructure and its associated stationarity. This new narrative must incorporate alternative approaches that may include gray infrastructure, but also include more adaptive measures and governance to create a more resilient infrastructure system that incorporates and mimics ecosystem services to address rapid and slow-moving changes.<sup>27</sup>

Even though local infrastructure on private property is pervasive and critical to community resilience,<sup>28</sup> little, if any, scholarship focuses on the

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22. See Robinson Meyer, *September Is the Strongest Hurricane Month Ever Recorded—Probably*, ATLANTIC (Sept. 27, 2017), <https://www.theatlantic.com/science/archive/2017/09/september-2017-hurricane-energy-record-irma-maria-harvey/541185/> [https://perma.cc/F6JR-CXB6]. The accumulated cyclone energy index, referred to as the “ACE index,” is a somewhat complicated index the National Oceanic and Atmospheric Administration uses to measure individual hurricanes and hurricane seasons. *Background Information: The North Atlantic Hurricane Season*, NAT’L WEATHER SERV., [http://www.cpc.ncep.noaa.gov/products/outlooks/background\\_information.shtml](http://www.cpc.ncep.noaa.gov/products/outlooks/background_information.shtml) [https://perma.cc/TCJ6-4KCR] (“The ACE index is a wind energy index, defined as the sum of the squares of the maximum sustained surface wind speed (knots) measured every six hours for all named storms while they are at least tropical storm strength. NOAA uses the ACE index, combined with the seasonal total number of named storms, hurricanes, and major hurricanes, to categorize North Atlantic hurricane seasons as being above normal, near normal, or below normal.”).

23. See Meyer, *supra* note 22.

24. See Sorkin, *supra* note 9, at 37.

25. For purposes of this Article “stationarity” concerns the assumption that “natural systems fluctuate within an unchanging envelope of variability.” P.C.D. Milly et al., *Stationarity Is Dead: Whither Water Management?*, 319 SCI. 573, 573 (2008).

26. See *infra* Part I (describing intense and rapidly changing conditions communities are facing).

27. See *infra* section IV.C for a discussion of green infrastructure.

28. See Maike Sippel & Till Jansen, *What About Local Climate Governance? A Review of Promise and Problems* 3 (Discussion Paper, Nov. 2009), <http://ssrn.com/abstract=1514334>



role that thousands of developers play in building an essential part of the infrastructure system. Research on local infrastructure resilience typically focuses on large public infrastructure projects, such as President Donald Trump’s promise to spend \$1 trillion on infrastructure projects across the United States, such as State Route 520—Washington State’s floating concrete bridge—or New York City’s World Trade Center Transportation Hub.<sup>29</sup> These projects can be significant not only in their impact on local communities, but also in their budgets.<sup>30</sup> Equally important, however, are the millions of smaller projects that incorporate some infrastructure and are directly regulated by local land use laws. These projects include commercial, industrial, and residential properties developed each year. Unlike large well-known public infrastructure projects, these projects are part of everyday life in communities across the United States.

This Article begins the process of critically analyzing land use laws and their impact on infrastructure and community resilience by describing a predominant land use law narrative. That narrative overwhelmingly consists of a focus on gray infrastructure and stationarity. The Article pieces this narrative together by analyzing a broad swath of land use

[<https://perma.cc/TF73-N88X>] (“[U]rban planning, infrastructure and local emergency management are instrumental to build climate resilience.”).

29. See Michael Kimmelman, *Santiago Calatrava’s Transit Hub Is a Soaring Symbol of a Boondoggle*, N.Y. TIMES (Mar. 2, 2016), [https://www.nytimes.com/2016/03/03/arts/design/santiago-calatravas-transit-hub-is-a-soaring-symbol-of-a-boondoggle.html?\\_r=0](https://www.nytimes.com/2016/03/03/arts/design/santiago-calatravas-transit-hub-is-a-soaring-symbol-of-a-boondoggle.html?_r=0) [<https://perma.cc/A637-SW4U>] (“[P]roject’s cost soared toward a head-slapping, unconscionable \$4 billion in public money.”); Wash. State Dep’t of Transp., *SR 520 Floating Bridge Documentary—April 2017*, YOUTUBE (Apr. 25, 2017), <https://www.youtube.com/watch?v=LH3cNXu26hA> [<https://perma.cc/K9D4-YXLZ>]; Sergio Flores, *The Longest Floating Bridge: SR 520*, AM. INFRASTRUCTURE, at 66–71 (2017), <https://americaninfrastructuremag.com/longest-floating-bridge-sr-520/> [<https://perma.cc/9GCS-WBTH>]; Ashley Halsey III, *Trump Promised \$1 Trillion for Infrastructure, But the Estimated Need Is \$4.5 Trillion*, WASH. POST (Mar. 9, 2017), [https://www.washingtonpost.com/local/trafficandcommuting/trump-promises-1-trillion-for-infrastructure-but-the-estimated-need-is-45-trillion/2017/03/08/2f2eca7c-0414-11e7-ad5b-d22680e18d10\\_story.html?utm\\_term=.22aa94979a4b](https://www.washingtonpost.com/local/trafficandcommuting/trump-promises-1-trillion-for-infrastructure-but-the-estimated-need-is-45-trillion/2017/03/08/2f2eca7c-0414-11e7-ad5b-d22680e18d10_story.html?utm_term=.22aa94979a4b) [<https://perma.cc/6RN3-XG3Y>]; Roberta Mann, *Why American Infrastructure gets a “D+” and What Can be Done*, AUSTAXPOLICY: TAX & TRANSFER POL’Y BLOG (Apr. 28, 2017), <http://www.austaxpolicy.com/american-infrastructure-gets-d-can-done/> [<https://perma.cc/PZX3-Z38P>]; see, e.g., Caswell F. Holloway et al., *Solving the CSO Conundrum: Green Infrastructure and the Unfulfilled Promise of Federal-Municipal Cooperation*, 38 HARV. ENVTL. L. REV. 335, 359–60 (2014). For a brief history of public infrastructure and how it was a response to calamities in infrastructure developed by private parties, see Jonathan Rosenbloom, *Can a Private Corporate Analysis of Public Authority Administration Lead to Democracy?*, 50 N.Y.U. L. REV. 851, 856–67 (2006).

30. See *SR 520 Budget and Performance*, WASH. ST. DEP’T TRANSP., <https://www.wsdot.wa.gov/Projects/SR520Bridge/Budget.htm> [<https://perma.cc/GJS8-6WZ4>] (presenting a \$4.56 billion budget to build floating bridge and other projects); *World Trade Center Transportation Hub*, PORT AUTH. N.Y. & N.J., <https://www.panynj.gov/wtcprogress/transportation-hub.html> [<https://perma.cc/BMU9-NN82>].

provisions to identify general trends. The analysis reveals how the differing land use laws for each of the fifty states continues the path toward dependency on gray infrastructure. Further, such infrastructure has left communities ill-prepared to face catastrophic events and an uncertain and changing future as climate change alters the forces and disturbances impacting communities.<sup>31</sup>

Part I below describes the challenges and uncertainty facing local infrastructure. It does so in two ways: by surveying infrastructure standards and studies nationwide and by illustrating the challenges one infrastructure entity—the Des Moines Water Works—faces. Part II describes resilience and the importance of strengthening the resilience of the infrastructure system in the face of the challenges described in Part I. To tease out general trends, Part III provides a broad survey of land use laws across the nation. The survey reveals a focus on stationarity and gray infrastructure that promotes vulnerable infrastructure. The Article concludes in Part IV by proposing a new land use narrative based on adaptive measures and ecosystem services to replace stationarity and gray infrastructure and help build more resilient communities. Part IV sets forth examples from diverse communities, such as Los Angeles, California and Dubuque, Iowa to illustrate the ways adaptive measures and ecosystems services can be incorporated to enhance resilience.

## I. AN UNCERTAIN FUTURE AND DETERIORATED INFRASTRUCTURE

### A. *Uncertainty in the Infrastructure Challenge*

There are many challenges facing local officials and infrastructure across the nation. Some of those challenges are operational, such as the high cost of public infrastructure projects and the lack of financial resources,<sup>32</sup> the increasing demands and increasing populations that stress

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31. See Cynthia Rosenzweig et al., *Developing Coastal Adaptation to Climate Change in the New York City Infrastructure-shed: Process, Approach, Tools, and Strategies*, 106 CLIMATE CHANGE 93 (2011).

32. See also Rosenbloom, *supra*, note 4, at 669 (“In 2009, the National Association of Clean Water Agencies (NACWA) estimated the cost of adapting water utilities to climate change in the U.S. to be between \$448 billion and \$944 billion. The report states that NACWA based its estimates on the IPCC’s 2007 report and expects changes upon a review of the now-released IPCC 2013 report, which shows significantly more severe climate changing impacts. NACWA’s report is nonetheless telling, as it provides a uniquely comprehensive estimate of the costs to adapt a single local government service.”); Dan Rivoli, *Report: New York City’s Infrastructure Needs \$47 Billion in Repairs*, A.M. N.Y. (Mar. 11, 2014), <http://www.amny.com/news/report-new-york-city-s-infrastructure-needs-47-billion-in-repairs-1.7361185> [<https://perma.cc/NZNS-UL8V>].

existing infrastructure,<sup>33</sup> and the current dilapidated state of infrastructure.<sup>34</sup> In addition to operational challenges, local governments face legal challenges, such as state and federal preemption that can hamper local efforts.<sup>35</sup> Local governments also face political challenges, including the political difficulties associated with increasing fees or assessments in order to charge the true costs of services,<sup>36</sup> the political realities involved with discussing climate change and its impact on infrastructure,<sup>37</sup> and collective action and other jurisdictional challenges that can result in a race to the bottom.<sup>38</sup> One massive, national challenge that is integral to infrastructure and beyond the purview of this Article concerns environmental justice issues and infrastructure.<sup>39</sup> Some of the issues involved with this challenge concern the low-income individuals and minorities that are often hit hardest by environmental disasters,

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33. See JAMES FLETCHER & DOUG MCARTHUR, LOCAL PROSPERITY: OPTIONS FOR MUNICIPAL REVENUE GROWTH IN BRITISH COLUMBIA 18 (2010), <http://www.publicsolutions.ca/images/tc/Local%20Prosperity%20Final%20Med%20Res%20-%20Nov.%2019.10.pdf> [<https://perma.cc/6UU6-6VZE>] (“BC’s population will grow by approximately one million people over the next 20 years, and about 500,000 over the next ten years. Such population growth will exert significant pressure on local governments for new infrastructure and additional services.”).

34. See *infra* Part III.

35. See, e.g., *Metro. Taxicab Bd. of Trade v. City of New York*, 615 F.3d 152, 155 (2d Cir. 2010) (striking down local law attempting to reduce greenhouse gases as being preempted under the Supremacy Clause); *Air Conditioning, Heating & Refrigeration Inst. v. City of Albuquerque*, No. 08–633 MV/RLP, 2008 WL 5586316 (D.N.M. Oct. 3, 2008) (striking down local building ordinance requiring minimum energy efficiency standards for new buildings and remodels). *But see* *Bldg. Indus. Ass’n of Wash. v. Wash. State Bldg. Code Council*, No. 3:10-cv-05373-RJB, 2011 WL 485895 (W.D. Wash. Feb. 7, 2011), *aff’d*, 683 F.3d 1144 (9th Cir. 2012) (upholding similar state provision).

36. See WATER SECTOR RESILIENCE FINAL REPORT, *supra* note 4, at 4.

37. See generally Lorena Pasquini & Clifford Shearing, *Municipalities, Politics, and Climate Change: An Example of the Process of Institutionalizing an Environmental Agenda Within Local Government*, 23 J. ENV’T & DEV. 271 (2014); *Environmental Law, Episode IV*, *supra* note 1, at 21.

38. See THOMAS P. SEAGER ET AL., REDESIGNING RESILIENT INFRASTRUCTURE RESEARCH 20–21 (2017), [https://www.researchgate.net/profile/Thomas\\_Seager/publication/317078833\\_Redesigning\\_Resilient\\_Infrastructure\\_Research/links/59246602458515e3d41a7d94/Redesigning-Resilient-Infrastructure-Research.pdf](https://www.researchgate.net/profile/Thomas_Seager/publication/317078833_Redesigning_Resilient_Infrastructure_Research/links/59246602458515e3d41a7d94/Redesigning-Resilient-Infrastructure-Research.pdf) [<https://perma.cc/6JH3-SHYS>] (uncorrected pre-publication draft) (“Infrastructure in the United States is owned, financed, operated, and reconstructed by a myriad of different private and public organizations with overlapping jurisdictions. . . . As different infrastructure systems provide a diverse array of services . . . the design, operation and adaptation of these systems are often incompatible with one another.”). For a discussion on how collective action challenges among local governments can lead to a race to the bottom, see Blake Hudson & Jonathan Rosenbloom, *Uncommon Approaches to Commons Problems: Nested Governance Commons and Climate Change*, 64 HASTINGS L.J. 1273, 1312–14 (2013); Jonathan Rosenbloom, *New Day at the Pool: State Preemption, Common Pool Resources, and Non-Place Based Municipal Collaborations*, 36 HARV. ENVTL. L. REV. 446, 450–61 (2012).

39. See WATER SECTOR RESILIENCE FINAL REPORT, *supra* note 4, at 4.

provided with inadequate or disparate public services and infrastructure, and provided with fewer resources to rebuild after disaster.<sup>40</sup>

Notwithstanding these challenges, one of the most critical challenges facing infrastructure is uncertainty in how climate change will fundamentally alter ecosystems.<sup>41</sup> Infrastructure systems are vulnerable to a variety of climate changing events and changes to ecosystems. “[L]oss of biodiversity, degraded land, diffuse air pollution, serious degradation to coast and oceans, and deteriorating water and soil quality are among” the many challenges that local infrastructure faces.<sup>42</sup> Such challenges stress infrastructure across the country. The following example from Iowa concerning the Des Moines Water Works (Water Works) is illustrative because the city and the public utility have commonalities with many cities and public utilities across the country. For example, Des Moines is one of dozens of cities with populations around 200,000.<sup>43</sup> As with many cities, it has a sub-billion-dollar budget.<sup>44</sup> Further, the Water Works was

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40. See Natalie Delgadillo, *How Cities Can Protect Poor People and Minorities from Climate Change*, GOVERNING (Sept. 28, 2017), <http://www.governing.com/topics/transportation-infrastructure/gov-climate-change-environmental-justice-cap-report.html> [<https://perma.cc/5K5Q-V42Q>].

41. See Robin Kundis Craig, *Putting Resilience Theory into Practice: The Example of Fisheries Management*, NAT. RESOURCES & ENV'T (2017) [hereinafter *Putting Resilience Theory into Practice*] (citing BRIAN WALKER & DAVID SALT, RESILIENCE THINKING: SUSTAINING ECOSYSTEMS AND PEOPLE IN A CHANGING WORLD 62–63 (2006)); WATER SECTOR RESILIENCE FINAL REPORT, *supra* note 4, at 26 (“The increased intensity and frequency of severe weather (e.g., major flooding) patterns linked to climate change, threatens drinking water and wastewater infrastructure. For example, many water facilities are located near bodies of water. Expected climate change impacts are sea level rise and storm surge, which can flood facilities, damaging equipment and halting operations.”) (“[N]atural systems exist in continual flux, subject to drivers and influences occurring at multiple spatial and temporal scales. Moreover, most systems can exist in multiple relatively stable configurations, transforming from one to another as a result of crossing an *ecological threshold*.”); *Environmental Law, Episode IV*, *supra* note 1, at 2 (“It is a period of uncertainty and change.”); *Infrastructure: Introduction*, NAT'L CLIMATE ASSESSMENT, <http://nca2014.globalchange.gov/highlights/report-findings/infrastructure#statement-10240> [<https://perma.cc/EU3Y-9LFM>] (“Sea level rise, storm surge, and heavy downpours, in combination with the pattern of continued development in coastal areas, are increasing damage to U.S. infrastructure including roads, buildings, and industrial facilities, and are also increasing risks to ports and coastal military installations.”).

42. Cameron Holley, *Removing the Thorn from New Governance's Side: Examining the Emergency of Collaboration in Practice and the Roles for Law, Nested Institutions, and Trust*, 40 ENVTL. L. REP. NEWS & ANALYSIS 10,656, 10,656.

43. *Ten U.S. Cities Now Have 1 Million People or More; California and Texas Each Have Three of These Places*, U.S. CENSUS BUREAU (May 21, 2015), <https://www.census.gov/newsroom/press-releases/2015/cb15-89.html> [<https://perma.cc/6227-PPAL>] (listing the ten U.S. cities with populations over one million, from most to least populated: New York, Los Angeles, Chicago, Houston, Philadelphia, Phoenix, San Antonio, San Diego, Dallas, San Jose).

44. *Citizen Budget Engagement*, CITY OF DES MOINES, <https://budget.dmgov.org/#budgetlink> [<https://perma.cc/BT23-9QRV>] (discussing the Des Moines 2018 fiscal year budget: “[t]he total \$687

not hit by a catastrophic event, such as a hurricane or earthquake. Rather, the disturbances stressing the Water Works are similar to common disturbances facing infrastructure across the country.

Des Moines, the capital of Iowa, sits at the southern tip of the Des Moines Lobe, shown in Figure 1 below. The Lobe was glaciated (covered by glaciers or ice sheets) until about 12,000 years ago.<sup>45</sup> As the glaciers receded, wetlands and extremely fertile soil remained. Much of the wetlands in the Des Moines Lobe were drained for farmland and subsequently tiled.<sup>46</sup>

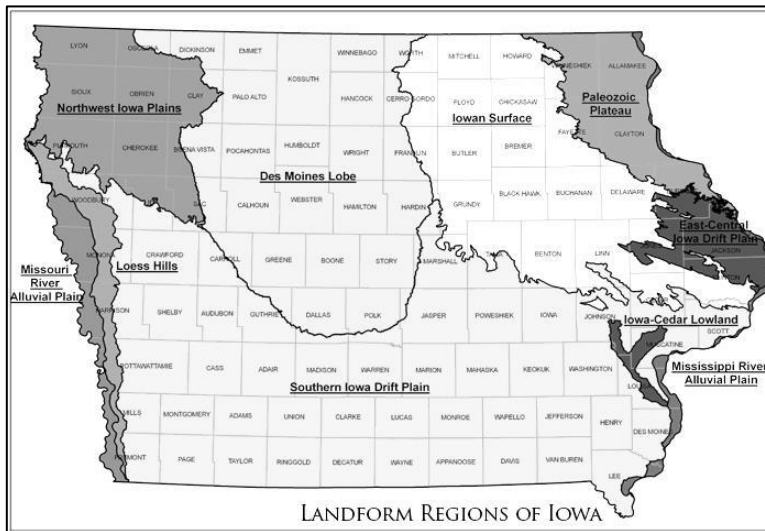
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million budget can be better understood as a \$570 million operating budget and a \$117 million capital budget”).

45. *Glaciers*, NAT’L GEOGRAPHIC, <https://www.nationalgeographic.org/encyclopedia/glacier/> [https://perma.cc/MW8X-G9C3].

46. Roberta H. Yuhas, *Loss of Wetlands in the Southwestern United States*, U.S. GEOLOGICAL SURVEY (Dec. 9, 2016, 2:28 PM), <https://geochange.er.usgs.gov/sw/impacts/hydrology/wetlands/> [https://perma.cc/C42W-QWWZ] (noting wetland loss in Iowa of 89% between 1780–1980). “Tiling is a sophisticated underground drainage system, designed to get water off agricultural land as quickly as possible. An example of the widespread use of tiling can be seen in the Midwest where about 48%, 48%, and 42% of Illinois’s, Ohio’s, and Indiana’s cropland, respectively, is tiled.” Keith H. Hirokawa & Jonathan Rosenbloom, *Thinking Ecosystems, Providing Water: The Water Infrastructure Imperative*, in CONTEMPORARY ISSUES IN CLIMATE CHANGE LAW & POLICY 46 n.1 (Robin Craig & Stephen Miller eds., 2016) (citing ZACHARY SUGG, ASSESSING U.S. FARM DRAINAGE: CAN GIS LEAD TO BETTER ESTIMATES OF SUBSURFACE DRAINAGE EXTENT 6 (WORLD RES. INST. 2007), [http://pdf.wri.org/assessing\\_farm\\_drainage.pdf](http://pdf.wri.org/assessing_farm_drainage.pdf) [https://perma.cc/2Q3X-BDGS]).

**Figure 1:**  
**Various Landforms in the State of Iowa<sup>47</sup>**



In 2012–13, the community in Des Moines faced three rapid and diverse disturbances in the course of only six months. The Raccoon and Des Moines Rivers meet in Des Moines just south of downtown, by the Chicago Cubs’s Triple A ballfield (shown in Figure 2 below), which then connects with the Mississippi River about 120 miles north of St. Louis.

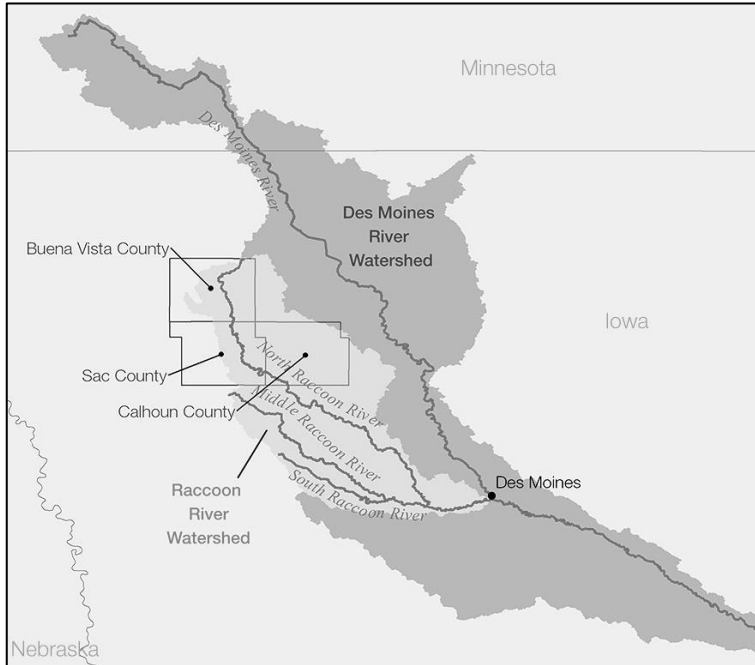
**Figure 2:**  
**Confluence of Des Moines and Raccoon Rivers, Des Moines, Iowa**



47. *Iowa Wildlife Action Plan*, IOWA DEP’T NAT. RESOURCES, <http://www.iowadnr.gov/Conservation/Iowas-Wildlife/Iowa-Wildlife-Action-Plan/ItemId/750> [<https://perma.cc/J5XJ-NP6S>].

The watersheds for the rivers are shown in Figure 3 below and lie within the Mississippi River watershed.

**Figure 3:**  
**Watersheds for the Des Moines and Raccoon Rivers<sup>48</sup>**



As indicated in Figure 4 below, in fall 2012 the majority of Iowa was experiencing an “extreme” drought, with the remainder of the state experiencing “exceptional” or “severe” drought conditions.<sup>49</sup> The drought put immense pressure on infrastructure pertaining to energy, transportation, emergency services, and, most relevant to this story, the provision of water.<sup>50</sup> Tributaries to the Raccoon and Des Moines Rivers,

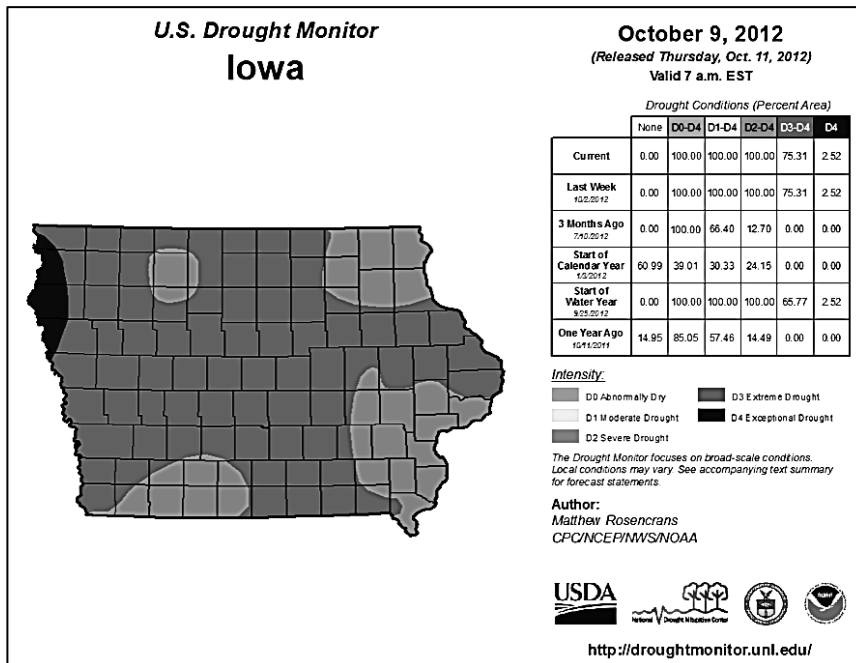
48. Brett Walton, *Des Moines Initiates Clean Water Act Lawsuit to Stem Farm Pollution*, CIRCLE BLUE: WATERNEWS (Jan. 20, 2015), <http://www.circleofblue.org/2015/world/des-moines-initiates-clean-water-act-lawsuit-to-stem-farm-pollution/> [https://perma.cc/7WPY-JU5B].

49. *U.S. Drought Monitor Background*, U.S. DROUGHT MONITOR, [http://droughtmonitor.unl.edu/data/pdf/20121009/20121009\\_ia\\_trd.pdf](http://droughtmonitor.unl.edu/data/pdf/20121009/20121009_ia_trd.pdf) [https://perma.cc/RD55-VGAV]. The U.S. Drought Monitor, established in 1999, is a weekly map of drought conditions produced jointly by the National Oceanic and Atmospheric Administration, the U.S. Department of Agriculture, and the National Drought Mitigation Center (NDMC) at the University of Nebraska–Lincoln.

50. See AM SOC’Y OF CIVIL ENG’RS, IOWA INFRASTRUCTURE, 2015 REPORT CARD: A CALL FOR IOWA’S INFRASTRUCTURE 33 (2015), <http://www.infrastructurereportcard.org/wp-content/uploads/>

the two primary sources from which the Water Works draws to provide potable water to almost 600,000 people, were drying up.

**Figure 4:**  
**U.S. Drought Monitor, Iowa, Oct. 9, 2012**



The drought led 138 science faculty and research staff from twenty-seven Iowa colleges and universities to issue the following excerpted statement:

Iowans are living with climate change now and it is already costing us money . . . [D]rought that we are currently experiencing is consistent with an observed warmer climate . . . The following observations support the case that more droughts and floods are likely in the future. . . .

2016/10/ASCE-Report-Card-2.16.15-FINAL-1.pdf [https://perma.cc/QZ3U-RWAB] (“The sources from which Iowa draws water are mostly adequate, but there are signs that challenges lie ahead. During the most recent drought (2011–12), surface water sources became marginal for a number of communities.”); IOWA ST. UNIV. DEP’T OF ECON., ANTICIPATING ECONOMIC IMPACTS OF THE 2012 DROUGHT IN IOWA I (2012), <http://www.extension.iastate.edu/Documents/Drought/2012AnticipatingEconomicImpacts.pdf> [https://perma.cc/6KFL-LPPW] (“The initial impact of a drought is a sharp reduction in the state’s water supply, which in turn has immediate impacts on agricultural productivity, commercial activities that require water, and public goods that are water-based.”).



2. In a warmer climate, wet years get wetter and dry years get dryer. And dry years get hotter—that is precisely what happened in Iowa this year. We can expect Iowa to experience higher temperatures when dry weather patterns predominate. . . .

3. Iowa also has experienced an increasing frequency of intense rains over the past 50 years . . . likely due to a higher surface evaporation in a warmer world. Because of these extremes in precipitation (drought and flood), Iowans will increasingly need infrastructure investments to adapt to climate fluctuations while developing and implementing mitigation.<sup>51</sup>

The scientists' warning concerning precipitation came to fruition. While the Water Works was struggling to provide adequate water, the drought ended with devastating floods that included more than sixteen inches of spring rainfall in 2013,<sup>52</sup> the most spring rain in "141 years of records."<sup>53</sup> In 1993, flood waters inundated the Water Works, as shown in Figure 5 below, rendering it unable to provide potable water for almost three weeks.<sup>54</sup> By the 2013 floods, the Water Works had adapted its facilities by installing a more protective berm so that it would not have another catastrophic flood in the facility. Nonetheless, the 2013 floods greatly stressed the infrastructure and the Water Works' ability to provide potable water to its customers.<sup>55</sup>

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51. *Iowa Climate Statement: The Drought of 2012*, IOWA ENVTL. FOCUS, <https://iowaenvironmentalfocus.wordpress.com/2012/11/19/iowa-climate-statement-the-drought-of-2012/> [<https://perma.cc/QJ9C-QBCK>].

52. See Cindy Hadish, *Iowa Sets Record with Rainfall; Most Precipitation in 141 Years*, HOME GROWN IOWAN (May 30, 2013), <http://homegrowniowan.com/iowa-sets-record-with-rainfall-most-precipitation-in-141-years/> [<https://perma.cc/7H4H-AWM9>] ("Swinging from drought concerns to flooding worries within weeks, Iowa has set two precipitation record highs in 2013: the statewide average precipitation for March, April and May collectively at 16.65 inches; and a year-to-date precipitation total of 18.92 inches. These are highs among 141 years of records.").

53. *Id.*; Hillaker, *The Wettest Spring in 141 Years of Records*, KCCI DES MOINES (May 29, 2013), <http://www.kcci.com/article/hillaker-the-wettest-spring-in-141-years-of-records/6880188> [<https://perma.cc/7X3C-352G>] ("State Climatologist Harry Hillaker said statewide average rainfall of 16.4 inches as of Tuesday morning is the most rain in March, April and May in 141 years of records. The previous record was 15.5 inches in 1892 and normal is just over 10 inches.").

54. Pat Ripley, *Remembering the Flood of 1993*, DSM: H20 (July 10, 2013), <http://www.dsmh2o.com/remembering-the-flood-of-1993/> [<https://perma.cc/NAR9-QXL3>].

55. See Ben Jordan, *Update on Flooding at Fleur Drive*, KCCI DES MOINES (May 31, 2013), <http://www.kcci.com/article/update-on-flooding-at-fleur-drive/6880268> [<https://perma.cc/G5ES-TFGE>] (discussing Des Moines Water Works's utilization of improved floods gates during the 2013 flooding).

**Figure 5:  
Water Works and the 1993 Flood<sup>56</sup>**



In addition to bringing overwhelming volumes of water, the quick shift in moisture also stressed infrastructure by changing the ecology and introducing an influx of nutrients to the watershed.<sup>57</sup> An increase in nutrients, such as phosphorous and nitrates, has been tied to damage to both the ecological and human health.<sup>58</sup> Figure 6 below tracks the nitrate levels in the two primary water sources, the Raccoon and Des Moines Rivers, during the spring of 2013. The dark line in the middle represents the U.S. Environmental Protection Agency's (EPA) regulation prohibiting the distribution of potable water when nitrate levels are in excess of 10 milligrams per liter (mg/L).<sup>59</sup> Both rivers were well above the EPA maximum during the spring 2013 floods,<sup>60</sup> putting pressure on

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56. Ripley, *supra* note 54.

57. See Peter C. Van Metre et al., *High Nitrate Concentrations in Some Midwest United States Streams in 2013 After the 2012 Drought*, 45 J. ENVTL. QUALITY 1696, 1698 (2016) (explaining how the wet conditions of 2013 that followed the 2012 drought affected nutrients level).

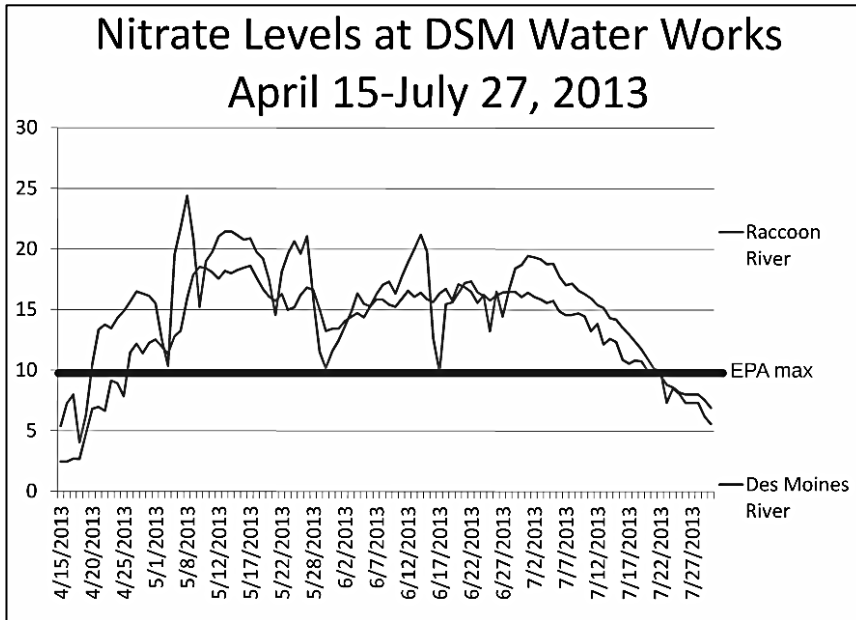
58. See ENVTL. LAW & POL'Y CTR., CULTIVATING CLEAN WATER: STATE-BASED REGULATION OF AGRICULTURAL RUNOFF POLLUTION 1 (2010), <http://elpc.org/wp-content/uploads/2010/05/ELPC-Cultivating-Clean-Water-updated-May-5-2010.pdf> [<https://perma.cc/8MA3-TCXK>]; Walter K. Dodds, *Nutrients and the "Dead Zone": The Link Between Nutrient Ratios and Dissolved Oxygen in the Northern Gulf of Mexico*, 4 FRONTIERS ECOLOGY & ENV'T 211 (2006) (noting increased nutrients led to toxic algae and hypoxia, which is the reduction of sunlight and decreased oxygen levels in the water, leading to "dead zones"); Zdravka Tzankova, *The Difficult Problem of Nonpoint Nutrient Pollution: Could the Endangered Species Act Offer Some Relief?*, 37 WM. & MARY ENVTL. L. & POL'Y REV. 709 (2013) (same).

59. 40 C.F.R. § 141.11(d)(3) (2017).

60. Laura Sarcone, *Board of Water Works Trustees Issue a Notice of Intent to Sue for Polluted Drinking Water*, DMS: H20 (Jan. 8, 2015), <http://www.dsmh2o.com/board-of-water-works-trustees-issue-a-notice-of-intent-to-sue-for-polluted-drinking-water/> [<https://perma.cc/NC5Q-WDU3>] ("Des Moines Water Works uses both the Raccoon and Des Moines Rivers as water sources and has

infrastructure, because this water must be specially treated through a reverse osmosis system before personal consumption.<sup>61</sup>

**Figure 6:**  
**Nitrate Levels at Water Works, Spring 2013**



The Water Works example tells several stories. One story illustrates how critical local services—here, potable water—are facing multiple, intense, and often unexpected disturbances. In a relatively short amount of time, the Water Works was faced with too little water, too much water, and a changing quality of the water. Experts have cautioned that society now faces “a future of changing conditions, including climate change, for which we have no analogies to understand, model, or predict.”<sup>62</sup> This uncertainty is stressing infrastructure across the country and is putting

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experienced extremely high concentrations of nitrate in both rivers in the spring and summer of 2013 and the fall and winter of 2014.”).

61. *Water Treatment Process*, DES MOINES WATER WORKS, <http://www.dmww.com/water-quality/treatment-process/> [<https://perma.cc/B6VU-YZ4S>] (explaining how “water is sent through reverse osmosis (RO) filtration”).

62. Craig Anthony (Tony) Arnold, *Adaptive Watershed Planning and Climate Change*, 5 ENVTL. & ENERGY L. & POL’Y J. 417, 434 (2010) (citing Douglas Fox, *Back to the No-Analog Future?*, 316 SCI. 823 (2007); J.B. Ruhl, *Climate Change and the Endangered Species Act: Building Bridges to the No-Analog Future*, 88 B.U. L. REV. 1, 11 (2008)).

communities at great risk. For example, California's massive five-year drought ended with one of the wettest years on record, which was followed by catastrophic wildfires in 2017;<sup>63</sup> Kansas's and Oklahoma's 2017 deadly wildfires were some of the largest in history and were followed by flooding in April 2017;<sup>64</sup> Colorado's 2013 September flood resulted in a year's worth of rain in six days and was preceded by summer wildfires that made the ground unstable, resulting in massive flooding and mudslides;<sup>65</sup> the increasing challenges sea level rise brings to Miami are often straddled by heat waves;<sup>66</sup> and the previously mentioned Hurricanes Harvey, Irma, and Maria decimated various parts of the United States.

### B. *An Already Vulnerable Infrastructure*

To get a more complete picture of infrastructure resilience, it is helpful to view the uncertainties discussed above in light of infrastructures' decaying state.<sup>67</sup> Overall, "the Nation's infrastructure suffer[s] from

63. Peter Gleick, *A Wet Year Won't Beat California's Never-Ending Drought*, WIRED (Jan. 22, 2017, 7:00 AM), <https://www.wired.com/2017/01/wet-year-wont-beat-californias-never-ending-drought/> [<https://perma.cc/9TX9-5XY2>] ("By any measure, California's five-year drought, from 2012 to 2016, was extreme."); Mark Gomez, *California Storms: Wettest Water Year, So Far, in 122 Years of Records*, MERCURY NEWS (Mar. 9, 2017, 11:12 AM), <http://www.mercurynews.com/2017/03/08/california-storms-wettest-water-year-so-far-in-122-years-of-records/> [<https://perma.cc/S5H8-2CUG>] ("California is in the midst of its wettest water year in 122 years of record-keeping, according to federal scientists. Between October 2016 and February 2017, California averaged 27.81 inches of precipitation, the highest average since such records began being kept in 1895."); Vanessa Martinez, *Here Are the 5 Largest California Wildfires*, L.A. TIMES (Dec. 22, 2017, 7:10 PM), <http://www.latimes.com/local/lanow/la-me-california-wildfires-20171221-htm1story.html> [<https://perma.cc/YR3Q-TCYQ>].

64. Alex Johnson, *Record Wildfires in Southern Plains Could Keep Growing Through Weekend*, NBC NEWS (Mar. 8, 2017, 11:11 PM), <http://www.nbcnews.com/news/us-news/record-wildfires-southern-plains-could-keep-growing-through-weekend-n730861> [<https://perma.cc/6WX3-FQ7S>]; *Flood Watches in Oklahoma, Arkansas, Kansas and Missouri*, U.S. NEWS (Apr. 20, 2017, 11:01 AM), <https://www.usnews.com/news/best-states/oklahoma/articles/2017-04-20/flood-watches-in-oklahoma-arkansas-kansas-and-missouri> [<https://perma.cc/7K3U-DDHP>].

65. See URBAN DRAINAGE FLOOD CONTROL DIST., A SEPTEMBER TO REMEMBER: THE 2013 COLORADO FLOOD WITHIN THE URBAN DRAINAGE AND FLOOD CONTROL DISTRICT (2014).

66. Joey Flechas, *Miami Beach to Begin New \$100 Million Flood Prevention Project in Face of Sea Level Rise*, MIAMI HERALD (Jan. 28, 2017, 7:00 AM), <http://www.miamiherald.com/news/local/community/miami-dade/miami-beach/article129284119.html> [<https://perma.cc/WC4E-KDZP>]; Carli Teproff, *Heat Wave! South Florida Sizzles, Breaks Temperature Records*, MIAMI HERALD (Apr. 26, 2015, 4:42 PM), <http://www.miamiherald.com/news/local/community/miami-dade/article19639410.html> [<https://perma.cc/H3NQ-ZCVH>]; James Wieland, *Dangerous Heat Wave Hits South Florida*, WPTV (July 7, 2016, 5:59 AM), <http://www.wptv.com/news/region-c-palm-beach-county/dangerous-heat-wave-hits-south-florida> [<https://perma.cc/JJ2W-9J3H>].

67. WATER SECTOR RESILIENCE FINAL REPORT, *supra* note 4, at 22 ("The risks posed by systemic underinvestment in water infrastructure are being intensified by increasing vulnerability to extreme-weather events, cybersecurity challenges, and other threats.")

chronic underinvestment, system failures and service shortfalls.”<sup>68</sup> In 2017, the American Society of Civil Engineers (ASCE) (a 160-year-old provider of technical and educational civil engineering information with over 150,000 members)<sup>69</sup> gave U.S. infrastructure a “D+” grade.<sup>70</sup> According to the ASCE, this grade means that U.S. infrastructure “is in poor to fair condition and mostly below standard, with many elements approaching the end of their service life. A large portion of the system exhibits significant deterioration. Condition and capacity are of serious concern with strong risk of failure.”<sup>71</sup>

The provision of potable water, which the ASCE graded a “D,”<sup>72</sup> provides a snapshot of local infrastructure and its deteriorated state. A 2013 study noted that approximately 240,000 water main breaks per year stem from deteriorated infrastructure.<sup>73</sup> Further, that number is projected to increase over the next thirty years.<sup>74</sup> In 2016, the National Infrastructure Advisory Council (NIAC), a federal government advisory council under the Department of Homeland Security, made the following findings relative to water:

- Community water systems are not typically connected to adjacent systems . . . .
- Most State and municipal decision-makers are constrained by long-held expectations by customers for water as a low-cost, affordable service that does not account for true lifecycle costs. . . .
- Like other sectors, water has an aging infrastructure that requires massive reinvestment to upgrade pipes, mains, and equipment. Many assets are nearing or beyond their expected

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68. WATER SECTOR RESILIENCE FINAL REPORT, *supra* note 4, at 21.

69. *About ASCE*, AM. SOC’Y OF CIVIL ENG’RS, [http://www.asce.org/about\\_asce/](http://www.asce.org/about_asce/) [<https://perma.cc/G89L-6HG4>].

70. *Report Card*, *supra* note 1 (“[e]very four years, the American Society of Civil Engineers’ Report Card for America’s Infrastructure depicts the condition and performance of American infrastructure” in sixteen categories and assigns a letter grade to each category and an overall grade “based on the physical condition and needed investments for improvement”). Grades are based on the following criteria: Capacity, Condition, Funding, Future Need, Operation and Maintenance, Public Safety, Resilience, and Innovation. *2017 Infrastructure Report Card: What Makes a Grade?*, AM. SOC’Y OF CIVIL ENG’RS, <http://www.infrastructurereportcard.org/making-the-grade/what-makes-a-grade/> [<https://perma.cc/F8H3-KUVD>] [hereinafter *What Makes a Grade?*].

71. *What Makes a Grade?*, *supra* note 70.

72. *Drinking Water*, AM. SOC’Y OF CIVIL ENG’RS, <https://www.infrastructurereportcard.org/cat-item/drinking-water/> [<https://perma.cc/X3Y5-CF2J>].

73. *Water & Wastewater*, AM. SOC’Y OF CIVIL ENG’RS, <http://www.asce.org/advocacy/clean-water/> [<https://perma.cc/Y5JG-KV3H>].

74. *Id.*

lifespan, leading to roughly 240,000 water main breaks and between 23,000 and 75,000 sanitary sewage overflows per year in the United States. The estimated investment gap ranges from about \$400 billion to nearly \$1 trillion to maintain current levels of water service.<sup>75</sup>

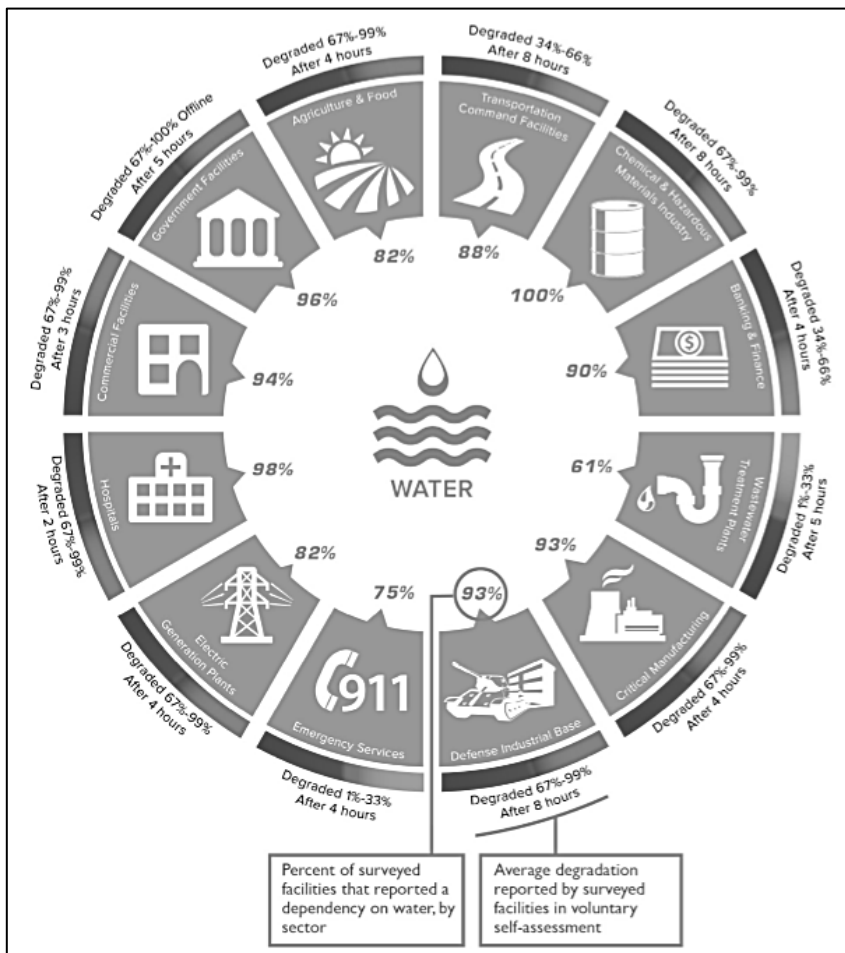
In raising these three points, NIAC highlights three challenges facing local infrastructure that are in addition to questions of uncertainty. The first bullet reflects the failure to consider infrastructure as an interconnected, dependent system.<sup>76</sup> As shown in Figure 7 below, many services rely heavily on water and its associated infrastructure.

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75. WATER SECTOR RESILIENCE FINAL REPORT, *supra* note 4, at 3.

76. In my experience as a land use attorney and as a plan and zoning commissioner, I have often noticed that some planning offices do not consider infrastructure to be within their purview. Rather, infrastructure is a matter to be reviewed by public works. Once public works accepts a developer's infrastructure plan, planning proceeds without reviewing the infrastructure for purposes of consistency or other concerns.

**Figure 7:**  
**“Critical Infrastructure Dependence on Water and Potential  
 Function Degradation Following Loss of Water Services”<sup>77</sup>**



The second bullet notes that the cost consumers pay for water rarely reflects the true costs of providing water. This is often because of an underfunding and mis-funding of infrastructure.<sup>78</sup> Part of the costs that are

77. WATER SECTOR RESILIENCE FINAL REPORT, *supra* note 4, at 2.

78. For a discussion of infrastructure funding priorities see Charles Marohn, *Everything That's Wrong with America in Two Charts. Yeah, Right.*, STRONG TOWNS (Sept. 18, 2017), <https://www.strongtowns.org/journal/2017/9/17/everything-thats-wrong-with-america-in-two-charts-not> [<https://perma.cc/3JWK-HBWN>] (taking issue with an article noting that infrastructure is underfunded by \$400 billion a year in public investment).

not reflected in consumers' payments are services provided by ecosystems. For example, forest ecosystems can purify water.<sup>79</sup> This service and others are typically not part of utility costs or development costs.

In the last bullet, NIAC highlights the deteriorated state of existing infrastructure. This should be of particular concern given the increased frequency of hurricanes and other changes.<sup>80</sup> In light of the challenges facing infrastructure, communities risk losing critical services as climate and ecosystem changes can be amplified against the already weakened system.<sup>81</sup> Given its deteriorated state, an update of infrastructure is no doubt warranted. It is equally important, if not more so, for the sustainable longevity of communities to also reconsider the laws that have encouraged the construction of less resilient infrastructure. Before proposing law and policy solutions to enhance infrastructure resilience, however, it is necessary to define "resilient infrastructure," the subject of the next section.

## II. WHAT IS RESILIENT INFRASTRUCTURE?

The definition of resilience has been found to vary "considerably across academic and practitioner fields."<sup>82</sup> The focus of this Article is not to resolve or weigh-in on discussions defining resilience or resilient infrastructure. Rather, this Article offers an analysis and policy options that may help protect the health and safety of communities and ecologies. In doing so, it relies on resilience theory as applied to infrastructure to provide information as to whether infrastructure is prepared for future changes. Such information can help elucidate the challenges local communities face and the potential policy options. While resilience theory does not dictate *which* policies should be adopted, the information concerning the resilience of a system can help inform policy, particularly where uncertainty is an issue.<sup>83</sup>

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79. Hirokawa, *supra* note 46.

80. *See* Flatt, *supra* note 6.

81. *See Environmental Law, Episode IV, supra* note 1, at 2.

82. Dan Sage & Chris Zebrowski, *Resilience and Critical Infrastructure: Origins, Theories and Critiques*, in INTERNATIONAL SECURITY HANDBOOK 1–2 (Palgrave MacMillan, R. Dover, M. Goodman eds., 2016).

83. *See Learning to Live with the Trickster, supra* note 19, at 389 ("Importantly, however, resilience thinking does not itself posit a normative goal for environmental management, law, or policy because resilience itself (ecological or engineering) is merely a property of a system that says nothing about whether that state is itself desirable or undesirable."); *Environmental Law, Episode IV, supra* note 1, at 1.



The definition of “resilience” relied upon for purposes of this Article derives from “ecological resilience,” as contrasted with “engineering resilience.”<sup>84</sup> Engineering resilience focuses primarily on “stability near an equilibrium steady state, where resistance to disturbance and speed of return to the equilibrium are used to measure the property.”<sup>85</sup> C.S. Holling notes that by focusing on “near-equilibrium” engineering resilience requires “an implicit assumption of global stability.”<sup>86</sup> This idea of global stability, Holling states, assumes “that only one equilibrium steady state exists, or, if other operating states exist, they should be avoided by applying safeguards.”<sup>87</sup> Robin Kundis Craig echoes this point, stating engineering resilience assumes “there is an equilibrium balance of nature to which natural systems will return after a shock or disturbance.”<sup>88</sup> Craig continues by noting that engineering resilience presumes nature is “knowable, predictable, and largely controllable. . . . This assumption is perhaps most obvious in the reigning legal presumption that . . . we can keep important systems from changing in the first place and that we can restore any system that we’ve already changed to its previous state.”<sup>89</sup> As discussed in more detail in Part III, these two elements of engineering resilience—keeping systems from changing and attempting to restore systems we have changed—are wholly consistent with the current land use law narrative encouraging or requiring gray infrastructure.

Rather than focus on global stability, the modern theory of ecological resilience “emphasizes conditions far from any equilibrium steady state.”<sup>90</sup> Ecological resilience is the “magnitude of disturbance that can be

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84. For a more in-depth description of the differences between engineering and ecological resilience, see C.S. Holling, *Engineering Resilience Versus Ecological Resilience*, in NAT’L ACAD. OF SCI., *ENGINEERING WITHIN ECOLOGICAL CONSTRAINTS*, 32–33 (Peter C. Schulze ed., 1996) (“Resilience of a system has been defined in two different ways in the ecological literature.”); *Putting Resilience Theory into Practice*, *supra* note 41, at 1 (describing the difference between engineering resilience and ecological resilience).

85. Holling, *supra* note 84, at 33–34; *Putting Resilience Theory into Practice*, *supra* note 41, at 1 (describing engineering resilience as “the ability of a person, thing, or system to *resist* a shock or disturbance or to *bounce back* to its former state. Engineering resilience plays a large role in actual engineering, such as when architects design skyscrapers in Los Angeles and San Francisco to withstand earthquakes”).

86. Holling, *supra* note 84, at 33–34; *see also* Sage, *supra* note 82 at 11 (stating Holling “provides a rich theoretical starting place for understanding the implications of resilience for critical infrastructure initiatives”).

87. Holling, *supra* note 84, at 34 (citation omitted); *see also* Sage & Zebrowski, *supra* note 82 (citation omitted).

88. *Putting Resilience Theory into Practice*, *supra* note 41, at 1.

89. *Id.*

90. Holling, *supra* note 84, at 33; *see also* Janine S. Hiller & Jordan M. Blanke, *Smart Cities, Big Data, and the Resilience of Privacy*, 68 HASTINGS L.J. 309, 342 (2017).

absorbed before the system changes its structure by changing the variables and processes that control behavior.”<sup>91</sup> “[A]s a concept, [ecological] resilience not only connotes persistence, but also adaptive capacity or adaptability; the capacity for both the human and ecological components of a system to respond to, learn from, create, and shape variability and change in the state of the system and influence resilience.”<sup>92</sup> In other words, ecological resilience recognizes and embraces uncertainty, change, and the ability of ecosystems to adapt and thrive in more than one stable state.<sup>93</sup>

Craig describes ecological resilience and uncertainty as “acknowled[ging] that change and coping with change are a continual reality within natural systems.”<sup>94</sup> Ecological resilience recognizes the regularity of changes in ecosystems by accounting for their adaptability and transformability in times of uncertainty.<sup>95</sup> Importantly, the failure to account for change and uncertainty can increase system vulnerabilities. Ecologist Brian Walker and author David Salt state: “[a]t the heart of resilience thinking is a very simple notion—things change—and to ignore or resist this change is to increase our vulnerability and forego emerging opportunities.”<sup>96</sup>

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91. Holling, *supra* note 84, at 33. “‘Disturbances’ are external influences that disrupt a system’s core characteristics and impact the system’s resilience. Disturbances can be altered by outside influences that can change their intensity, prevalence, and extent. Such influences are often extensions of law, policy, and behaviors. A system’s ability to bounce-back, resist, adapt, or transform following or in response to a disturbance is a measure of the system’s resilience to that disturbance.” SHELLEY SAXER & JONATHAN ROSENBLUM, *RESILIENCE & SUSTAINABILITY: FROM THEORY TO PRACTICE* 14–15 (2018).

92. Tracy-Lynn Humby, *Law and Resilience: Mapping the Literature*, 4 SEATTLE J. ENVTL. L. 85, 89–95, 104–06 (2014) (providing background and general description of ecological resilience).

93. *See id.* at 104–06.

94. *Learning to Live with the Trickster*, *supra* note 19, at 388. *See* Melinda Harm Benson, *Reconceptualizing Environmental Challenges—Is Resilience the New Narrative?*, 21 J. ENVTL. & SUSTAINABILITY L. 99, 115 (2015) (“[R]esilience thinking is grounded in an acknowledgement of uncertainty and disequilibrium within [socio-ecological systems], with a ground-level acknowledgement that change is not only always possible but also to be expected.”); Holling, *supra* note 84, at 33 (“The two contrasting aspects of stability—essentially one that focuses on maintaining *efficiency* of function (engineering resilience) and one that focuses on maintaining *existence* of function (ecological resilience)—are so fundamental that they can become alternative paradigms. . . .”); *Putting Resilience Theory into Practice*, *supra* note 41, at 2 (“[O]ne of the tenets of contemporary ecology is that natural systems are always changing.”).

95. Carl Folke et al., *Resilience Thinking: Integrating Resilience, Adaptability and Transformability*, 15 *ECOLOGY & SOC’Y*, art. 20, tbl.1 (2010) (transformability is “the capacity [of people] . . . to create a fundamentally new [social-ecological] system when ecological, economic, or social structures make the existing system untenable”).

96. BRIAN WALKER & DAVID SALT, *RESILIENCE THINKING: SUSTAINING ECOSYSTEMS AND PEOPLE IN A CHANGING WORLD* 9–10 (2006).

As Walker and Salt state, not only do systems change, but also failure to acknowledge this change can result in increased vulnerabilities and lost opportunities. Ecologists have identified four stages of ecological resilience.<sup>97</sup> For purposes of this Article, it is critical to understand that the four stages contemplate change in the system and reorganization as being part of resilience. “Thus, mere resistance to change might actually decrease systemic resilience over time by making it brittle and inflexible, and thus unable to adapt to unexpected or unprecedented disturbances.”<sup>98</sup> As discussed further below, this is particularly true where infrastructure—the physical manifestation of the law—is inflexible, fixed in time, and fails to account for ongoing changes.

Also, relevant to infrastructure is that, in addition to failing to recognize adaptive ecosystems, isolating only a part of an ecosystem can enhance vulnerabilities:

One of the key insights of resilience theory is that . . . [r]esource management strategies that attempt to optimize only particular elements of an ecosystem frequently weaken the entire system. Such interventions are blind to the fact that while resource management practices keep one component of an ecosystem constant, the other elements continue to change at other spatial and temporal scales.<sup>99</sup>

Given these general aspects of ecological resilience theory, resilient *infrastructure* might refer to the ability of “the basic physical systems and structures essential to the operation of a society or enterprise”<sup>100</sup> to resist, bounce back, adapt, or transform following disturbances.<sup>101</sup>

On the one hand, critical infrastructures are often essential to the resilience of broader systems. Telecommunications infrastructures, for example, have been recognized as “fundamental enablers” of resilience underpinning a wide

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97. Eric Desjardins et al., *Promoting Resilience*, 90 Q. REV. BIOLOGY 147, 149 (2015) (describing the four stages as growth, conservation, release, and reorganization).

98. *Environmental Law, Episode IV*, *supra* note 1, at 11.

99. Humby, *supra* note 92, at 89–95, 104–06; *see also* Jessica A. Shoemaker, *Complexity’s Shadow: American Indian Property, Sovereignty, and the Future*, 115 MICH. L. REV. 487, 546 (2017) (ecological resilience captures the notion that “complex systems operate not as one monolithic ‘thing,’ but, rather, as a series of nested subsystems that influence each other in unpredictable and cascading ways”).

100. *Sustainable Development Goal 9 Build Resilient Infrastructure, Promote Inclusive and Sustainable Industrialization and Foster Innovation*, U.N. ENV’T, <http://www.unep.org/nairo/biconvention/sustainable-development-goal-9-build-resilient-infrastructure-promote-inclusive-and-sustainable> [<https://perma.cc/K5BU-V4S8>]. For a more complete discussion on what resilience means in the context of infrastructure, *see* Sage & Zebrowski, *supra* note 82, at 9–15.

101. Adapted from Carl Folke et al., *Resilience Thinking*, *supra* note 95.

assortment of activities from ensuring the continuity of economic processes to the organization of rescue operations in the wake of a disaster. On the other hand, given the important role critical infrastructures often play in underpinning resilience, they must themselves be made resilient. In the case of telecommunications networks, this can involve investing in built-in redundancies and layered back-up solutions such as satellite communications.<sup>102</sup>

The telecommunications example above highlights the double-edged sword of technology. Relying on technology can improve lives in many ways, but it can also create new vulnerabilities. For example, the loss of cellular communication during natural disasters, such as the well-chronicled loss of cellular service in New Orleans during Hurricane Katrina, can hamper emergency response.<sup>103</sup>

Building an *engineering* resilient infrastructure system may focus on controlling ecosystems in an attempt to keep them from changing; and, if they do change, the infrastructure would attempt to restore them to their prior state. In contrast, building an *ecological* resilient infrastructure system may include, among other things: recognizing that ecosystems change (and such change can affect infrastructure), accommodating that change, and considering the infrastructure system as a whole.

One method of increasing infrastructure resilience to change is to embrace intact ecosystems and their services. The resilience of local infrastructure can be supported by the preservation of ecosystems and their associated services.<sup>104</sup> For example, “[n]ational forests and grasslands capture and filter drinking water for 180 million people.”<sup>105</sup> As ecosystems are destroyed, the resilience of many of the services provided by local infrastructure is weakened. Preservation of ecosystems can promote the resilience of communities and coupled social-ecological systems.

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102. Sage & Zebrowski, *supra* note 82, at 13–14.

103. See Christina Richards, *When Communications Infrastructure Fails During a Disaster*, DISASTER RECOVERY J. (Nov. 12, 2015, 6:00 AM), <https://www.drj.com/articles/online-exclusive/when-communications-infrastructure-fails-during-a-disaster.html> [<https://perma.cc/UUJ6-XWTS>] (describing several ways in which communications infrastructure fails during disaster and the consequences); John Wohlstetter, *Katrina: The Sounds of Communications Silence*, DISCOVERY INST. (Sept. 22, 2005), <http://www.discovery.org/a/2881> [<https://perma.cc/3CER-936A>].

104. This is not to say that untamed ecosystems will never pose a real threat to community resilience, as they clearly can.

105. AM. SOC’Y OF CIVIL ENG’RS, 2017 INFRASTRUCTURE REPORT CARD, PUBLIC PARKS (2017), <https://www.infrastructurereportcard.org/wp-content/uploads/2017/01/Parks-Final.pdf> [<https://perma.cc/R59J-DAPN>]. For additional ecosystem services examples see *infra* section IV.A.

In this regard, the theory of ecological resilience is helpful as local communities face a barrage of uncertain challenges that stress local infrastructure. Analyzing systems in terms of ecological resilience can help inform what, if anything, should be done to alter law and policy as communities prepare for this uncertainty. As a means to “inform[] how we can better manage to reach a normatively desirable transformation in an otherwise unpredictable environment,” ecological resilience is relied upon here to help understand a critical part of the infrastructure system in this time of uncertainty.<sup>106</sup>

### III. GRAY INFRASTRUCTURE, STATIONARITY, AND “HUMANS AS CONTROLLING ENGINEERS”

While infrastructure can be funded, developed, and regulated pursuant to federal, state, or local law, this Article is primarily concerned with local land use law. As of late 2017, there has been little serious discussion at the federal level about the intersection of climate change, infrastructure adaptation, and local preparedness.<sup>107</sup> For example, the Trump Administration has axed a task force on preparedness and resilience, revoked President Obama-era standards that required the federal government to account for sea-level rise when building new infrastructure, stalled the release of a toolkit designed to help communities rebuild in safe ways following disasters, and taken other obstructionist steps.<sup>108</sup> In addition, the federal government has failed to update many minimum environmental standards that could facilitate the strengthening of local resilience. For example, the list of unregulated chemicals found in potable water that can harm individuals has not been updated in twenty years, notwithstanding technological advances that provide better and more data concerning the health and safety of communities.<sup>109</sup>

Local communities are already suffering and cannot wait for an inept federal administration to see localities’ reality. One of the most influential tools communities have to strengthen local infrastructure resilience to

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106. See Shoemaker, *supra* note 99, at 546; *Learning to Live with the Trickster*, *supra* note 19, at 390 (when managing for resilience “we must ask: managing for the resilience of what to what?”).

107. See, e.g., Flatt, *supra* note 6.

108. *Id.* To be sure, several state governments are taking similar action. *Id.* (noting regressive action in North Carolina).

109. Natalie Delgadillo, *Drinking Water Isn’t Safe for Millions of Americans. It’s Up to States to Fix.*, GOVERNING (Sept. 14, 2017), <http://www.governing.com/topics/transportation-infrastructure/gov-clean-water-14-dioxane-epa-states.html> [<https://perma.cc/QDG6-VVQW>] (“The EPA has not added a new chemical [to regulate] in 20 years, even as our environment and use of chemicals has changed dramatically,” says Nneka Leiba, director of healthy living science at EWG. ‘Around the country, almost all utilities are providing legal water. But they’re not providing completely safe and healthy water.’”).

climate and ecosystem changes is land use laws. There are many land use laws that implicate infrastructure resilience. The most relevant here are the laws that govern private sector development. These laws touch a broad spectrum of private projects and affect critical services. They are also pervasive throughout the United States. Nearly every community is governed by some local land use law regulating private development infrastructure. As such, a comprehensive review of land use codes is not possible in a single article. Instead, this Article consists of an analysis of several pervasive, diverse, and common land use regulations to determine whether land use laws are encouraging developers to construct infrastructure that is prepared for climate change. The local ordinances explored below provide a broad swath of the types of content covered in land use codes. The ordinances also vary in their scale, ranging from the largest geographic scale (the comprehensive plan) in section A to specific lot requirements in section B. The analysis includes diverse jurisdictions across the United States to illustrate that the provisions analyzed here are not merely isolated or regional practices, but rather are found in codes throughout the country.

#### A. *Planning for Stationarity*

Comprehensive plans can vary in their content and whether and to what extent they are binding on future land use decisions.<sup>110</sup> Typically, state law requires comprehensive plans to include an overall perspective of land use for the next several years. For example, the state of Rhode Island requires comprehensive plans to include:

[A] land use component that designates the proposed general distribution and general location and interrelationships of land uses including, but not limited to, residential, commercial,

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110. See, e.g., IOWA CODE § 414.3(1) (2017) (local governments' exercise of zoning must be "made in accordance with a comprehensive plan"); N.Y. TOWN LAW § 272-a(2)(g) (McKinney 2017) (setting forth requirements for comprehensive plans, including "[e]xisting and proposed general location of public and private utilities and infrastructure."); Iowa Coal Mining Co. v. Monroe County, 494 N.W.2d 664, 669 (Iowa 1993) ("[C]ompliance with the comprehensive plan requirement [§ 414.3] merely means that zoning authorities have given 'full consideration to the problem presented, including the needs of the public, changing conditions, and the similarity of other land in the same area.'" (quoting Montgomery v. Bremer Cty. Bd. of Supervisors, 299 N.W.2d 687, 695 (Iowa 1980))); see GROWING SMART LEGISLATIVE GUIDEBOOK: MODEL STATUTES FOR PLANNING AND THE MANAGEMENT OF CHANGE 7–62 (Stuart Meck ed., 2002); Osiecki v. Town of Huntington, 565 N.Y.S.2d 564 (N.Y. App. Div. 1991) (reviewing binding nature of comprehensive plans in New York); Edward J. Sullivan & Thomas G. Pelham, *The Evolving Role of the Comprehensive Plan*, 29 URB. LAW. 363, 370 (1997) ("[F]uture uses are controlled by the comprehensive plan"). For more on comprehensive plans, see NOLON ET AL., LAND USE AND SUSTAINABLE DEVELOPMENT LAW 67–134 (9th ed. 2017).

industrial, open space, agriculture, [and] recreation facilities . . . . The land use component . . . shall relate the proposed standards of population density and building intensity to the capacity of the land and available or planned facilities and services . . . .<sup>111</sup>

State law governing comprehensive plans often requires plans to be completed every decade or two.<sup>112</sup> Many local governments' economies, societies, and—most relevant here—environments; however, change dramatically in ten to twenty years. For example, the City of Warwick, Rhode Island, (the second largest city in Rhode Island) drafted its comprehensive plan for the years 2013–33 and received approval for that plan through August 17, 2024.<sup>113</sup> It is questionable; however, whether the goals and objectives set in 2013 will be relevant in ten or twenty years, and whether the estimates concerning population and land use trends (chapter 3 of Warwick's comprehensive plan), natural resources (chapter 4), economic development (chapter 8) or any other data-driven policy will be even remotely applicable given ecosystem, societal, technological, and other changes.

While local governments can amend comprehensive plans, doing so in many states is a time-consuming process that can take months or years and involve many public meetings and comments.<sup>114</sup> Maintaining a set of planning objectives for this extended period of time reflects land use laws' preference for stationarity in comprehensive planning. This stationarity is particularly troubling in jurisdictions where comprehensive plans are binding, as opposed to recommending, on future land use decisions. In these jurisdictions, zoning and development code decisions can be dictated by a plan that is obsolete.

Although many comprehensive plans do not discuss specific infrastructure projects in detail, when they do, the discussion is often focused on gray infrastructure. Comprehensive plans typically set overall goals and objectives for infrastructure based on projected population

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111. *See, e.g.*, 45 R.I. GEN. LAWS § 45-22.2-6(b)(11) (2016). Sections (b)(1–10) “may be . . . presented as deemed suitable and appropriate by the municipality,” however, Sections (b)(11–12) are required. *Id.* § 45-22.2-6(b).

112. *See, e.g., id.* § 45-22.2-6(a) (minimum 20 years); 53 PA. CONS. STAT. § 10301(c) (2016) (minimum 10 years).

113. CITY OF WARWICK COMPREHENSIVE PLAN 2033 (2014), [https://www.warwickri.gov/sites/warwickri/files/uploads/part\\_a\\_front\\_matter.pdf](https://www.warwickri.gov/sites/warwickri/files/uploads/part_a_front_matter.pdf) [<https://perma.cc/K8L9-S337>].

114. *See, e.g.*, CITY OF COVINGTON, COMPREHENSIVE PLAN AMENDMENT INSTRUCTION GUIDE AND TIMELINE 3 (2016), [http://www.covingtonwa.gov/city\\_departments/communitydevelopment/Comp%20Plan%20Amend.%20Instruction%20Guide%20&%20Timeline\\_updated%2009132016.pdf](http://www.covingtonwa.gov/city_departments/communitydevelopment/Comp%20Plan%20Amend.%20Instruction%20Guide%20&%20Timeline_updated%2009132016.pdf) [<https://perma.cc/2N8Z-43PW>] (outlining the timeline of comprehensive plan amendment).

growth and few, if any, additional criteria.<sup>115</sup> For example, Greenville, Texas, fifty miles east of Dallas with a population of 25,557,<sup>116</sup> reviewed several core pieces of its infrastructure system in its comprehensive plan. In the plan, the city concluded that projected population increases necessitated the construction of several gray infrastructure components.<sup>117</sup> In the section entitled “Stormwater Management & Control Alternatives,” the city relied almost entirely on gray infrastructure tools, such as on-site and regional detention ponds, concrete channels, pipes, and impact fees to raise money for additional gray infrastructure.<sup>118</sup> Greenville’s plan envisions the following infrastructure improvements:

- Construction of more than ten pipes for the provision of water, ranging in diameter from 16 to 36 inches and in length between 3,280 feet and 18,900 feet, and costing over \$6 million
- Two high service pumps, costing \$100,000
- Two ground storage tanks, costing \$1.2 million
- Construction of more than 30 pipes for waste water, ranging from 8 inches to 72 inches and 2,700 feet to 30,700 feet, costing

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115. *See, e.g.*, CITY OF SUNRISE COMPREHENSIVE PLAN A1 (2016), <https://www.sunrisefl.gov/modules/showdocument.aspx?documentid=2084> [https://perma.cc/933R-QKKV] (“Residential Uses: Provide an adequate amount of residential area to accommodate the existing and future residents of Sunrise and which allows for the flexibility to provide a varied mix of residential densities and housing types.”); MONROE COUNTY COMPREHENSIVE PLAN 3 (2012), [http://www.co.monroe.in.us/TSD/DesktopModules/Bring2mind/DMX/Download.aspx?TabID=140&Command=Core\\_Download&EntryId=31189&PortalId=0&TabId=140](http://www.co.monroe.in.us/TSD/DesktopModules/Bring2mind/DMX/Download.aspx?TabID=140&Command=Core_Download&EntryId=31189&PortalId=0&TabId=140) [https://perma.cc/DR7V-PDKW] (“[A] comprehensive plan is fundamentally concerned with the physical development of the community and most specifically with property use, transportation, public facilities, infrastructure, natural and environmental features, and housing.”); *id.* at 5 (“Monroe County shall support the development and expansion of an inventory of relatively constraint-free property for business use and growth coupled with sufficient infrastructure to sustain that use and growth.”).

116. *Demographics*, GREENVILLE ECON. DEV., <http://www.greenvilletxedc.com/community-profile/demographics> [https://perma.cc/ZN48-TF4B].

117. The plan also acknowledges the ecosystem destruction that had occurred in its jurisdiction. CITY OF GREENVILLE, CHAPTER 1: BASELINE ANALYSIS, COMPREHENSIVE PLAN 2025, 11 (2014), <http://www.ci.greenville.tx.us/DocumentCenter/Home/View/577> [https://perma.cc/3JJP-2KBJ] (“Originally, the Blackland Prairies were covered with little bluestem, big bluestem, indiangrass, tall dropseed, and Silveus dropseed. However, in the early 1900’s, 98 percent of the Blackland Prairies were cultivated. The crops that were grown in place of the original vegetation were cotton, sorghum, corn, wheat, and forages (food for animals).”).

118. CITY OF GREENVILLE, CHAPTER 6: THE INFRASTRUCTURE PLAN, COMPREHENSIVE PLAN 2025, 38–39 (2014), <http://www.ci.greenville.tx.us/DocumentCenter/Home/View/582> [https://perma.cc/EK7D-DFBN] [hereinafter CHAPTER 6: THE INFRASTRUCTURE PLAN, COMPREHENSIVE PLAN 2025]. To be sure, the focus on gray infrastructure is throughout the plan, not only water. *See, e.g.*, CITY OF GREENVILLE, CHAPTER 4: THE THOROUGHFARE PLAN, COMPREHENSIVE PLAN 2025 (2014), <http://www.ci.greenville.tx.us/DocumentCenter/Home/View/580> [https://perma.cc/J4HN-DXRW] (transportation portion focuses heavily on updated and developing new roads and new asphalt coverage).



over \$35 million (plus borings and manholes, amounting to another \$3 million)

- Wastewater facility improvements (“wastewater reclamation centers”) amounting to \$214,000,000<sup>119</sup>

The infrastructure tools and strategies mentioned in the plan focus on engineering the landscape as opposed to working with the existing ecosystems. Further, the plan views natural environments as problem areas that must be controlled. For example, one of the few natural environments mentioned are “creeks,” and they are listed under “[a]ssessment of current and future *problem areas*.”<sup>120</sup>

Additionally, the Greenville plan fragments infrastructure. It addresses its potable water infrastructure in one chapter, transportation in another, stormwater in another, and so on. When writing about water management, Tony Arnold notes: “[i]n many cases, this fragmentation is not an adaptive structure of polycentricity and modularity, but instead a set of hard, impermeable, organizational and institutional silos that prevent coordination or integration of laws and policies across systems and scales.”<sup>121</sup> This fragmentation of infrastructure makes the system more vulnerable, less resilient, and unable to adapt.<sup>122</sup>

Having a process in place that facilitates adaptation can increase resilience as infrastructure can accommodate change instead of fighting it.<sup>123</sup> A process of adaptation may include continuous monitoring, learning, and changing policies as information is analyzed and is discussed in more detail in section IV.<sup>124</sup> Instead of setting all

119. CHAPTER 6: THE INFRASTRUCTURE PLAN, COMPREHENSIVE PLAN 2025, *supra* note 118, at 32–33.

120. *Id.* at 40 (emphasis added).

121. *Environmental Law, Episode IV, supra* note 1, at 15.

122. See generally Brian C. Chaffin et al., *A Decade of Adaptive Governance Scholarship: Synthesis and Future Directions*, 19 *ECOLOGY & SOC’Y* 56, 59 (2014) (“Given the uncertainties associated with global environmental change, including climate change and massive shifts in land use, environmental governance systems going forward must be highly adaptive.”); *Environmental Law, Episode IV, supra* note 1, at 21 (“Adaptive planning processes, adaptive legal frameworks, and adaptive governance institutions are needed for social-ecological resilience.”).

123. See Craig Anthony (Tony) Arnold, *Resilient Cities and Adaptive Law*, 50 *IDAHO L. REV.* 245, 264 (2014); Fred Bosselman, *A Role for State Planning: Intergenerational Equity and Adaptive Management*, 12 *U. FLA. J. L. & PUB. POL’Y* 311, 326–27 (2001); Chaffin et al., *supra* note 122, 59 (“[Thomas] Dietz et al. (2003) cited the need for a system of resource governance that is highly adaptive and allows rules to evolve from feedbacks originating both in the human and biophysical realms as well as combined elements of the system.”). See *infra* section IV.B for a discussion of adaptive governance.

124. See Arnold, *supra* note 123, at 261; Chaffin et al., *supra* note 122, at 56 (“This suggested form of ‘adaptive governance’ of SESs requires adequate information about the resource (ecological),

infrastructure pieces in place at one time, adaptation helps infrastructure and infrastructure policies evolve as information comes to light.<sup>125</sup>

Sunrise, Florida, provides another example. It begins its comprehensive plan by stating that its infrastructure expansion will respond directly to accommodate growth.<sup>126</sup> Particularly telling are the metrics Sunrise uses to determine whether additional infrastructure is needed:

Design capacity shall be determined as follows: Sewage: The capacity of the sewage treatment plants. Water: The capacity of the water treatment plants. . . . Roadways: The standard for measuring highway capacities shall be the Broward County Trips Model printout or other techniques . . . . In determining capacity, existing volumes plus “committed” trips from approved site plans and recorded plats shall be included.<sup>127</sup>

Almost all of the metrics set forth by Sunrise measure gray infrastructure capacity. If that capacity dips below a certain level, more gray infrastructure is necessary. There is limited measuring of ecosystems and whether they are changing and how to adapt if changes occur. If most of the measurements are based on gray infrastructure capacity, the city is more likely to craft solutions to enhance gray infrastructure so as to address the metric.<sup>128</sup>

The lack of adaptive planning and the failure to account for ecosystems in comprehensive plans is reflected in broad studies exploring comprehensive adaptation plans. For example, a survey administered by the International Council for Local Environmental Initiatives (ICLEI) found the U.S. had the lowest percentage of cities across the globe that were pursuing adaptation planning:

Latin American and Canadian cities have the highest (95% and 92% respectively). . . . [O]nly 13% of the U.S. cities surveyed had even completed an assessment of their vulnerabilities and risks, the lowest percentage of all regions surveyed. . . .

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values (social), the human-environment interactions (e.g., feedbacks through monitoring), as well as the most up-to-date information on uncertainty.”).

125. See Arnold, *supra* note 123, at 261.

126. CITY OF SUNRISE COMPREHENSIVE PLAN, *supra* note 115, at D1, D3.

127. *Id.* at H6.

128. See also Robert L. Glicksman, *Ecosystem Resilience to Disruptions Linked to Global Climate Change: An Adaptive Approach to Federal Land Management*, 87 NEB. L. REV. 833, 867 (2009) (“As one observer put it, land use plans are ‘an accountability tool . . . . What is not in a plan tends to be considered unimportant.’”).

Many communities [in the United States] have not yet calculated and evaluated risks associated with climate change for infrastructure.<sup>129</sup>

### B. *Zoning and Building for Gray Infrastructure*

While comprehensive plans set forth the broad land use objectives; development, zoning, and building codes are where the rubber meets the road when it comes to regulation of infrastructure for private developments. There are many specific land use provisions that influence developers and the construction of infrastructure. While typically not “headline” areas of the law, they are some of the most influential because they have significant impacts on how we live our lives, form communities, and prepare for uncertainty.

Described below are three areas of land use laws that require gray infrastructure for private projects. The three—impervious surfaces and parking, stormwater management, and tree mitigation—are pervasive throughout local codes and have significant impacts on many types of infrastructure, including those related to energy, transportation, stormwater management, and emergency services. Deconstructing the ordinances below reveals not only a preference for gray infrastructure and stationarity, but also an aversion to ecosystems. Such laws have the dual effect of removing ecosystems and the resilience benefits they provide and replacing them with infrastructure that creates vulnerabilities. Although the examples are discussed individually (mirroring how they are laid out in many local codes), they are intricately related to each other and are often part of the same projects and public services.

#### 1. *Impervious Surfaces and Parking*

A number of provisions in land use codes encourage or require private developments to install impervious surfaces.<sup>130</sup> These code provisions

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129. Adams-Schoen & Thomas, *supra* note 3, at 529 (2015) (quoting THE WHITE HOUSE, PRESIDENT’S STATE, LOCAL, AND TRIBAL LEADERS TASK FORCE ON CLIMATE PREPAREDNESS AND RESILIENCE: RECOMMENDATIONS TO THE PRESIDENT 35 (2014), [https://obamawhitehouse.archives.gov/sites/default/files/docs/task\\_force\\_report\\_0.pdf](https://obamawhitehouse.archives.gov/sites/default/files/docs/task_force_report_0.pdf) [<https://perma.cc/DNC6-QHWM>]); *id.* at 527 (“Indeed, many communities are already experiencing climate change related threats, including eroding shores, more massive storm surges, more severe storms, salt water intrusion, loss of land, heat waves, droughts, and other extreme weather conditions.”); *see also* WATER SECTOR RESILIENCE FINAL REPORT, *supra* note 4, at 18 (“Secure and resilient water and wastewater infrastructure is essential to daily life, ensuring the economic vitality of the Nation and maintaining public confidence in utility services.”).

130. *See, e.g.*, CHELAN COUNTY, WASH., ADMIN. CODE § 15.30.250(1)(B)(i) (2017), <http://www.codepublishing.com/WA/ChelanCounty/html/Chelco15/Chelco1530.html>

govern a wide array of construction projects common in almost every city, including private streets, curbs, gutters, and parking lots. Such construction is often required to be asphalt, concrete, and other heat-absorbing and water-resisting materials.<sup>131</sup> These surfaces become part of and impact the infrastructure necessary to deliver many public services, including stormwater management, potable water, transportation, emergency services, and energy.<sup>132</sup>

One pervasive area of the law involving impervious surfaces is minimum parking standards.<sup>133</sup> These standards typically consist of at least three key factors. First, they require developers to install a minimum number of parking spaces depending on the building size and use. Second, they require parking spaces to be constructed with impervious materials, such as asphalt or concrete. Third, they prohibit or greatly limit any sharing of spaces.

As to the first factor, developers are typically required to install a minimum number of parking spaces as set forth in a grid. For example, the Yakima, Washington code provides minimum parking for more than eighty uses listed under nine categories (amusement and recreation, community services, retail trade and services, etc.). A portion of the grid is set forth below. It is followed by an example from the code. The left column provides the use, while the right provides the minimum parking slots.<sup>134</sup>

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[<https://perma.cc/4572-9JTW>] (requiring paved roads); OMAHA, NEB., MUN. CODE § 55-734 (2017), [https://library.municode.com/ne/omaha/codes/code\\_of\\_ordinances?nodeId=OMMUCOCHGEORV\\_OIL\\_CH55ZO\\_ARTXIVOREPALORE\\_S55-734SCOREPARE](https://library.municode.com/ne/omaha/codes/code_of_ordinances?nodeId=OMMUCOCHGEORV_OIL_CH55ZO_ARTXIVOREPALORE_S55-734SCOREPARE) [<https://perma.cc/98P5-EWZ6>] (requiring paved parking lots).

131. See, e.g., COPPELL, TEX., MUN. CODE §§ 12-31-1 to -2 (2017), [https://library.municode.com/TX/coppell/codes/code\\_of\\_ordinances?nodeId=CO\\_CH12ZO\\_ART31OREPARE](https://library.municode.com/TX/coppell/codes/code_of_ordinances?nodeId=CO_CH12ZO_ART31OREPARE) [<https://perma.cc/5B46-LMDX>].

132. See Benjamin O. Brattebo & Derek B. Booth, *Long-Term Stormwater Quantity and Quality Performance of Permeable Pavement Systems*, 37 WATER RES. 4369, 4369 (2003).

133. This discussion is focused on adapting to climate change. Minimum parking standards raise critical mitigation issues, as well, that stem from encouraging more car usage, discouraging walking and biking, burning more fossil fuels, and using more greenhouse gas-intensive concrete.

134. YAKIMA, WASH., MUN. CODE § 15.06.040 tbl.6-1 (2017), <http://www.codepublishing.com/WA/Yakima/?Yakima15/Yakima1506.html&?f> [<https://perma.cc/DC5H-ULPM>].

**Table 1:**  
**Yakima, Washington Municipal Code**<sup>135</sup>

LAND USE	PARKING STANDARDS
<b>AMUSEMENT AND RECREATION</b>	
Game rooms, card rooms, electronic game rooms	1 space for each playing table, for every 3 seats or every 3 machines, whichever is greater . . .
Bowling alleys	5 spaces for each lane . . .
Swimming pools	1 space for each 50 sq. ft. of water surface area
Movie theatres	1 space for each 4 seats
Golf courses	5 spaces per green and 1 space per 300 sq. ft. of gross floor area
Golf driving ranges	1 space per tee or 1 space per 15 feet of driving line, whichever is greatest . . .
<b>COMMUNITY SERVICES . . .</b>	
Libraries	1 space for each 100 sq. ft. of gross floor area
Museums, art galleries	1 space for each 100 sq. ft. of gross floor area
<b>RETAIL TRADE AND SERVICES . . .</b>	
Coffee restaurant/stand with or without drive-through	1 space for each 50 sq. ft. of public seating area, including outside seating and 1 space for each employee . . .
Professional office building for use by accountants, attorneys, etc.	1 space for each 200 sq. ft. of gross floor area . . .
Restaurant, cafe, and drive-in eating facilities	1 space for each 50 sq. ft. of indoor public floor area, and
	1 space for each 200 sq. ft. of outdoor public eating area . . .
<p>. . . . Example:</p> <p>— The gross floor area of the structure is 3,000 sq. ft. 1,000 sq. ft. of the structure is used for storage. The parking standard for storage rooms is one space per 500 sq. ft. . . . <math>1,000 \div 500 = 2</math> off-street parking spaces for the storage area.</p> <p>— The proposed use is a shoe shop. According to Table 6-1, shoe shops require one off-street parking space for each 300 sq. ft. of gross floor area. <math>2,000 \div 300 = 6.6</math> or seven spaces, since fractions of parking spaces are rounded up . . . .</p> <p>— The total required off-street parking of this use is: 2 spaces (for storage area) + 7 spaces (for the rest of the gross area) = 9 spaces.</p>	

135. *Id.*

Code provisions similar to the Yakima code are found in local codes around the country from the West, such as Santa Ana, California<sup>136</sup> and Scottsdale, Arizona<sup>137</sup> to the Plains and South Central, such as Omaha, Nebraska<sup>138</sup> and Coppell, Texas<sup>139</sup> and to the East, such as Lititz, Pennsylvania<sup>140</sup> and Naples, Florida.<sup>141</sup> For example, Clive, Iowa requires restaurants to provide fifteen parking spaces per 1,000 square feet of floor area.<sup>142</sup> A restaurant with approximately 4,000 square feet, such as the McDonald's in Figure 8 below from Clive, would be required to provide a minimum of sixty parking spaces. Thus, the parking lot could be three-to-five times the size of the restaurant.

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136. SANTA ANA, CAL., MUN. CODE § 41-1300 to 1420, (2017), [https://library.municode.com/ca/santa\\_ana/codes/code\\_of\\_ordinances?nodeId=PTIITHCO\\_CH41ZO\\_ARTXVOREPA\\_DIV1GERE\\_S41-1300LOREOREPA](https://library.municode.com/ca/santa_ana/codes/code_of_ordinances?nodeId=PTIITHCO_CH41ZO_ARTXVOREPA_DIV1GERE_S41-1300LOREOREPA) [<https://perma.cc/ZS8F-TM4W>].

137. SCOTTSDALE, ARIZ., MUN. CODE § 9.103 (2017), [https://library.municode.com/az/scottsdale/codes/code\\_of\\_ordinances?nodeId=VOLII\\_APXBBAZOOOR\\_ARTIXPALORE\\_S9.100PA](https://library.municode.com/az/scottsdale/codes/code_of_ordinances?nodeId=VOLII_APXBBAZOOOR_ARTIXPALORE_S9.100PA) [<https://perma.cc/MY3A-LYYF>].

138. OMAHA, NEB., MUN. CODE § 55-734 (2017), [https://library.municode.com/ne/omaha/codes/code\\_of\\_ordinances?nodeId=OMMUCOCHGEORVOII\\_CH55ZO\\_ARTXIVOREPALORE\\_S55-734SCOREPARE](https://library.municode.com/ne/omaha/codes/code_of_ordinances?nodeId=OMMUCOCHGEORVOII_CH55ZO_ARTXIVOREPALORE_S55-734SCOREPARE) [<https://perma.cc/98P5-EWZ6>].

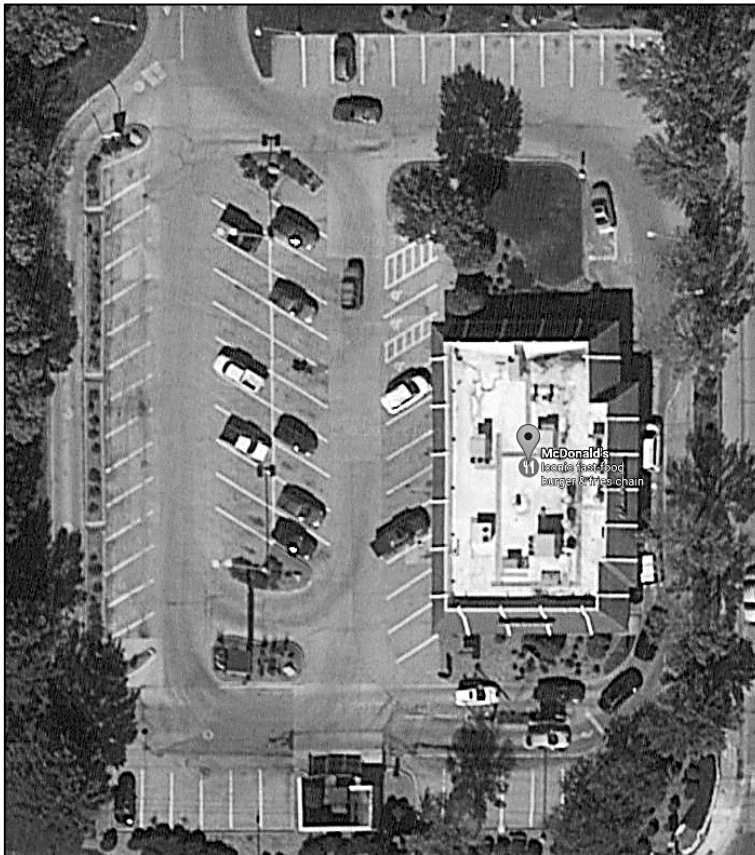
139. COPPELL, TEX., MUN. CODE § 12-31-6 (2018), [https://library.municode.com/TX/coppell/codes/code\\_of\\_ordinances?nodeId=CO\\_CH12ZO\\_ART31OREPARE](https://library.municode.com/TX/coppell/codes/code_of_ordinances?nodeId=CO_CH12ZO_ART31OREPARE) [<https://perma.cc/5B46-LMDX>].

140. LITITZ, PA., ZONING ORDINANCE § 307 (2018), <https://www.lititzborough.org/zoning-board-of-appeals/pages/section-307-off-street-and-on-street-parking-requirements> [<https://perma.cc/PV7B-PH7Z>].

141. NAPLES, FLA., MUN. CODE § 50-104 (2018), [https://library.municode.com/fl/naples/codes/code\\_of\\_ordinances?nodeId=PTIICOOR\\_CH50DEDEST\\_ARTIVPALO](https://library.municode.com/fl/naples/codes/code_of_ordinances?nodeId=PTIICOOR_CH50DEDEST_ARTIVPALO) [<https://perma.cc/X5DQ-YZDU>].

142. CLIVE, IOWA, MUN. CODE § 11-13-8 (2017), [http://www.sterlingcodifiers.com/codebook/index.php?book\\_id=595&chapter\\_id=38828#s350231](http://www.sterlingcodifiers.com/codebook/index.php?book_id=595&chapter_id=38828#s350231) [<https://perma.cc/8LRF-NXU8>].

**Figure 8:**  
**Google Maps View of McDonald's, Clive, Iowa**



Importantly, because most parking standards are minimums, developers may go beyond them. For example, pursuant to the code in West Des Moines, Iowa, developers of the site in Figure 9 below were required to build a minimum of 448 parking spaces. The developers requested and the city permitted the construction of 691 parking spaces, leaving a massive concrete, impervious landscape.

**Figure 9:**  
**Google Maps View of Development in West Des Moines, Iowa**



In addition to mandating a minimum amount of parking, codes often require such parking to be constructed with impervious surfaces, such as concrete and asphalt. Coppel, Texas provides an emblematic provision:

Sec. 12-31-1. - Special off-street parking provisions, residential districts. . . [R]equired off-street parking . . . shall be allowed only on a paved concrete surface.



Sec. 12-31-2. - Special off-street parking provisions, non-residential districts. . . In non-residential districts, surface parking . . . shall be allowed only on a paved concrete surface.<sup>143</sup>

While some jurisdictions do not prevent developers from using green infrastructure and low-impact development techniques discussed in Section IV, in these jurisdictions, the challenge can be that norms, practices, incentives, policies, and path-dependent private actions do not take advantage of these practices. The focus of this Article is on the role of local governments in facilitating the development of less invasive practices, which many local governments do not.

Local codes not only require a minimum amount of parking spaces and require those spaces to be paved, but also often set minimum dimensions for each parking spot, assuring at least some gray infrastructure on almost every project. For example, Coppell, Texas, requires:

Sec. 12-31-5. - Off-street parking requirements, all districts. . . a parking space shall be a minimum of nine feet wide and a minimum of 19 feet long.<sup>144</sup>

Finally, many jurisdictions prohibit the sharing of parking spaces even when sharing might meet all the parties' needs (such as a commercial office space sharing parking with an evening entertainment spot).<sup>145</sup>

143. COPPELL, TEX., MUN CODE §§ 12-31-1 to -2 (2018), [https://library.municode.com/TX/coppell/codes/code\\_of\\_ordinances?nodeId=CO\\_CH12ZO\\_ART31OREPARE](https://library.municode.com/TX/coppell/codes/code_of_ordinances?nodeId=CO_CH12ZO_ART31OREPARE) [<https://perma.cc/5B46-LMDX>]. In addition, parking lots tend to be two-dimensional, greatly increasing the impermeable surface per parking slot. Three-dimensional lots (garages) may house the same number of vehicles, while covering a smaller impermeable footprint.

144. COPPELL, TEX., MUN. CODE § 12-31-5 (2018), [https://library.municode.com/TX/coppell/codes/code\\_of\\_ordinances?nodeId=CO\\_CH12ZO\\_ART31OREPARE](https://library.municode.com/TX/coppell/codes/code_of_ordinances?nodeId=CO_CH12ZO_ART31OREPARE) [<https://perma.cc/5B46-LMDX>].

145. NAPLES, FLA., MUN. CODE § 50-102 (2018), [https://library.municode.com/fl/naples/codes/code\\_of\\_ordinances?nodeId=PTICOOR\\_CH50DEDEST\\_ARTIVPALO](https://library.municode.com/fl/naples/codes/code_of_ordinances?nodeId=PTICOOR_CH50DEDEST_ARTIVPALO) [<https://perma.cc/456Q-VSR4>] (“Sec. 50-102. - General requirements. . . The off-street parking and loading facilities required by this article shall be located on the same lot or parcel of land they are intended to serve.”). For more information on shared parking spots, see MARSHALL TOWNSHIP, PA., CODE Art. 1900 § 208-1902(B) (2017), [https://library.municode.com/pa/marshall\\_township\\_\(allegheny\\_county\)/codes/code\\_of\\_ordinances?nodeId=PTIIGELE\\_CH208ZO\\_ART1900OREPAL\\_O\\_S208-1902PAFARE](https://library.municode.com/pa/marshall_township_(allegheny_county)/codes/code_of_ordinances?nodeId=PTIIGELE_CH208ZO_ART1900OREPAL_O_S208-1902PAFARE) [<https://perma.cc/6P5L-9VEZ>]; SUSSEX, DEL., MUN. CODE § 115-165(B) (2017), <https://ecode360.com/8884812> [<https://perma.cc/7B48-CESK>]; TUMWATER, WASH., MUN. CODE § 18.50.090 (2017), <http://www.codepublishing.com/WA/Tumwater/?Tumwater18/Tumwater18.html> [<https://perma.cc/SGR5-TLJY>]; CITY OF SAN DIEGO, SHARED PARKING AGREEMENT (2009), <https://www.sandiego.gov/sites/default/files/legacy/development-services/pdf/industry/forms/ds267.pdf> [<https://perma.cc/H32U-U2H9>]; *Chapter 4.10 Model Shared Parking Ordinance*, in SMART CODES: MODEL LAND-DEVELOPMENT REGULATIONS, PLANNING ADVISORY SERVICE REPORT NUMBER 556 (Marya Morris ed., 2009); Abeles Phillips Preiss & Shapiro, Inc., *Shared Parking Fact Sheet*, in CAPITOL REGION COUNCIL OF GOV'TS, CRCOG BEST PRACTICES MANUAL 8-1 (2002), [http://crocog.org/wp-content/uploads/2016/07/Ch08\\_FactSheet\\_Parking.pdf](http://crocog.org/wp-content/uploads/2016/07/Ch08_FactSheet_Parking.pdf) [<https://perma.cc/89JC-SMUK>]; Michael Davidson & Fay Dolnick, *The Dynamics of Off-Street*

Putting aside the utility of requiring this many parking spaces,<sup>146</sup> this type of gray infrastructure and the laws that encourage it reduce infrastructure resilience to climate change, as they are fixed (often literally and figuratively) and are not able to adapt or transform to an uncertain future. Oversized parking lots create numerous problems for local governments and communities. They force stormwater into a local governments' sewer systems and into waterways, leading to flooding, pollution, and increased water treatment costs and, ultimately, additional gray infrastructure to address the influx of water.<sup>147</sup> Further, impervious parking lots

exacerbate sprawl, making driving—rather than walking, biking and even public transit—virtually mandatory. They contribute to traffic congestion, air pollution and poorer public health. Traffic congestion in turn may result in calls for wider streets, bigger intersections, and even higher parking requirements, increasing local costs and further damaging local ecosystems. Finally, the cost of building parking lots - from \$4,800 per spot for suburban surface lots to more than \$43,400 per spot for central business district surface lots—inevitably get passed onto consumers. When those spots are under-utilized, consumers, developers, and cities are paying unnecessary charges.<sup>148</sup>

## 2. *Stormwater Management and Private Roads*

This subsection explores stormwater management and private roads and streets regulations.<sup>149</sup> Streets have a significant impact on

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*Parking*, in PARKING STANDARDS, PLANNING ADVISORY REPORT NO. 510/511 (2002); Todd Litman, *Parking Management Best Practices: Making Efficient Use of Parking Resources*, in ZONING PRACTICE (2009); Vinit Mukhija & Donald Shoup, *Quantity Versus Quality in Off-Street Parking Requirements*, 72 J. AM. PLAN. ASS'N 296 (2002).

146. See ERAN BEN-JOSEPH, *RETHINKING A LOT: THE DESIGN AND CULTURE OF PARKING* (2012) (noting that many parking spaces are under-utilized).

147. BRATTEBO & BOOTH, *supra* note 132, at 4369.

148. Jonathan Rosenbloom & Andrew Duffelmeyer, *PARKING MAXIMUMS: MANAGING STORMWATER THROUGH SUSTAINABLE PARKING LOTS 2* (2015), <http://iowa.uli.org/wp-content/uploads/sites/77/2015/04/Parking-Maximum-Abstract-Ordinance-and-Analysis-4-14-15.pdf> [<https://perma.cc/C79C-VP34>] (citing Michael Lewyn, *Sprawl in Canada and the United States*, 44 URB. LAW. 85 (2012)); Todd Litman, *Parking Cost, Pricing and Revenue Calculator*, VICTORIA TRANSPORT POL'Y INST. (Jan. 6, 2012), <http://www.vtpi.org/parking.xls> [<https://perma.cc/SS7H-YK89>]; Donald C. Shoup, *The Trouble with Minimum Parking Requirements*, 33 TRANSP. RES. PART A 549 (1999); see also RICHARD W. WILLSON & DONALD C. SHOUP, *PARKING REFORM MADE EASY*, 34–36 (2014).

149. This Article's focus on local land use laws is not meant to imply that federal and state governments do not regulate stormwater management and infrastructure. Those regulations are beyond the purview of this piece. For a description of some of the relevant federal and state laws, see

transportation, stormwater management, waste management, and energy infrastructure. For example, they account for about one third of the land in cities and about half of the impervious surfaces.<sup>150</sup> The EPA and others have encouraged green infrastructure as an alternative to gray infrastructure for stormwater management on public streets and other impervious areas.<sup>151</sup> While several cities have implemented some of the EPA's suggestions, many have not. Those that have not often inform developers—in a very detailed manner—that they must cover all private interior roads and driveways with concrete asphalt.<sup>152</sup> For example, Chelan County, Washington requires that all driveways and private roads, such as those used to access subdivisions, be topped with at least three inches of asphalt.<sup>153</sup> Woodinville, Washington provides similar criteria:

For a private street to be considered to be accepted into the City as a public street . . . all the following criteria must be met:

(1) Pavement Surface. Asphalt concrete pavement with curbing or 24-inch gravel edges. On noncurbed streets, asphalt driveway aprons must extend a minimum of 24 inches past the edge of the aligned road edge.

(2) Street Width. Twenty-two feet at the narrowest point.<sup>154</sup>

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*Water Enforcement*, EPA, <https://www.epa.gov/enforcement/water-enforcement> [<https://perma.cc/M8TK-PA54>]; Randy Hill & David Allnut, “*Wet Weather*” *Regulations: Control of Stormwater and Discharges from Concentrated Animal Feeding Operations and Other Facilities*, in MARK A. RYAN, *THE CLEAN WATER ACT HANDBOOK*, 163–78 (2d ed. 2003); John H. Minan, *General Industrial Storm Water Permits and the Construction Industry: What Does the Clean Water Act Require?*, 9 CHAP. L. REV. 265 (2006).

150. Daniel C. Vock, *Greener City Streets Aren't Just About Traffic. They're About Rainwater, Too.*, GOVERNING (July 10, 2017), <http://www.governing.com/topics/transportation-infrastructure/gov-cities-green-streets-water-runoff-transportation.html> [<https://perma.cc/WMB5-YAGA>].

151. The EPA has a website devoted entirely to green infrastructure. The site has guidance on a host of topics including parks and stormwater management. *Green Infrastructure*, EPA, <https://www.epa.gov/green-infrastructure> [<https://perma.cc/M3JV-XS6N>]. In addition, the National Association of City Transportation Officials (NACTO) has a new helpful guide on green infrastructure and stormwater management entitled *Urban Street Stormwater Guide*. *Urban Street Stormwater Guide*, NACTO, <https://nacto.org/publication/urban-street-stormwater-guide> [<https://perma.cc/4MLM-6YFZ>].

152. For a particularly detailed account of private and public road construction, see TOWN OF MALTA, N.Y., *STANDARD SPECIFICATIONS FOR ROADS AND HIGHWAYS* (2014), <http://www.maltatown.org/DocumentCenter/View/286> [<https://perma.cc/76RB-9UQ9>] (a twenty-nine-page document detailing exact asphalt construction).

153. CHELAN COUNTY, WASH., CTY. ADMIN. CODE § 15.30.250(1)(B)(i) (2017), <http://www.codepublishing.com/WA/ChelanCounty/html/Chelco15/Chelco1530.html> [<https://perma.cc/4572-9JTW>].

154. WOODINVILLE, WASH., CODE § 12.27.020 (2017), <http://www.codepublishing.com/WA/Woodinville/html/Woodinville12/Woodinville1227.html> [<https://perma.cc/227R-DSG5>].

Woodinville's provision is instructive because it not only requires private streets to be covered with impervious surfaces but also demands a certain width. In addition, subsection (4) of the ordinance acknowledges that because the surface is impervious there will be runoff. It states:

(4) Surface Drainage. Drainage must be provided for road surface runoff either by an open ditch, gutter, or enclosed pipe system.<sup>155</sup>

The ordinance requires developers to use gray infrastructure to engineer their way around the runoff that was created by the impervious street. The land use code relies on human engineering of ecosystems to address problems (here, runoff) that humans created (here, through the use of impervious surfaces).

These stormwater management challenges often get addressed through separate stormwater management guidelines that further focus on gray infrastructure.<sup>156</sup> Stormwater management guidelines address on-site and off-site water runoff. Stormwater management guidelines are often dozens of pages long and set forth detailed engineering and hydrological requirements pertaining to measurements of adequate levels of on-site water, flow rates off-site, erosion and sediment control, water quality levels, and minimum design standards for managing stormwater.<sup>157</sup>

Depending on the project and jurisdiction, developers are required to submit a stormwater management plan.<sup>158</sup> These plans set forth the developers' precise strategies to address stormwater runoff.<sup>159</sup> These strategies often rely on gray infrastructure. For example, the City of Waco, Texas defines "Drainage System" as a:

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155. *Id.*

156. *See supra* note 149 (recognizing the role federal and state governments play that is beyond the purview of this Article).

157. *See, e.g.,* CITY OF DUBLIN, OHIO, STORMWATER MANAGEMENT DESIGN MANUAL (2007), <http://dublinohiousa.gov/dev/dev/wp-content/uploads/2012/09/StormwaterDesignManual.pdf> [<https://perma.cc/SHE3-6EGH>] [hereinafter STORMWATER MANAGEMENT DESIGN MANUAL].

158. *See, e.g., id.* at 5, 19 (noting that the plan applies to "the alteration, construction, installation, demolition or removal of a structure, impervious surface or drainage facility; or clearing, scraping, grubbing, killing or otherwise removing the vegetation from a site; or adding, removing, exposing, excavating, leveling, grading, digging, burrowing, dumping, piling, dredging or otherwise significantly disturbing the soil, mud, sand or rock of a site").

159. *See, e.g., id.; see also* DES MOINES, IOWA, MUN. CODE §§ 82-206 to -219 (2017), [https://library.municode.com/ia/des\\_moines/codes/code\\_of\\_ordinances?nodeId=MUCO\\_CH82PL\\_ARTVSIPLRE\\_S82-206PU](https://library.municode.com/ia/des_moines/codes/code_of_ordinances?nodeId=MUCO_CH82PL_ARTVSIPLRE_S82-206PU) [<https://perma.cc/XZ6K-LKK8>] (finding that the required information for a stormwater management plan and site review include "Indicate paved surfaces, Show traffic flows and parking, Soil tests, where appropriate, Request for grading permit . . . Garage access located to the rear").

System made up of pipes, ditches, streets and other structures designed to contain and transport surface water generated by a storm event.<sup>160</sup>

Similarly, Dublin, Ohio's guidelines require developers' stormwater management plan to include information that pertains almost exclusively to the engineering of the landscape through gray infrastructure:

The Stormwater Management Plan shall be a bound report containing all pertinent stormwater calculations for detention/retention basins, storm sewers, culverts, open channels, and other stormwater management system features . . . .

1. Location and type of structures. 2. Length of facility and dimensions, including diameter, height, and/or width for pipes. 3. Cross-sections for open channels. 4. Sub-basin areas tributary to each structure. 5. Runoff coefficients or curve numbers per sub-basin for both the pre-construction and post-construction site conditions. 6. Time of concentration to the inlet of each structure.<sup>161</sup>

In addition, the construction plan must note:

1. Overall project plan of roads, lots, and retention or detention facilities. 2. Cross-section of retention/detention facilities and BMPs [best management practices]. 3. Typical swale, ditch, or canal sections. 4. Drainage rights-of-way. 5. Road plan and profile with groundwater elevation shown in profile. 6. Overall project grading plan (at 1-foot contours) and individual lot grading plans. 7. Density of the project.<sup>162</sup>

Exacerbating the effects of stormwater management plans is that the gray infrastructure is often situated on or through existing ecosystems. Often these existing ecosystems are providing stormwater management services relative to quality and quantity as well as other undervalued services. For example, the Dublin, Ohio stormwater management plan

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160. WACO, TEX., STORMWATER MANAGEMENT REGULATIONS § 1.1-3 (2018), <http://www.waco-texas.com/pdf/engineering/Stormwater-Management-13.pdf> [<https://perma.cc/WLM2-JU8X>]; see also Caswell F. Holloway, Carter H. Strickland, Jr., Michael B. Gerrard & Daniel M. Firger, *Solving the CSO Conundrum: Green Infrastructure and the Unfulfilled Promise of Federal-Municipal Cooperation*, 38 HARV. ENVTL. L. REV. 335, 359–60 (2014) (“Until very recently, urban stormwater and sewer infrastructure has meant pipes and treatment facilities. For millennia, sanitation technology consisted of the collection, transportation, treatment, and disposal of wastewater to limit human contact with unsanitary conditions and prevent the spread of disease. Pipes, storage facilities, and [Publicly Owned Treatment Works] are single-purpose stormwater infrastructure known by the shorthand of ‘grey infrastructure’ to acknowledge the vast amounts of concrete and other materials with high embedded energy necessary in their construction.”).

161. STORMWATER MANAGEMENT DESIGN MANUAL, *supra* note 157, at 19.

162. *Id.* at 23.

above is applicable not only to structures, but also to the “clearing, scraping, grubbing, killing or otherwise removing the vegetation from a site.”<sup>163</sup> This “vegetation” can serve, and in many cases has served, as a means of increasing the resilience of infrastructure relevant to stormwater management and others.<sup>164</sup>

As discussed in Section IV, these ecosystems can help more easily adapt to changing precipitation levels than gray infrastructure systems can because gray infrastructure systems are fixed. Thus, not only do the local stormwater management guidelines require an inflexible gray infrastructure system to be installed, but they do so at the expense of working ecosystems that can enhance stormwater infrastructure resilience and provide added benefits pertaining to energy, air quality, wildlife, and others.

### 3. *Tree Removal and Mitigation Ordinances*

Many tree removal and mitigation ordinances not only encourage gray infrastructure, but they do so at the expense of ecosystems. Des Moines, Iowa has a fairly typical, if not slightly aggressive, tree mitigation ordinance,<sup>165</sup> which requires one replacement tree for every new tree removed that is over twelve inches in diameter at breast height and two for every tree over eighteen inches.<sup>166</sup> The ordinance continues, however, by stating that replacement of trees is not required when “removal is required to conform with any . . . infrastructure requirements including . . . streets, sidewalks, and stormwater detention.”<sup>167</sup>

This tree ordinance, like many others across the country, allows ecosystems to be removed and replaced with gray infrastructure, and exempts some gray infrastructure projects from mitigation requirements. Given the massive loss of natural landscapes in the United States,<sup>168</sup> any loss of existing ecosystems or even standalone trees is magnified. Even under a specific local code provision that is designed to remediate tree removal and maintain or replace some lost vegetation, developers are not

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163. *Id.* at 5.

164. *See supra* notes and accompanying text in section IV.A for a discussion of ecosystems and resilience.

165. *See* DES MOINES, IOWA, MUN. CODE § 42-550 to -557 (2017), [https://library.municode.com/ia/des\\_moines/codes/code\\_of\\_ordinances?nodeId=MUCO\\_CH42EN\\_ARTXTRREMI\\_S42-550TI](https://library.municode.com/ia/des_moines/codes/code_of_ordinances?nodeId=MUCO_CH42EN_ARTXTRREMI_S42-550TI) [<https://perma.cc/MGE4-YDX2>].

166. *Id.* §§ 42-550 to -557.

167. *Id.* § 42-555.

168. *See, e.g.,* Yuhas, *supra* note 46 (noting loss of wetlands between 1780–1980 in states (for example, Iowa has suffered an 89% loss; Illinois, 85%; Indiana, 87%; Ohio, 90%; and Kentucky, 81%)).

required to do so when a tree is removed to install gray infrastructure, such as streets, pipes, and ditches.

C. *Summary of Land Use Laws: A Fixation on Gray Infrastructure*

Sections A and B above set forth examples that only scratch the surface of the many provisions in the many land use codes that encourage, if not compel, the construction of *gray infrastructure*. Such infrastructure transforms static laws into static physical forms that embody *stationarity* and dominate ecosystems. These laws lead developers to contribute vulnerable infrastructure to an already weakened infrastructure system.

The idea that laws can create vulnerabilities or, at least, are incapable of addressing uncertainty is captured by C.S. Holling, who stated: “[i]n a system anticipating transformation, in a flip from one state to another [such as that experienced by the Des Moines Water Works], laws are truly of limited help, because the transformed system has unknown key variables and processes and unknown risks and opportunities emerge.”<sup>169</sup> The traditional method of drafting laws involves a “front end” gathering of information and then fixing a policy based on that information. There is little, if any, continual evaluation and monitoring to determine if the policy is functioning as planned and whether there are unintended consequences or changes. Finding this type of front end regulation in natural resources law, J.B. Ruhl states:

[N]atural resource management agencies are locked in an administrative law system that . . . shows no signs of being flexible . . . . The system’s fixation on predecisional environmental assessment, cost-benefit analysis, records of decisions, and judicial review litigation has pushed the system toward a ‘front-end’ focus on reliability and efficiency.<sup>170</sup>

The challenge with this type of rulemaking is that:

[f]ixed rules are likely to fail because they place too much confidence in the current state of knowledge, whereas systems that guard against the low probability, high consequence possibilities and allow for change may be suboptimal in the short

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169. C.S. Holling, *Response to “Panarchy and the Law,”* 17 *ECOLOGY & SOC’Y* (2012), <https://www.ecologyandsociety.org/vol17/iss4/art37/> [<https://perma.cc/SM6P-FHT5>].

170. J.B. Ruhl, *General Design Principles for Resilience and Adaptive Capacity in Legal Systems: Applications to Climate Change Adaptation Law*, 89 *N.C. L. REV.* 1373, 1392–93 (2011).

run but prove wiser in the long run. This is a principal lesson of adaptive management research.<sup>171</sup>

Stationarity as built into the law is prevalent throughout land use laws and can be found in comprehensive plans that are decades old when the community and world around them has changed dramatically;<sup>172</sup> in site plan reviews and stormwater management guidelines that favor gray infrastructure;<sup>173</sup> and in individual lot requirements, such as parking minimum standards that require gray infrastructure.<sup>174</sup> These laws are not only fixed, but also the physical manifestation of the laws is reflected in rigid and static gray infrastructure. Such infrastructure is inflexible, fixed in time, and fails to account for ongoing changes.

Observing a similar perspective embedded in environmental and natural resources law, Robin Kundis Craig found that the law was historically marked by human control and dominance over ecological and social-ecological systems.<sup>175</sup> Noting the importance placed on engineering ecosystems, Craig stated that the domination of nature accepted a “faith in the ability of science and technology to make the world a better place” because science and technology could help manipulate ecosystems.<sup>176</sup> Craig called this approach, in which humans dominate ecosystems and use technology to that end, a “Humans as Controlling Engineers” narrative.<sup>177</sup>

The reliance on technology to facilitate human control and dominance over nature harks back to a core theme found throughout the Industrial Revolution. That theme is:

an outgrowth of the Enlightenment (late seventeenth and early eighteenth century) . . . . Nature, [it was believed,] was not only subordinate to humans, but also at humans’ disposal. Science, technology, and reason served only as tools to help humans overcome any natural barriers to exploitation.

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171. Thomas Dietz, Elinor Ostrom & Paul C. Stern, *The Struggle to Govern the Commons*, 302 *SCI.* 1907, 1909 (2003).

172. See *infra* section III.B for a discussion of comprehensive plans.

173. See *infra* section III.C.2 for a discussion of stormwater management guidelines. See generally John J. Costonis, *Two Years and Counting: Land Use and Louisiana’s Post-Katrina Recovery*, 68 *LA. L. REV.* 349, 349 (2008) (“Louisiana’s land use governance system [was] largely the same [immediately before and after the storm] as when its governing statutes were adopted some seventy years ago.”).

174. See *infra* section III.C.1 for a discussion of minimum parking standards.

175. *Learning to Live with the Trickster*, *supra* note 19, at 352.

176. *Id.* at 362 (quoting Benson, *supra* note 94, at 102–03).

177. *Id.* at 359.



Many believed that science and reason could break through any obstacles or limits presented by nature, thereby allowing humans to tame and manipulate the environment to optimize its use. As author Kirkpatrick Sale noted, “[t]he Industrial Revolution was the first spectacular triumph of the human species over the patterned, ancient limitations of the natural world.”<sup>178</sup>

Echoing the Enlightenment and the belief that technology is a means to facilitate human control and dominance over nature, Craig describes the Humans as Controlling Engineers narrative as follows:

Within this narrative, for most of the history of environmental law in the United States, humans have claimed the considerable ability to control and modulate human impact on ecological systems. . . . Americans could, it seemed, do anything we wanted with respect to harnessing nature’s resources—down to and including atoms—and with respect to conquering nature’s challenges, like the vacuum, cold, and immense distances of outer space. Humans appeared to be the technological masters of the universe.<sup>179</sup>

Such manipulation of the landscape “came with environmental consequences—dustbowls and exhausted soils in farm lands; the loss of salmon runs in the Pacific Northwest and many parts of the Northeast; polluted waters throughout the United States; and increasing numbers of increasingly endangered species.”<sup>180</sup> Fixing these consequences fell under the rubric of further engineering resilience: “[i]n essence, if humans broke it, humans could fix it. Or, from perhaps a more nuanced perspective, if human priorities for particular ecosystems had changed, there was nothing to prevent humans from re-engineering the relevant natural systems to suit these new priorities.”<sup>181</sup>

While modern land use laws pre-date the U.S. environmental movement, Craig’s description of the Humans as Controlling Engineers narrative is apt to and reflected in land use laws and the regulation of infrastructure for private development. This narrative is clearest in land use laws’ focus on gray infrastructure. Gray infrastructure epitomizes the idea that humans can engineer gray infrastructure to replace ecosystems and perform their functions. Gray infrastructure is simply a human-made tool to transform ecosystems to promote the values that are fully human-controlled, rather than controlled by nature.

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178. SAXER & ROSENBLUM, *supra* note 91, at 71–72.

179. *Learning to Live with the Trickster*, *supra* note 19, at 363.

180. *Id.* at 367 (citations omitted).

181. *Id.* at 367–68.

Land use laws also reflect a pattern of fixing problems stemming from the manipulation of nature with further manipulation. As illustrated in the ordinances above, land use codes often require gray infrastructure. Such infrastructure introduces new challenges. For example, paved private streets often lead to stormwater runoff challenges. In turn, these new challenges are addressed through additional gray infrastructure, such as stormwater management plans that require ditches, channels, and pipes.

The alteration of nature through gray infrastructure creates vulnerabilities. It “assume[s] that ecological change is predictable and that human impacts are generally reversible.”<sup>182</sup> The combination of and relationship between gray infrastructure and stationarity “will inevitably frustrate the engineers—those who want to continue to believe that humans are in control of ecological and socio-ecological systems, those who seek to avoid change and maintain the status quo.”<sup>183</sup> As discussed in Section II, ecosystems are unpredictable and can change in unpredictable ways. Further, climate change can heighten uncertainty.

It is important to remember . . . that climate change underscores rather than creates the reality disjunction that the “Humans as Controlling Engineers” narrative creates. In essence, humans cannot assert complete control over ecosystems and expect desirable results indefinitely, because we just don’t know enough about those ecosystems and their ever-changing multi-scalar complexity.<sup>184</sup>

These two sources of uncertainty—ecosystem behaviors and climate change—work in tandem and often against gray infrastructure. In the next section, a new land use narrative built on adaptation and ecosystem services is explored to address this uncertainty and to support the construction of resilient infrastructure and communities.

#### IV. INCREASING INFRASTRUCTURE RESILIENCE THROUGH LAND USE LAWS

While changes in the climate and other systems may be unknown, we can integrate a number of approaches that can help acknowledge and respond to change to create more resilient communities and prepare for an uncertain future. Ecosystem services management and adaptive governance are two approaches that can be integrated across land use laws

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182. *Id.* at 371 (alteration in original) (quoting Robin Kundis Craig, “Stationarity Is Dead”—*Long Live Transformation: Five Principles for Climate Change Adaptation Law*, 34 HARV. ENVTL. L. REV. 9, 35 (2010)).

183. *Learning to Live with the Trickster*, *supra* note 19, at 387.

184. *Id.* at 374.

to manifest a new land use narrative that prepares communities and their infrastructure for uncertainty. Incorporating ecosystem services management and adaptive governance represent two techniques to address the most problematic portions of gray infrastructure and stationarity. While they are not the only techniques, they are sufficiently broad and flexible to be incorporated into diverse land use laws across the country. In addition, they can be structured as regulatory requirements or construction incentives. Most of the examples below are drafted as regulatory requirements. These requirements, however, could easily be converted to incentives in which developers receive a variety of benefits, such as fee reductions or height and floor area ratio bonuses, upon implementing certain types of infrastructure.

Subsection A below describes ecosystem services management in the context of infrastructure. Subsection B describes adaptive governance and how it can help overcome stationarity by framing a process for evaluation and adaptation. Subsection C provides examples of land use laws that incorporate adaptive governance and ecosystem services to help prepare for an uncertain future.

#### A. *Ecosystem Services Management (ESM)*

ESM helps local communities adapt to changes by leveraging ecosystems' natural abilities.<sup>185</sup> It does so by recognizing a monetary value for services provided by ecosystems.<sup>186</sup> While ESM does not dictate policy, it provides critical information that can highlight vulnerabilities and lead to policy changes. The information gleaned through an ESM approach helps decision-makers more accurately weigh the true costs associated with decisions. "One cannot begin to understand flood control, for example, without realizing the impact of widespread wetland

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185. See Keith H. Hirokawa, *Sustaining Ecosystem Services Through Local Environmental Law*, 28 PACE ENVTL. L. REV. 760, 760–61 (2011); *Learning to Live with the Trickster*, *supra* note 19, at 391 (The Humans as Controlling Engineers narrative should be replaced with "across-the-board serious implementation of ecosystem-based management based on a strong precautionary principle . . . now informed by the new reality that all bets are off for ecosystems in a climate change era."). For a more detailed description of the Precautionary Principle, see INTERDEPARTMENTAL WORKING GROUP ON THE PRECAUTIONARY PRINCIPLE, THE PRECAUTIONARY PRINCIPLE IN SWITZERLAND AND INTERNATIONALLY 16 (2003), [http://www.who.int/ifcs/documents/forums/forum5/synthesepaper\\_precaution\\_ch.pdf](http://www.who.int/ifcs/documents/forums/forum5/synthesepaper_precaution_ch.pdf) [<https://perma.cc/X6MK-4M8V>]; SAXER & ROSENBLUM, *supra* note 91, at 172–79 (citing U.N. Conference on Environment and Development, Rio Declaration on Environment and Development, U.N. Doc. A/CONF.151/26/Rev. 1 (Vol. 1), Principle 22 (Aug. 12, 1992); SUMUDU A. ATAPATTU, EMERGING PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW, 228–29 (2006).

186. See Robert Costanza et al., *The Value of the World's Ecosystem Services and Natural Capital*, 387 NATURE 254, 259 (1997); Hirokawa, *supra* note 185, at 760–61.

destruction on the ecosystem service of water retention; nor can one understand water quality without recognizing how development in forested watersheds degrades the service of water purification.”<sup>187</sup>

J.B. Ruhl and James Salzman trace the ecosystem services literature to three publications.<sup>188</sup> The first is a book, titled *Nature’s Services: Societal Dependence on Natural Ecosystems*,<sup>189</sup> which was conceived following a collective lamentation about the “near total lack of public appreciation of societal dependence upon natural ecosystems.”<sup>190</sup> *Nature’s Services* focuses on two primary ESM questions: “(1) what services do natural ecosystems provide society, and (2) what is a first approximation of their monetary value?”<sup>191</sup>

According to Ruhl and Salzman, the next seminal publication on ecosystem services was an article in *Science* entitled *The Value of the World’s Ecosystem Services and Natural Capital*.<sup>192</sup> The authors in the *Science* piece found that ecosystems make up part of the world’s “natural capital” (trees, minerals, the atmosphere, etc.), which exists in addition to manufactured capital (machines and buildings) and human capital (labor).<sup>193</sup> In the *Science* article, the authors define ecosystem services as consisting “of flows of materials, energy, and information from natural capital stocks which combine with manufactured and human capital services to produce human welfare.”<sup>194</sup> In valuing the economic impact of

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187. Blake Hudson, *Federal Constitutions: The Keystone of Nested Commons Governance*, 63 ALA. L. REV. 1007, 1023 (2012) (quoting DAVID HUNTER ET AL., INTERNATIONAL ENVIRONMENTAL LAW AND POLICY 11 (4th ed. 2010)).

188. J.B. Ruhl & James Salzman, *The Law and Policy Beginnings of Ecosystem Services*, 22 J. LAND USE & ENVT'L. L. 157, 157 (2007).

189. NATURE’S SERVICES: SOCIETAL DEPENDENCE ON NATURAL ECOSYSTEMS (Gretchen Daily ed., 1997).

190. *Id.* at xv.

191. Ruhl & Salzman, *supra* note 188, at 159.

192. Costanza et al., *supra* note 186, at 253.

193. *Id.* at 254.

194. *Id.* Costanza et al. identified seventeen distinct ecosystem services: gas regulation, climate regulation, disturbance regulation, water regulation, water supply, erosion control and sediment retention, soil formation, nutrient cycling, waste treatment, pollination, biological control, refugia (habitat), food production, raw materials, genetic resources, recreation, and cultural. *See id.* at 254 tbl.1. In addition, the authors identified sixteen different biomes. *Id.* at 256 tbl.2. The two main biomes are marine and terrestrial, and each is broken into a number of more specific biomes (see Table 2 for the list of all biome subdivisions). For a number of major biomes, the authors were unable to identify valuation studies measuring their economic impact (desert, tundra, ice/rock, and cropland), so the final \$33 trillion valuation does not include any estimation from those biomes. There have been a number of challenges to Costanza et al.’s work. *See* Nancy E. Bockstael et al., *On Measuring Economic Values for Nature*, 34 ENVT’L. SCI. & TECH. 1384, 1386 (2000) (criticizing Costanza et al.’s aggregation of ecosystem services valuations from multiple studies, whose values were measured at the hectare level, to an entire biome, arguing that “[v]alues estimated at one scale cannot be

ecosystem services, the authors acknowledge, “[a] large part of the contributions to human welfare by ecosystem services are of a purely public goods nature,” and have no necessary relationship to market valuations.<sup>195</sup>

The last major publication noted by Ruhl and Salzman is an essay in *Nature* titled *Economic Returns from the Biosphere*.<sup>196</sup> In this essay, the authors describe New York City’s steps to enhance the resilience of its watershed and potable water supply by integrating ESM into law and policy. In 1905, when the city began accessing water from the watershed in upstate New York, 95% of the land was native old growth forest.<sup>197</sup> That forest ecosystem purified the city’s water. Over time, a number of land use practices such as an increased amount of impervious surfaces (for example, roads and parking lots) led to the degradation of the ecosystem.

By the turn of the millennium, New York City’s water quality had diminished. The Federal government informed New York City that it would have to install a major water treatment facility estimated to cost between \$6 and 8 billion and about a half billion a year to operate. Essentially, the City was going to pay approximately a billion dollars a year (maintenance and debt service) for an ecosystem service it had once received for free.<sup>198</sup>

New York City officials decided to purchase and protect land in the watershed rather than build a pre-treatment plant.<sup>199</sup> This strategy supported and worked symbiotically with the ecosystem, rather than fight or dominate it. In doing so, the city saves approximately one billion

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expanded by a convenient physical index of area, such as hectares, to another scale; nor can two separate value estimates, derived in different contexts, simply be added together”); David Pearce, *Auditing the Earth*, 40 ENV’T 23, 23–28 (1998) (arguing that the willingness-to-pay metric was improperly used, and that the figures used by Costanza et al. represent total values of the various resources instead of marginal values, which would be the more appropriate value in an economic analysis); COMMITTEE ON ASSESSING AND VALUING THE SERVICES OF AQUATIC AND RELATED TERRESTRIAL ECOSYSTEMS, NAT’L RESEARCH COUNCIL, VALUING ECOSYSTEM SERVICES: TOWARD BETTER ENVIRONMENTAL DECISION-MAKING 189 (2004), [http://www.nap.edu/openbook.php?record\\_id=11139&page=189](http://www.nap.edu/openbook.php?record_id=11139&page=189) [<https://perma.cc/R9TN-NHEH>] [hereinafter NAT’L RESEARCH COUNCIL] (criticizing Costanza et al.’s assumption “that ecosystem service production is ‘scale-free’ in the sense that provision per unit area is constant no matter how big or small the ecosystem under consideration”).

195. Costanza et al., *supra* note 186, at 257 (examples of ecosystem contributions to human welfare that are not accounted for in financial markets include “clean air and water, soil formation, climate regulation, waste treatment, aesthetic values and good health”).

196. Graciela Chichilnisky & Geoffrey Heal, *Economic Returns from the Biosphere*, 391 NATURE 629 (1998).

197. See SAXER & ROSENBLUM, *supra* note 91, at 188.

198. *Id.* (citing Chichilnisky & Heal, *supra* note 196, at 629).

199. Chichilnisky & Heal, *supra* note 196, at 629.

dollars a year.<sup>200</sup> “The moral of the story was simple—investing in natural capital can be a better commercial option than investing in built capital.”<sup>201</sup>

More recently and particularly relevant here, Keith Hirokawa argued that ESM is well-suited for environmental regulation at a local level because it allows local governments to identify “the types of advantages (ecological, economic, and social) that suit their communities” and to implement “innovative regulatory schemes aimed at capturing the advantages of ecosystem function.”<sup>202</sup> Further, Hirokawa notes that while an ecosystem deficiency or loss (such as through its destruction for purposes of building gray infrastructure) may be negligible on a regional or national level, it is more pronounced on a local level.<sup>203</sup> Partially because of their control of land use laws, “regulation by local governments may be the most effective way to slow or mitigate the degree to which the built environment interferes with [ecosystem service] functions.”<sup>204</sup>

The connection Hirokawa draws between local regulation and ecosystem degradation is particularly true in land use regulation of infrastructure for private developments for at least three reasons. First, integrating ESM into the regulation of land helps communities identify the parts of their ecological surroundings that they value and that provide resiliency benefits. As Hirokawa points out, ESM is best used in the local context because “[l]ocal governments are *always* environmentally situated, and ecosystems are always locally felt.”<sup>205</sup> This connection with ecosystems is acutely felt in the context of local, private property infrastructure where the ecosystems are providing necessities, such as potable water, for the community. Further, the development that necessitates the infrastructure becomes the physical make-up of the community. Thus, how that development and infrastructure are built are essential components of a community’s identity and survival. While ESM does not provide local officials with policy changes to address infrastructure, it provides information that can be used to implement

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200. *Id.*

201. Ruhl & Salzman, *supra* note 188, at 160. The National Academy of Sciences subsequently published a major study on this solution. See NAT’L ACAD. OF SCI., WATERSHED MANAGEMENT FOR POTABLE WATER SUPPLY: ASSESSING THE NEW YORK CITY STRATEGY (2000); Hirokawa, *supra* note 185, at 816–18 (describing Seattle’s purchase of land in its watershed to protect its water quality).

202. Hirokawa, *supra* note 185, at 786.

203. *Id.* at 781–82.

204. *Id.*

205. *Id.* at 778.

“innovative regulatory schemes aimed at capturing the advantages of ecosystem function.”<sup>206</sup> In essence, it takes steps toward working symbiotically with ecosystems instead of dominating them.

Second, in providing information concerning the value of ecosystems, ESM can help avoid losing or inefficiently using critical services. Losing ecosystems weakens infrastructure and community resilience, while leveraging ecosystems can reduce risk and enhance infrastructure resilient to change. Kenneth Arrow, 1972 Nobel Memorial Prize Laureate in Economic Sciences, states the connection between resilience and ecosystems as follows:

The loss of ecosystem resilience is potentially important for at least three reasons. First, the discontinuous change in ecosystem functions as the system flips from one equilibrium to another could be associated with sudden loss of biological productivity, and so to a reduced capacity to support human life. Second, it may imply an irreversible change in the set of options open both to present and future generations (examples include soil erosion, depletion of groundwater reservoirs, desertification, and loss of biodiversity). Third, discontinuous and irreversible changes from familiar to unfamiliar states increase the uncertainties associated with the environmental effects of economic activities.<sup>207</sup>

Third, ESM can help local communities recognize ecosystem changes and plan for growth with more resilient infrastructure.<sup>208</sup> Advocating for the integration of ESM into the planning for growth, Hirokawa states: “local governments may use the planning process as an opportunity to inventory and integrate ecosystem services information with a comprehensive assessment of challenges to ecosystem integrity that may be found in the local government’s plans for future growth.”<sup>209</sup> As discussed in section III.A, comprehensive planning is often focused on planning for future growth. Integrating ESM into comprehensive planning and working with ecosystems can help foster more resilient infrastructure as communities grow.

Instead of attempting to battle and control ecosystem and climate changes, integrating ESM into land use laws can help infrastructure leverage ecosystem services and better adapt as uncertainties arise. Where

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206. *Id.* at 786.

207. Kenneth Arrow et al., *Economic Growth, Carrying Capacity, and the Environment*, 15 *ECOLOGICAL ECON.* 91, 93 (1995).

208. See *Learning to Live with the Trickster*, *supra* note 19, at 372 (“Instead, nature is constantly changing, and humans should accept change *as* natural and allow it to occur.”).

209. Hirokawa, *supra* note 185, at 788.

gray infrastructure fails to recognize some of the ecosystem services' value, ESM as integrated into the regulation of infrastructure can help infrastructure work symbiotically with ecosystems.<sup>210</sup> By strategically embedding ESM into land use laws, local communities can help build resilience, while providing numerous additional health and environmental benefits.

### B. *Adaptive Governance (AG)*

For purposes of this Article, the definition of adaptive governance (AG) is rooted in the idea that: “[a]daptive governance focuses on experimentation and learning . . . . The notion of adaptation implies capacity to respond to change and even transform social-ecological systems into improved states.”<sup>211</sup> Carl Folke, et al. highlight four “aspects of importance in adaptive governance”:

- Build knowledge and understanding of resource and ecosystem dynamics; detecting and responding to environmental feedback in a fashion that contributes to resilience require ecological knowledge and understanding of ecosystem processes and functions. . . .
- Feed ecological knowledge into adaptive management practices; successful management is characterized by continuous testing, monitoring, and reevaluation to enhance adaptive responses, acknowledging the inherent uncertainty in complex systems. . . .
- Support flexible institutions and multilevel governance systems . . . . The sharing of management power and responsibility may involve multiple and often polycentric institutional and organizational linkages among user groups or

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210. *See, e.g., id.* at 760 (quoting BALTIMORE CITY PLANNING COMM’N, BALTIMORE SUSTAINABILITY PLAN 70 (2009), <http://www.baltimoresustainability.org/wp-content/uploads/2015/12/Baltimore-Sustainability-Plan.pdf> [<https://perma.cc/6U9P-S5HA>]) (“Long before modern engineering created air conditioning, sewer systems, and water and air purification technology, nature provided similar services through shade trees, grass, wetlands, and forests. Practicing good stewardship of our natural world improves the ability of future generation to eat fresh food, breath [sic] clean air, drink healthy water, and enjoy open space.”).

211. Carl Folke et al., *Adaptive Governance of Social-Ecological Systems*, 30 ANN. REV. ENV’T & RESOURCES 441, 443 (2005); *see also* Chaffin et al., *supra* note 122, at 56. The term “adaptive governance” was coined in the *Science* article: Thomas Dietz, Elinor Ostrom & Paul C. Stern, *The Struggle to Govern the Commons*, 302 SCIENCE 1907, 1908 (2003). For a listing of several definitions and a discussion of related concepts, such as adaptive management and adaptive planning, *see Environmental Law, Episode IV, supra* note 1, at 24–30.



communities, government agencies, and nongovernmental organizations . . . .

- Deal with external perturbations, uncertainty and surprise . . . a well-functioning multilevel governance system . . . needs to develop capacity for dealing with changes.<sup>212</sup>

In communities across the country, land use laws, infrastructure, and ecosystem services come together to form social-ecological systems associated with public services. Because these systems and services are susceptible to unknown changes and disturbances, AG can help strengthen community resilience by establishing a process to address those changes. One such process includes:

1. Inclusive planning for future infrastructure and service needs.
2. Assessing current resources and laws relevant to infrastructure and services.
3. Regularly obtaining information relevant to how infrastructure systems are performing and being impacted by changes. This often includes assessing critical metrics and baselines.<sup>213</sup>
4. Monitoring and assessing that information to determine whether infrastructure is adapting or is becoming more vulnerable, and
5. Amending land use laws and policies based on the information and assessment to ensure that future infrastructure development continues to increase resilience to uncertainty.<sup>214</sup>

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212. Folke et al., *supra* note 211, at 463–64; *see also Environmental Law, Episode IV, supra* note 1, at 28 (quoting Donald R. Nelson et al., *Adaptation to Environmental Change: Contributions of a Resilience Framework*, 32 ANN. REV. ENV'T & RESOURCES 395, 409 (2007)) (“For adaptation to be successful, institutions clearly need to endure and be persistent throughout the process of adjustment and change. But at the same time, they need themselves to cope with changing conditions. . . . [T]he strong normative message from resilience research is that shared rights and responsibilities for resource management (often known as comanagement) and decentralization are best suited to promoting resilience.”).

213. For a more in-depth discussion of baselines and metrics, *see* Jonathan Rosenbloom, *A Framework for Application: Three Concrete, Scalable Strategies to Accelerate Sustainability*, in *RETHINKING SUSTAINABLE DEVELOPMENT TO MEET THE CLIMATE CHANGE CHALLENGE* (Keith Hirokawa & Jessica Owley eds., 2014).

214. *See Environmental Law, Episode IV, supra* note 1, at 27–30. (“[M]any different scholars have many different lists of features of an adaptive governance system, but they tend to converge around common themes. . . . 1) getting representation of interests or stakeholders that there is sufficient to have buy-in to governance decisions but not unduly burdensome on governance structures and processes; 2) decision processes that are characterized by flexibility, legitimacy, transparency, expertise, trust, and accountability; 3) scientific learning; 4) public learning; and 5) policy decisions and implementation that respond well to the problem as measured by efficiency, equity, an appropriate

AG can help build community resilience by providing local officials with a constant flow of relevant information on how important systems are changing and a process for adapting.<sup>215</sup> AG helps navigate the complexities embedded in social-ecological systems: “the emphasis in resilience thinking is on understanding the dynamics and complexities of the [socio-ecological systems], not on determining and then maintaining a fixed system state. The emphasis is *building adaptive capacity* rather than *maintaining stationarity*.”<sup>216</sup> Furthermore, “[s]cholars of resilience call for AG to deal with uncertainty in the face of unexpected disturbance or sudden change.”<sup>217</sup>

Tony Arnold has called a movement in which adaptive tools are incorporated into environmental law the “fourth generation.”<sup>218</sup> The fourth generation is marked by a “focus[] on adaptive environmental governance and the resilience of interconnected ecosystems and human communities, a concept known as ‘social-ecological resilience.’”<sup>219</sup> Although land use laws have not undergone the same generational iterations that environmental laws have (as outlined by Arnold), land use laws face similar “non-static,” “massive, complex, overwhelming environmental and societal problems” that led to the consideration of adaptive tools.<sup>220</sup> As mentioned earlier, comprehensive plans, for example, often project ten or more years into the future and many zoning

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trade-off of adaptability with stability, and conservation of natural resources.”); Chaffin et al., *supra* note 122, at 59.

215. See *Environmental Law, Episode IV*, *supra* note 1, at 14 (“Systemic complexity, dynamics, uncertainty, and limits create the need for adaptive capacity in environmental law for social-ecological resilience. . . . Future conditions are uncertain; the idea that environmental or resource systems operate within a fixed range of historically observable parameters (‘stationarity’) is no longer a valid assumption on which to base management or governance decisions.”); Arnold, *supra* note 123, at 261; Chaffin et al., *supra* note 122, at 56.

216. Benson, *supra* note 94, at 116. See also Chaffin et al., *supra* note 122, at 56 (“AG is unanimously viewed as a system of environmental governance with the potential to mediate the complexity and uncertainty inherent in [social-ecological systems]. AG can be thought of simply as the social conditions that enable ecosystem management through the implementation of adaptive management.”); Arnold, *supra* note 62, at 431 (“Adaptive management is accepted today as the preferred method of ecosystem management, particularly by scholars and resource managers.”).

217. See Chaffin et al., *supra* note 122, at 56.

218. Craig Anthony (Tony) Arnold, *Fourth-Generation Environmental Law: Integrationist and Multimodal*, 35 WM. & MARY ENVTL. L. & POL’Y REV. 771 (2011); see also Craig Anthony (Tony) Arnold & Lance H. Gunderson, *Adaptive Law and Resilience*, 43 ENVTL. L. REP. 10,426 (2013). For a summary of the generations, see *Environmental Law, Episode IV* *supra* note 1, at 5–9.

219. *Environmental Law, Episode IV*, *supra* note 1, at 3.

220. *Id.* at 4.

and building codes are decades old.<sup>221</sup> They “are based on: (1) a set of unjustified assumptions about relatively stable conditions; (2) inaccurate models of predictable linear patterns of change in both nature and society; and (3) misplaced faith in the cognitive, predictive, and performance capacities of humans and ecosystem management organizations.”<sup>222</sup>

AG is needed in land use laws not only because the laws themselves are static, but also because the laws result in a rigid landscape that is also not prepared for changes. Gray infrastructure faces those same problems, but in a much more physical manner. Gray infrastructure does not accommodate changes, nor does it typically adapt. Rather, it resists at a pre-determined level. If that level is breached or if the circumstances change such that the infrastructure is directed at resisting the wrong disturbance, public services are at risk.

AG is particularly applicable to laws impacting infrastructure because there is a close physical connection between infrastructure and ecosystems. Infrastructure is often designed to physically control ecosystems, such as in the provision of potable water or stormwater management. As discussed above, these ecosystems can change in uncertain ways. The uncertainty and importance of ecosystems make incorporation of AG into land use laws critical because the more ecosystems change, the more the infrastructure will be impacted. AG can help recognize these changes as they occur.

AG is also helpful because local governments can struggle with the ability to “grasp, know, model, and plan rationally and comprehensively” relative to ecosystem services.<sup>223</sup> Land use laws rarely have a requirement for monitoring or updating infrastructure. Incorporating AG into land use laws can help communities obtain information necessary to determine whether and how infrastructure is being affected by changes. AG fills a critical gap in land use policy-making by instituting a process focused on the constant flow of information and on providing an outlet to incorporate that information into decision-making.

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221. See, e.g., Costonis, *supra*, note 173, at 349 (“Louisiana’s land use governance system [was] largely the same [immediately before and after the storm] as when its governing statutes were adopted some seventy years ago.”).

222. Arnold, *supra* note 62, at 434 (citing adaptive management critiques of conventional planning, John Friedmann, *A Conceptual Model for the Analysis of Planning Behavior*, 12 ADMIN. SCI. Q. 225, 225–26 (1967); J.B. Ruhl, *Taming the Suburban Amoeba in the Ecosystem Age: Some Do’s and Don’ts*, 3 WIDENER L. SYMP. J. 61, 70–78 (1998); Paramjit S. Sachdeva, *Development Planning—An Adaptive Approach*, LONG RANGE PLAN. 96, 96 (1984)).

223. Arnold, *supra* note 62, at 433.

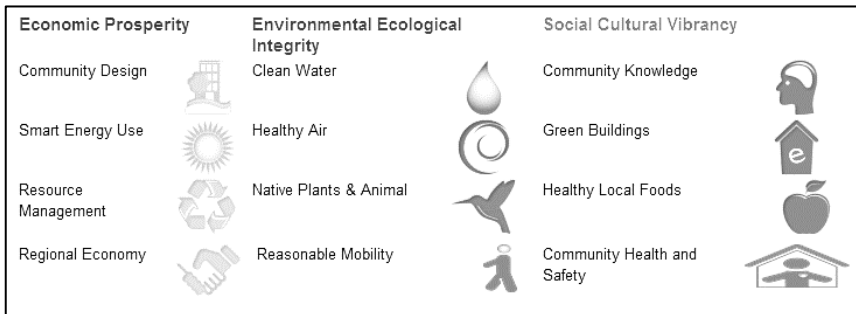
### C. *Ecosystem Services Management and Adaptive Governance in Land Use*

Few local governments have systematically and aggressively integrated ESM and AG into land use laws, and even fewer have done so for land use laws pertaining to infrastructure constructed by private parties. Part of the challenge local officials face is that there are many provisions in many land use codes affecting infrastructure on private properties. Local officials struggle not only with how to integrate these concepts, but also with where in the code to do so.<sup>224</sup>

Nonetheless, some local governments have taken steps. The primary example below is from Dubuque, Iowa and provides a good illustration of ESM and AG as drafted into law and policy and the infrastructure that can stem from such a policy. Integrated throughout the discussion of Dubuque are additional examples.

In 2012, Dubuque, Iowa began tracking its performance relative to resilience. The city selected twelve principles, grouped as shown in Figure 10 below, including clean water, green buildings, and smart energy use—all raising critical infrastructure and ecosystem issues on private property.<sup>225</sup>

**Figure 10:**  
**Twelve Resilience Principles, Dubuque, Iowa**



For the twelve principles, the city identified sixty metrics, many of which measure ecosystem changes and not solely gray infrastructure capacity (such as done by Sunrise, Florida and other cities mentioned in

224. In addition, there are political and financial, technological, human, and other resource challenges facing local governments. *Id.* at 479.

225. *12 Sustainability Principles*, SUSTAINABLE DUBUQUE, [http://www.sustainabledubuque.org/en/about\\_us/12\\_sustainability\\_principles/](http://www.sustainabledubuque.org/en/about_us/12_sustainability_principles/) [<https://perma.cc/Z4ZF-FQ89>].

Part III above).<sup>226</sup> For example, to assess its progress on “Clean Water,” Dubuque monitors: *bacterial concentration* (highest assessed average Escherichia coli (E. coli) concentration within Dubuque), *impaired stream segments* (miles of impaired streams as a percent of EPA assessed miles within the county); *chloride concentration* (highest average chloride concentration in city surface waters (mg/L)); *drinking water contamination* (number of EPA health based, public drinking water violations from local ground or surface water sources); and *wastewater discharged* (gallons of wastewater discharged from sanitary sewer overflows).<sup>227</sup>

For each metric, the city provides the method of measurement and time required to obtain the measurement.<sup>228</sup> Each metric provides key information to help the city ascertain whether infrastructure is performing and whether changes are occurring. For example, Figure 11 below provides a snapshot of the information the city gleaned from its measure of “[i]mpaired stream segments.”<sup>229</sup> The snapshot notes, among other things, that:

In 2006, just over 60% of the county’s assessed stream miles were listed as impaired by the U.S. EPA. By 2008, 74.2% of the assessed stream miles were impaired, an increase of 15%. There was a slight increase in the percent of stream miles impaired in 2010, as nearly 77% were classified as impaired.<sup>230</sup>

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226. For the sixty metrics, see UNIV. OF IOWA SCH. OF URBAN & REG’L PLANNING, SUSTAINABILITY PROGRESS REPORT 2012, at 5–75, [http://www.sustainableubuque.org/documents/filelibrary/documents/Final\\_Report\\_with\\_Appendices\\_29E33A454A218.pdf](http://www.sustainableubuque.org/documents/filelibrary/documents/Final_Report_with_Appendices_29E33A454A218.pdf) [<https://perma.cc/7789-8FWJ>].

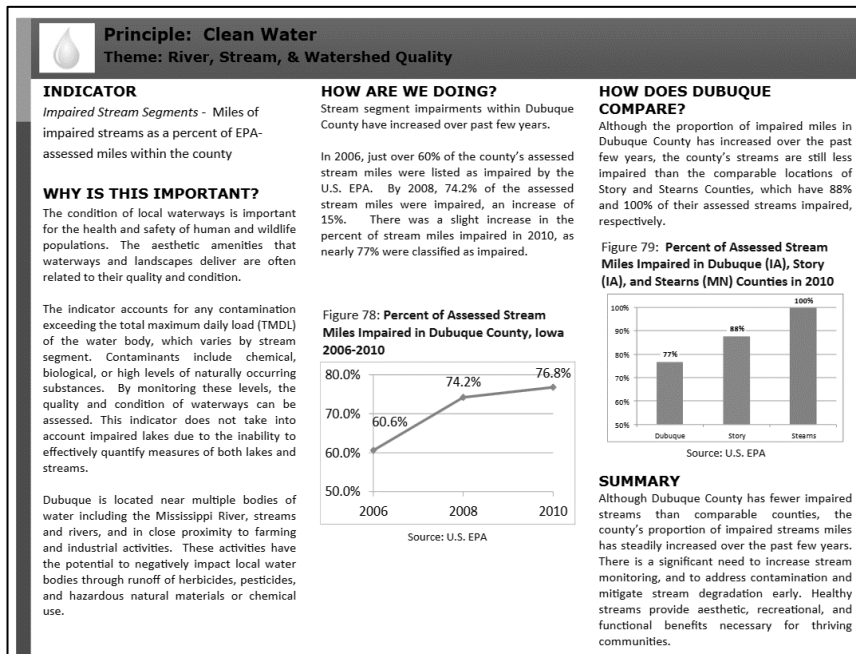
227. *Id.* at app. a.

228. *Id.* at 59–75.

229. *Id.* at 67.

230. *Id.*

**Figure 11:**  
**Snapshot of Dubuque Water Quality Measure**



By identifying key metrics, tracking those metrics, and evaluating changes, Dubuque incorporates several AG and ESM steps into land use planning and infrastructure. The metrics help the city determine what changes are occurring and whether the city is meeting its resilience goals, particularly as those goals relate to infrastructure and ecosystem services. In the snapshot above, for example, the city is measuring the health of the ecosystem relative to water quality. As the city states:

Proper monitoring is necessary to adequately determine whether the current infrastructure can continue to sustain the population and whether upgrades are needed, or other management practice must be taken, in order to ensure that the health and safety of the community is preserved.<sup>231</sup>

Similar comments pertaining to infrastructure appear throughout the city's analysis.<sup>232</sup> For example, "[w]astewater discharged" tracks the

231. *Id.* at 70.

232. *See, e.g., id.* at 20 ("The underlying issue of water scarcity is not the only reason why water consumption should be monitored; infrastructure age, function, and capacity of water systems are other important considerations. . . . Measuring the total residential water consumption is essential for

amount of wastewater contamination stemming from sewer overflows, which “can be the result of undersized sewer systems, pipe failures, and deteriorating systems,” noting not only the importance of changes in the ecosystem, but also how those changes are impacting infrastructure.<sup>233</sup>

The City of Los Angeles also adopted an aggressive tracking system, called “pLAn,” that incorporates a complex set of baselines, metrics, and action steps that integrate AG and ESM.<sup>234</sup> Similar to Dubuque, Los Angeles identifies key principles (fourteen), including urban ecosystems.<sup>235</sup> For each principle, the pLAn measures a mixture of complex and diverse aspects of social-ecological systems (thirty-six in total).<sup>236</sup> For each metric, the city set a baseline goal for what it hopes to achieve for that metric by 2017, 2025, and 2035 and a strategy to achieve its goal.<sup>237</sup>

The city’s vision for “local water,” for example, is to “lead the nation in water conservation and source the majority of our water locally.”<sup>238</sup> It plans to achieve its vision for local water by reducing its per capita water use by 20% by 2017, reducing its purchase of imported water by 50% by 2025, and sourcing 50% of water locally by 2035.<sup>239</sup>

Other pLAn metrics that impact ecosystems and depend on infrastructure include: sewer spills, water quality, solar capacity, transit-oriented new housing, average daily vehicle miles traveled per capita, air pollution, food access, and percentage of residents within half a mile of a park.<sup>240</sup> By tracking ecosystems, the pLAn incorporates parts of AG and ESM to facilitate a better understanding of its infrastructure system.

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Dubuque so that it can gauge the impact it is having on city infrastructure . . .”); *id.* at 32 (“Additionally, compact development utilizes existing infrastructure, such as roads and water mains, and is thus more cost effective and fiscally sustainable.”); *id.* at 70 (“Inflow involves water flowing into the system through direct channels, and infiltration is through cracks or leaks in the infrastructure.”).

233. *Id.* at 70.

234. CITY OF LOS ANGELES, pLAN: TRANSFORMING LOS ANGELES 8, <https://d3n8a8pro7vhmx.cloudfront.net/mayorofla/pages/17002/attachments/original/1428470093/pLAn.pdf?1428470093> [<https://perma.cc/3XMW-ZJE6>].

235. *Id.* at 9. As noted in the introduction: “[t]o ensure our bright future, we must protect what makes our city great: our incredible natural environment, our diverse economy, and the people that make our city thrive.” *Id.*

236. *Id.* (the measures are dispersed throughout the pLAn and are listed by section).

237. *See id.* On its website, <http://plan.lamayor.org/>, the city provides up-to-date data that helps inform whether the city is meeting its designated goals.

238. *Id.* at 17.

239. *Id.*

240. *Id.* at 4 (quoting Mayor Garcetti: “[w]e expect at least 500,000 more people to call Los Angeles home by 2035. So the question before us, like it was to those Angelinos of the past, is how

After identifying, tracking, and evaluating metrics, cities like Dubuque continue the AG process by basing subsequent policies on the information to adapt infrastructure to changing circumstances. For example, partially based on the water-testing data above that noted an increase in impaired streams, Dubuque replaced 240 alleys with permeable pavement. The new surface takes advantage of ecosystems' natural filtration and capture, which reduced stormwater runoff by 80% in these areas.<sup>241</sup>

Other local governments have also taken advantage of ESM to help build a more resilient infrastructure system. Infrastructure that stems from the incorporation of ESM in land use codes is often called Low Impact Development (LID) or Green Infrastructure (GI), as opposed to gray.<sup>242</sup> LID and GI have been incorporated in a number of land use areas relevant to infrastructure, but most commonly in stormwater management. In stormwater management, pipes, concrete, and other gray infrastructure is replaced with green roofs, trees, rain gardens, permeable pavement, bioretention and infiltration, and water harvesting.<sup>243</sup> These practices provide a number of benefits, including “reduce[d] urban temperatures and energy demands, carbon sequestration and other air quality improvements, reduce[d] flooding, and other community benefits such as improved aesthetics, local job creation, improved recreational and wildlife areas, and improved human health.”<sup>244</sup>

Incorporating GI and LID into land use laws can take a number of forms and can be located in a number of places throughout land use codes, including comprehensive plans, site plan reviews, tree ordinances, and

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can we improve our city today, and ensure future generations enjoy a place that is environmentally healthy, economically prosperous, and equitable in opportunity for all?”).

241. See also Vock, *supra* note 150 (describing Philadelphia's *Green Cities, Clean Waters* program, in which the city completed 124 green street projects since 2011, allowing much stormwater to stay out of the gray infrastructure system); *Permeable Pavers “Best Bang for the Buck” in Green Alley Reconstruction*, CTY. MATERIALS CORP., [https://www.countymaterials.com/en/news/item/permeable-pavers-best-bang-for-the-buck-in-green-alley-reconstruction?category\\_id=36](https://www.countymaterials.com/en/news/item/permeable-pavers-best-bang-for-the-buck-in-green-alley-reconstruction?category_id=36) [<https://perma.cc/DU7Y-8F8A>].

242. See Amena H. Saiyid, *Cities, Towns Writing New Water Permits Under EPA Direction*, BNA.COM, July 10, 2017 (GI “is an engineering approach that is designed to mimic nature by capturing stormwater through strategically planted shrubs and permeable pavements, reducing the flow of stormwater”).

243. CTR. FOR NEIGHBORHOOD TECH. & AM. RIVERS, *THE VALUE OF GREEN INFRASTRUCTURE 3* (2010), [http://www.cnt.org/sites/default/files/publications/CNT\\_Value-of-Green-Infrastructure.pdf](http://www.cnt.org/sites/default/files/publications/CNT_Value-of-Green-Infrastructure.pdf) [<https://perma.cc/W9F6-H7BF>]; see also Karen M. Hansen, *Green Infrastructure and the Law*, 65 PLAN. & ENVTL. L., August 2013, at 4.

244. Hansen, *supra* note 243, at 4; see also CTR. FOR NEIGHBORHOOD TECH. & AM. RIVERS, *supra* note 243, at 7.



parking/private street requirements.<sup>245</sup> A common example of GI/LID is the integration of “green roofs” into development codes. A “green roof” is a roof that is used to grow plant life.<sup>246</sup> The vegetation can be anything including grasses, wildflowers, or agricultural products.<sup>247</sup> To increase the energy reduction and stormwater management benefits, plant life should typically cover as much of the surface area of the roof as possible.<sup>248</sup> Additional GI tools include those set forth below in Figure 12:

**Figure 12:**  
**Five Green Infrastructure Options and Their Associated Benefits<sup>249</sup>**

Benefit	Reduces Stormwater Runoff					Improves Community Livability												
	Reduces Water Treatment Needs	Improves Water Quality	Reduces Grey Infrastructure Needs	Reduces Flooding	Increases Available Water Supply	Increases Groundwater Recharge	Reduces Salt Use	Reduces Energy Use	Improves Air Quality	Reduces Atmospheric CO <sub>2</sub>	Reduces Urban Heat Island	Improves Aesthetics	Increases Recreational Opportunity	Reduces Noise Pollution	Improves Community Cohesion	Urban Agriculture	Improves Habitat	Cultivates Public Education Opportunities
Practice																		
Green Roofs	●	●	●	●	○	○	○	●	●	●	●	●	●	●	●	●	●	●
Tree Planting	●	●	●	●	○	○	○	●	●	●	●	●	●	●	●	●	●	●
Bioretention & Infiltration	●	●	●	●	○	○	○	●	●	●	●	●	●	●	○	○	●	●
Permeable Pavement	●	●	●	●	○	○	○	●	●	○	○	○	○	○	○	○	○	○
Water Harvesting	●	●	●	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○

Yes     
  Maybe     
  No

Integrating ecosystem management into land use codes to address the rigidity of gray infrastructure helps create more dynamic and flexible infrastructure systems that are more flexible and better prepared for the

245. See, e.g., MONROE COUNTY COMPREHENSIVE PLAN, *supra* note 115, at 66, 68 (“Adopt and support funding for a green infrastructure component of a public facilities standard that includes, at a minimum, low impact development and design elements; . . . Avoid future conflict with Vulnerable Land and natural features as the expansion of future infrastructure occurs . . .”).

246. DAVID JOHNSTON & KIM MASTER, GREEN REMODELING: CHANGING THE WORLD ONE ROOM AT A TIME 212–13 (2004); Emily W. O’Keefe et al., *Raise the Roof: Green Roofing Options Offer Lower Energy Costs and Better Aesthetics*, 2008 J. PROP. MGMT. 64, 64; *Soak Up the Rain: Green Roofs*, U.S. ENVTL. PROT. AGENCY, <https://www.epa.gov/soakuptherain/soak-rain-green-roofs> [<https://perma.cc/36HM-Q3K5>].

247. JOHNSTON & MASTER, *supra* note 246, at 213; Dyanna Innes Smith, *Green Roofing*, in GREEN TECHNOLOGY: AN A-TO-Z GUIDE 230, 231–32 (Dustin Mulvaney ed., 2011).

248. O’Keefe et al., *supra* note 246, at 64.

249. CTR. FOR NEIGHBORHOOD TECH. & AM. RIVERS, *supra* note 243, at 3.

future. For example, Keith Hirokawa explains the benefits of incorporating an ESM and AG approach into local tree regulations:

[U]rban forests provide ecosystem services as they “aid in stabilizing the environment’s ecological balance by contributing to the processes of air purification, oxygen regeneration, groundwater recharge, and stormwater runoff retardation, as well as aiding in noise, glare, and heat abatement.” Local governments can capture these benefits through regulations that facilitate ecosystem management, and can do so in a way that has significant and positive economic consequences. . . .<sup>250</sup>

To implement urban forest planning, local governments regulate beyond individual trees or structural stability, with an eye on supporting the program by improving baseline information from inventory and monitoring, coordination among agencies, collaboration among landowner types, and dissemination of information about tree benefits and tree care. . . .<sup>251</sup>

[I]n 1999, American Forests . . . concluded that Seattle lost approximately 46% of its dense tree cover and 67% of its medium tree cover in the years between 1972 and 1996. It was estimated that this loss in canopy amounted to approximately \$1.3 million annually in stormwater control and \$226,000 in healthcare costs related to air pollution. Based on an analysis of tree services and a projection of benefits, Seattle estimated that an increase in canopy coverage from 18% to 36% would more than double the environmental and economic benefits accruing to Seattle residents. . . . [T]he city adopted a canopy cover goal of 30% by 2037. Importantly, this aggressive goal was informed by an inventory of planting and canopy coverage . . . .<sup>252</sup>

Section III set out several examples of stormwater management guidelines requiring gray infrastructure on private developments. Several cities, however, are also incorporating ESM into their stormwater management guidelines. Riverton, Utah provides such an example:

### **2.16 Low Impact Development (LID):**

A. Commercial development must include a LID analysis that meets the objective of mirroring the predevelopment hydrology . . . . No LID limits are defined except designs must not negatively impact surrounding properties. Analysis must include at least one LID and list the reasons why it will be incorporated or why the considered LIDs are not practical for the

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250. Hirokawa, *supra* note 185, at 804–05.

251. *Id.* at 806.

252. *Id.* at 791–92.

site use or conditions. The Stormwater Utility Fee is directly proportional to impervious area and is reduced by minimizing the impervious area. Also the Stormwater Utility Fee can be further reduced up to 45% for sites that retain all runoff. . . .

F. Suggested LIDs:

- 1) Reduce the amount of impervious area.
- 2) Reduce the amount of surface that drains to Right of Way . . . .
- 3) Connect roof drains to landscaping.
- 4) Slope dumpster enclosure pads towards landscaping.
- 5) Minimize concentrating runoff. Distribute runoff to multiple sumps or direct runoff to wide open fields facilitating infiltration and evaporation and minimizing the depth of standing water.<sup>253</sup>

Even energy infrastructure relevant to production, which traditionally was not considered part of private developers' infrastructure obligations, is beginning to play a role in land use codes. Lancaster, Sebastopol and San Francisco, California and other cities are establishing criteria such as renewable or distributive energy standards that must be satisfied as part of the site review process.<sup>254</sup> The Sebastopol ordinance, for example, requires all new and large retrofits to residential and commercial buildings to install solar power before a certificate of occupancy is issued.<sup>255</sup> Similarly, Lancaster's ordinance requires new homes to be outfitted with solar energy systems that can produce two watts of power for every square

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253. STORMWATER DIV., RIVERTON CITY, UTAH, STORMWATER DESIGN STANDARDS AND REGULATIONS 2.16, <http://www.rivertoncity.com/departments/Stormwater%20Design%20Standards%20and%20Regulations.pdf> [<https://perma.cc/DGY3-D26K>]. Relatedly, at Drake we have drafted fifteen model local ordinances relevant to stormwater management, economic development, waste management and energy, designed to enhance resilience. For each ordinance we provide an abstract, the ordinance, and a summary of cost/benefit research. One of those ordinances is a parking maximum ordinance that sets a maximum parking lot size and allows for increased lot sizes when the developer embraces an ecosystems management approach.

254. *See, e.g.*, LANCASTER, CAL., ENERGY CODE § 15.28.020 (2018), [https://library.municode.com/ca/lancaster/codes/code\\_of\\_ordinances?nodeId=TIT15BUCO\\_CH15.28ENCO\\_15.28.020IMSOENSY](https://library.municode.com/ca/lancaster/codes/code_of_ordinances?nodeId=TIT15BUCO_CH15.28ENCO_15.28.020IMSOENSY) [<https://perma.cc/K2QZ-L8XN>]; SAN FRANCISCO, CAL., GREEN BUILDING CODE § 4.201.2 (2016), [http://library.amllegal.com/nxt/gateway.dll/California/sfbuilding/greenbuildingcode2016edit ion/chapter4residentialmandatorymeasurements?f=templates\\$fn=default.htm\\$3.0](http://library.amllegal.com/nxt/gateway.dll/California/sfbuilding/greenbuildingcode2016edit ion/chapter4residentialmandatorymeasurements?f=templates$fn=default.htm$3.0) [<https://perma.cc/8WD2-ML3B>]; SANTA FE, N.M., MUN. CODE § 7-4.2 (2017), <http://clerkshq.com/default.ashx?client site=Santafe-nm> [<https://perma.cc/N2U3-XBLS>] (requiring that all buildings qualify for a set number of points; projects qualify for points by including any number of green building practices, one of which is including a solar energy system); SEBASTOPOL, CAL., MUN. CODE § 15.72 (2018), <http://www.codepublishing.com/CA/Sebastopol/html/Sebastopol15/Sebastopol1572.html> [<https://perma.cc/7KUR-5ZRH>].

255. SEBASTOPOL, CAL., MUN. CODE § 15.72 (2018), <http://www.codepublishing.com/CA/Sebastopol/html/Sebastopol15/Sebastopol1572.html> [<https://perma.cc/7KUR-5ZRH>].

foot of the home.<sup>256</sup> This requirement can be modified if the builder is able to show that the project requires less than the typical amount of power; likely through energy efficiencies.<sup>257</sup> While some might debate the merits of this program in terms of building distributive energy infrastructure, for these purposes it is important to recognize that the law resides in the land use code and that there are opportunities similar to these to enhance infrastructure resilience.

## CONCLUSION

It is clear we are now facing an uncertain future. Failure to prepare for this uncertainty will continue to stress an already weakened infrastructure system.<sup>258</sup> It is equally clear that many communities are in a precarious position. Their infrastructure is already deteriorated and deteriorating further; and that infrastructure provides critical public services.

Notwithstanding the formidable challenges facing infrastructure and communities, it is vitally important for local governments to protect their citizens from the climate-related threats that are coming. Part of ensuring the creation of resilient communities requires not just devotion, motivation, and funding—all of which are necessary—but also land use regulations that create and foster more resilient systems of infrastructure. While there are a number of approaches and specific provisions where local governments can seek to increase resilience to climate and other changes, this Article focuses on one area that is not often discussed, but is one of the most prevalent and problematic when it comes to resilience—gray infrastructure and stationarity as embedded in land use codes' regulation of infrastructure. Any part of a serious local resilience plan must consider how its land use laws are encouraging vulnerable infrastructure as part of private projects.

In many ways, the time is ripe for local officials, land use lawyers, planners, and communities across the country to strategically adopt a new land use narrative and better protect the health and safety of communities. The need to deal with aging infrastructure provides local governments with the excuse, opportunity, and ideal moment to approach land use planning in a new way. That new way assesses what infrastructure

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256. LANCASTER, CAL., ENERGY CODE § 15.28.020(c)(1) (2018), [https://library.municode.com/ca/lancaster/codes/code\\_of\\_ordinances?nodeId=TIT15BUCO\\_CH15.28ENCO\\_15.28.020IMSOENSY](https://library.municode.com/ca/lancaster/codes/code_of_ordinances?nodeId=TIT15BUCO_CH15.28ENCO_15.28.020IMSOENSY) [<https://perma.cc/K2QZ-L8XN>].

257. *Id.* § 15.28.020(d).

258. See *Learning to Live with the Trickster*, *supra* note 18, at 396 (“Nevertheless, acknowledging the reality of continuous change and the importance of complex system dynamics by adopting a resilience thinking framework provides us with a first step on a path toward coping with, rather than fighting or retreating from, the new reality that is the Anthropocene.”).

remains necessary in more or less its current form, what can be removed and replaced with green infrastructure, and what can be modified to be more adaptive and resilient—a greener shade of gray. By integrating adaptive governance and following up with an ecosystem services solution, local governments can leverage the opportunities in land use law to help recognize system changes and build resilience, and—quite frankly—shake hands with a new and uncertain reality.