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ARUP

THE CITY WATER RESILIENCE APPROACH

CITY CHARACTERISATION REPORT

MIAMI

ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

The City Water Resilience Approach (CWRA) helps cities plan and implement actions to build resilient urban water systems. A critical first step in this process is understanding the local water system, and the factors that contribute to or detract from resilience.

This report details research undertaken in Miami with the goals to:

1. Define the city water basin including natural basin(s), the urban water system and its governance structure, and the interdependencies with other systems
2. Identify the factors contributing to the resilience of the city water system and those increasing its vulnerability

In developing this characterisation report, the team collected desktop data on the biophysical characteristics of the basin and key actors in the water system. Arup then undertook a field mission in Miami 7 –18 May 2018 to build on the desktop work by engaging in-person with stakeholders.

MIAMI'S WATER SYSTEM

Miami-Dade County (MDC) is the south-eastern-most county on the U.S. mainland. With a population of 2.7 million people, MDC is the seventh most populous county in the United States. Miami-Dade County lies close to sea level therefore, major rain events sometimes leave rainwater nowhere to drain, causing occasional flooding in some areas of the County.

Currently, the sole water supply for the entire MDC is groundwater, which is abstracted through wells from the surficial Biscayne Aquifer. Three principal treatment works manage sewage, which is discharged through two marine outfalls in Biscayne Bay as well as through deep injection wells into the boulder zone geology. Surface water in the region is managed through the primary canal system constructed through the Central & Southern Florida (C&SF) Project by the U.S. Army Corps of Engineers after major flooding in the 1940s.

KEY STAKEHOLDERS

The State of Florida's Department of Environmental Protection (DEP), Division of Water Resource Management (DWRM) enforces state laws to uphold its water resource quality. The Miami-Dade Water and Sewer Department (WASD), provides the direct service to customers throughout the county. WASD have also taken a leadership role in founding the Resilient Utility Coalition (RUC). This provides leadership in assessing and adapting utility operations and strategies, and improving water management decision-making in the face of climate uncertainty. South Florida Water Management District (SFWMD) is responsible for managing and protecting water resources of South Florida. There are a number of other stakeholders that are responsible for the environment and risk management of Miami's water system.

SHOCKS AND STRESSES

The key interdependencies between the water system and city systems in Miami are Water and Sanitation, Energy, Environment and Economy systems. The critical interdependency being between the water systems themselves, due to the lack of boundary between the systems.

Fieldwork conversations noted how, fundamentally, the MDC water system is one that operates on extremely low tolerances, therefore a buffer capacity is limited which would otherwise contribute to the resilience of the system. A major challenge is the uncertainty around how future shocks and stresses will play out (i.e. sea level rise, changing rainfall patterns, urban activities) and how these shocks/stresses will impact the seamlessly interconnected water systems within Miami-Dade. When analysing these current vulnerabilities and understanding future risks scenarios for Miami, a wide range of shocks and stresses were identified to be impacting on Miami including coastal and surface flooding, ecosystem degradation, drought and hurricanes. These, coupled with ageing infrastructure, high unemployment rates and poor housing all inhibit the resilience.

BUILDING RESILIENCE

Through engagement with Miami's stakeholders, it was identified that good data management, consistent guidelines and codes, emergency preparedness, robust funding, integrated management, land management, community engagement and communications and lobbying would all positively contribute to the resilience of the Miami's urban water system.

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BACKGROUND

Miami-Dade County (MDC) is the south-eastern-most county on the U.S. mainland. The county is home to 36 incorporated cities (including City of Miami and City of Miami Beach) and many unincorporated areas. The western portion of the county extends into the Everglades National Park. East of the mainland in Biscayne Bay is also Biscayne National Park and the Biscayne Bay Aquatic Preserves. Miami-Dade County lies close to sea level and its underground water supply is just below the ground surface. Therefore, major rain events sometimes leave rainwater nowhere to drain, causing occasional flooding in some areas of the County (Flood Protection, 2017). Miami-Dade County, the City of Miami, and the City of Miami Beach have formed the Resilient Greater Miami and the Beaches collaboration within the 100 Resilient Cities (100 RC) network.

Miami Beach, Florida

POPULATION

With a population of 2.7 million people, MDC is the seventh-most populous county in the United States. In 2010, 51.1% of the county's population was foreign born. The principal ethnic groups are Latino or Hispanic (65%), white (non-Hispanic) (15%), and black (non-Hispanic) (17%). (Wikipedia, n.d.)

Because Miami-Dade County is located in a unique geographical area, it is particularly susceptible to flooding from major rain events and storm surge. The County is surrounded by major water bodies such as the Atlantic Ocean, Biscayne Bay, and many rivers, lakes and canals. (Flood Protection, 2017).

Since 1870, Southeast Florida, sea level has risen by about 8 inches. Florida is the most vulnerable state to sea-level rise in the United States and Miami has the fourth largest population vulnerable to sea-level rise in the world. (Deconcini, 2014)

MDC takes pride in its innovation and growth in the education sector. 80.6% percent of the population over the age of 25 years are high school graduates or have a higher degree of education (Bureau, 2017). In 2012, Miami-Dade County made an investment in a technology start-up and has relocated more than 20 start-ups from all over the globe to their community. It is helping to position Miami-Dade as the next great tech hub. (Gimenez, 2014)

In partnership with the City of Miami and City of Miami Beach, MDC is currently working to create a tactical roadmap that expresses its community's resilience priorities and outlines specific initiatives for implementation (County, 2018)

ECONOMY

The northern, central and eastern portions of MDC are heavily urbanized with many high rises up the coastline, plus the location of South Florida's central business district Downtown Miami. Miami-Dade County's economy is led by its two largest economic engines: Miami International Airport and Port Miami. The county's Gross Regional Product (GRP) grew 2.7% from 2014 to $142 billion USD. (County, 2016 Gross Regional Product & Productivity, 2017)

Port Miami is the county's second largest economic engine, contributing approximately $27 billion and supporting more than 207,000 jobs in South Florida.

Southern Miami-Dade County includes the Redland and Homestead areas, which make up the agricultural economy of Miami. Miami-Dade County's Agricultural industry is one of the most diverse in the country. The tropical climate provides a year-round growing season, as well as the ability to produce an extremely wide range of crops and employs more than 20,000 people and producing more than $2.7 billion in economic impact each year.

Tourism to Miami-Dade County is at record highs. From September 2017 to August 2018, there were 16 million overnight visitors. That represents a 1 percent increase, year-over-year. These visitors spent $26.5 billion in Miami-Dade County. Their expenditures were up 2 percent, year-over-year, according to the bureau. (Lewis, 2018)

According to the OECD, Miami-Dade County is the most vulnerable urban area in the world to coastal flooding with over an estimated $416 billion of assets at risk. (OECD, 2014)

As stated in a recent study by Florida Atlantic University, up to 70% of the drainage capacity of the 28 coastal flood/salinity control structures protecting Southeast Florida from flooding and saltwater intrusion could be lost with sea level rise of only 3 to 9 inches, anticipated by about 2030 to 2050. Adaptation may require the addition of high capacity pumping stations costing approximately $70 million each (plus necessary land acquisitions). Three pumping stations costing a total of over $200 million (plus land) could be needed in north Miami-Dade County in the near future. (Deconcini, 2014)

For MDC, it is crucial to plan long term to be resilient to climate change such abrupt increases in sea level and to maintain the economic benefits in tourism, agricultural and expensive assets. across the County and building artificial reefs to support tourism and fishing industries, and keep its ecosystems healthy. (Green, 2018)

The U.S. federal government works within MDC. For example, like the rest of the country, MDC is protected by the Environmental Protection Agency's (EPA) Clean Water Act and Safe Drinking Water Act. The Department of Defense's United States Army Corps of Engineers (USACE) designed and constructed the Central and South Florida Project (C&SF Project), the primary canal system.

State-level responsibilities include state laws for the protection of the quality of Florida's drinking water, groundwater, wetlands, estuaries, lakes, and rivers.

Miami-Dade County provides water and wastewater services to the 35 municipalities within MDC as well as the thirteen districts that make up the unincorporated areas. Miami-Dade County Department of Regulatory and Economic Resources includes an Office of Resilience.

GOVERNANCE

Miami-Dade County has operated under a unique metropolitan system of government, a "two-tier federation", since 1957. Unlike a consolidated city-county, where the city and county governments merge into a single entity, these two entities remain separate. Instead there are two "tiers", or levels, of government: city and county. There are 34 municipalities in the county, the City of Miami being the largest. (Wikipedia, n.d.)

Miami-Dade County is pursuing many initiatives and programs for a more ecologically, economically and socially sensitive approach to local government and the global environment as a whole. Miami-Dade County has been a leader in environmental initiatives for many years. It has made progress that includes departmental efforts such as establishing Home Chemical Collection and Trash and Recycling Centers

The municipalities have their own mayoral government structures.

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RESEARCH METHODOLOGY

Engagement with Greater Miami and the Beaches (GM&B) was carried out over three stages:

STAGE 1	The first step was desktop data collection on the biophysical characteristics of the basin and identification of key water governance actors. Data and information on the city's basin(s) and governance was collected and a spatial map of the city's basin and a stakeholder map produced.
STAGE 2	Arup's fieldwork in Miami-Dade County focused on a better understanding of the local water systems, their limits, interdependencies, and the stakeholders involved in various water governance processes. Fieldwork activities included: - Environment and Ecosystems Focus Group Discussion - Water Management Focus Group Discussion (co-hosted with the Resilient GM&B Living With Water workshop) - Business & Insurance Focus Group Discussion - Emergency Response & Planning Focus Group Discussion (co-hosted with the Resilient GM&B Robust Recovery Workshop) - Urban Planning Focus Group Discussion - Energy Focus Group Discussion - Resilience Assessment Workshop - Governance of Resilient Water Systems Workshop
STAGE 3	This report was created by combining the desktop study and the fieldwork results to provide a clear picture of the city's basin, its key stakeholders, its shocks and stresses, and its factors of resilience.

Engagement with 'Wave 1' cities included a two week field mission, where workshops, focus groups and interviews were conducted.

Engagement with 'Wave 2' cities included remote support to city partners where surveys and interviews were conducted.

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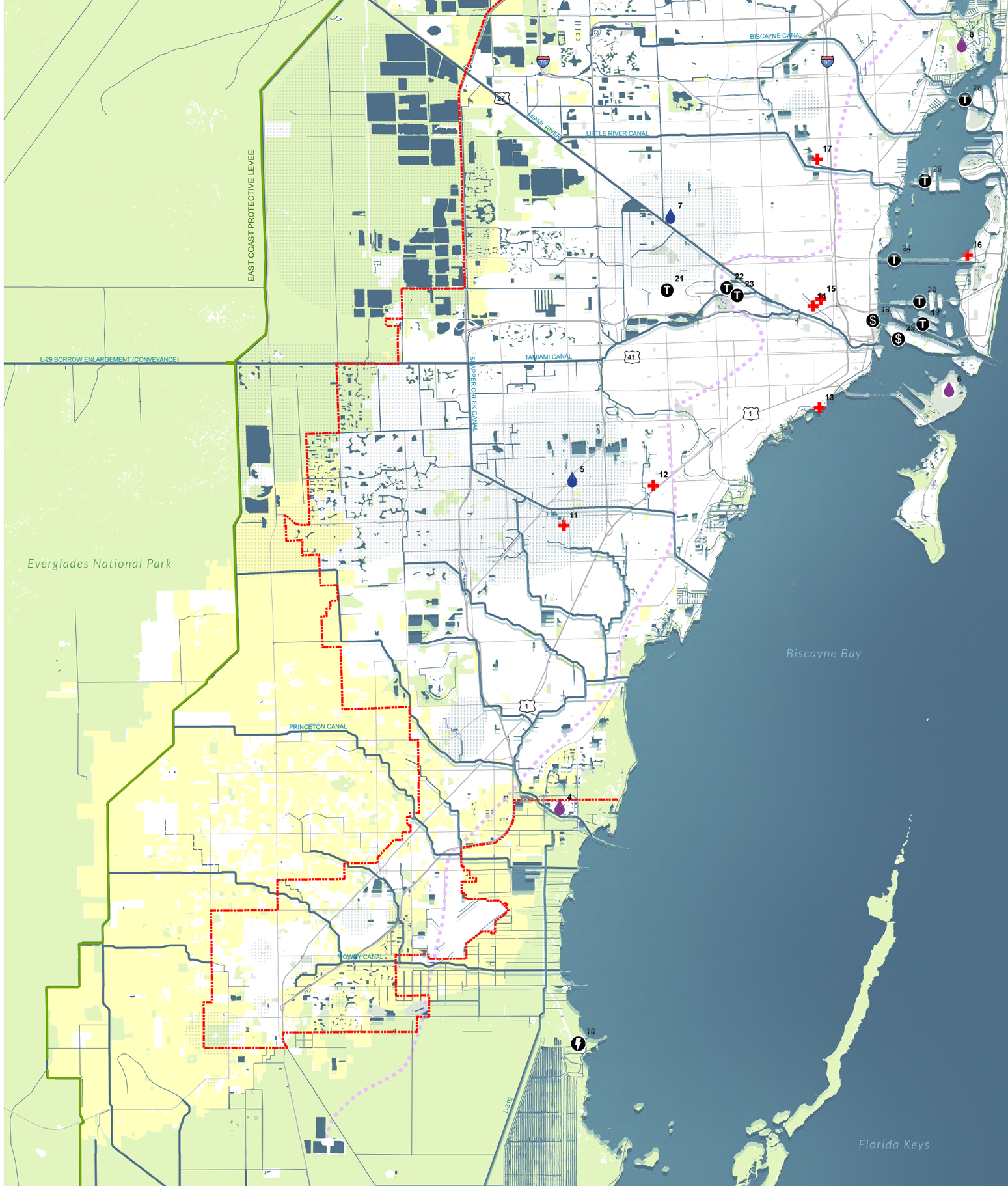
UNDERSTANDING MIAMI'S WATER SYSTEM

The hydrological basin which includes Miami-Dade County originates in Lake Okeechobee in the north and extends all the way to the southern coast where it discharges into the Everglades National Park and Biscayne Bay, incorporating the Biscayne National Park. The basin is extremely flat with only about 3 meters (m) of elevation drop over the approximate 100 miles between Lake Okeechobee and the coast.

The hydrogeology of the basin is defined by the extremely porous limestone that forms the Biscayne Aquifer and that lies only a few feet below ground level. Due to the sandy soils and extremely porous geology, the surface water, groundwater, and coastal water systems are essentially unconfined and entirely interconnected—both in terms of quantity and quality of water.



Greater Miami and the Beaches water basin map

WATER SUPPLY

Currently the sole water supply for the entire MDC is groundwater, which is abstracted through wells from the surficial Biscayne Aquifer. Water supply in MDC is permitted through the Lower East Coast (LEC) water supply plan, which is updated every five years.

WASTEWATER

Three principal treatment works manage sewage, which is discharged through two marine outfalls in Biscayne Bay as well as through deep injection wells into the boulder zone geology. New regulations require Miami to stop using marine outfalls and to recycle 60% of the wastewater previously discharged into the ocean by 2025. (Koopman, et al., 2006) Large areas of the urban

SURFACE WATER MANAGEMENT

Surface water in the region is managed through the primary canal system constructed through the C&SF Project by the U.S. Army Corps of Engineers after major flooding in the 1940's. The C&SF Project continues to play a critical role in capturing wet season stormwater, moving water between natural systems, and delivering water to agricultural areas and the urbanised coastal communities.

Case study

Resilient Utilities Coalition

The Resilient Utility Coalition (RUC) provides leadership in assessing and adapting utility operations to address any potential disruption. The term 'resilience' as defined by the U.S. government, refers to the ability to adapt to changing conditions and withstand, and rapidly recover from, disruption due to emergencies. RUC seeks to enhance the usefulness of climate science as well as other sciences by developing adaptation strategies and improving water management decision-making in the face of uncertainty. (Resilient Utilities Coalition, n.d.)

RUC has five primary objectives.

- Benchmarking—Develop regional guidelines and best practices manuals for utilities' information sharing and implement a sharing platform with databases, contacts, guidelines, and other information.
- Data Management—Offer data analytics and coordinated software platforms for utilities.
- Foster Innovation—Promote partnerships with universities for research and development, technology committees, and internships.
- Emergency Preparedness—Formulate tools for regional integration.
- Partnerships and Community Outreach—Develop key partnerships with stakeholders and encourage community involvement.

Basin map of Miami Dade County (South Florida WMD)

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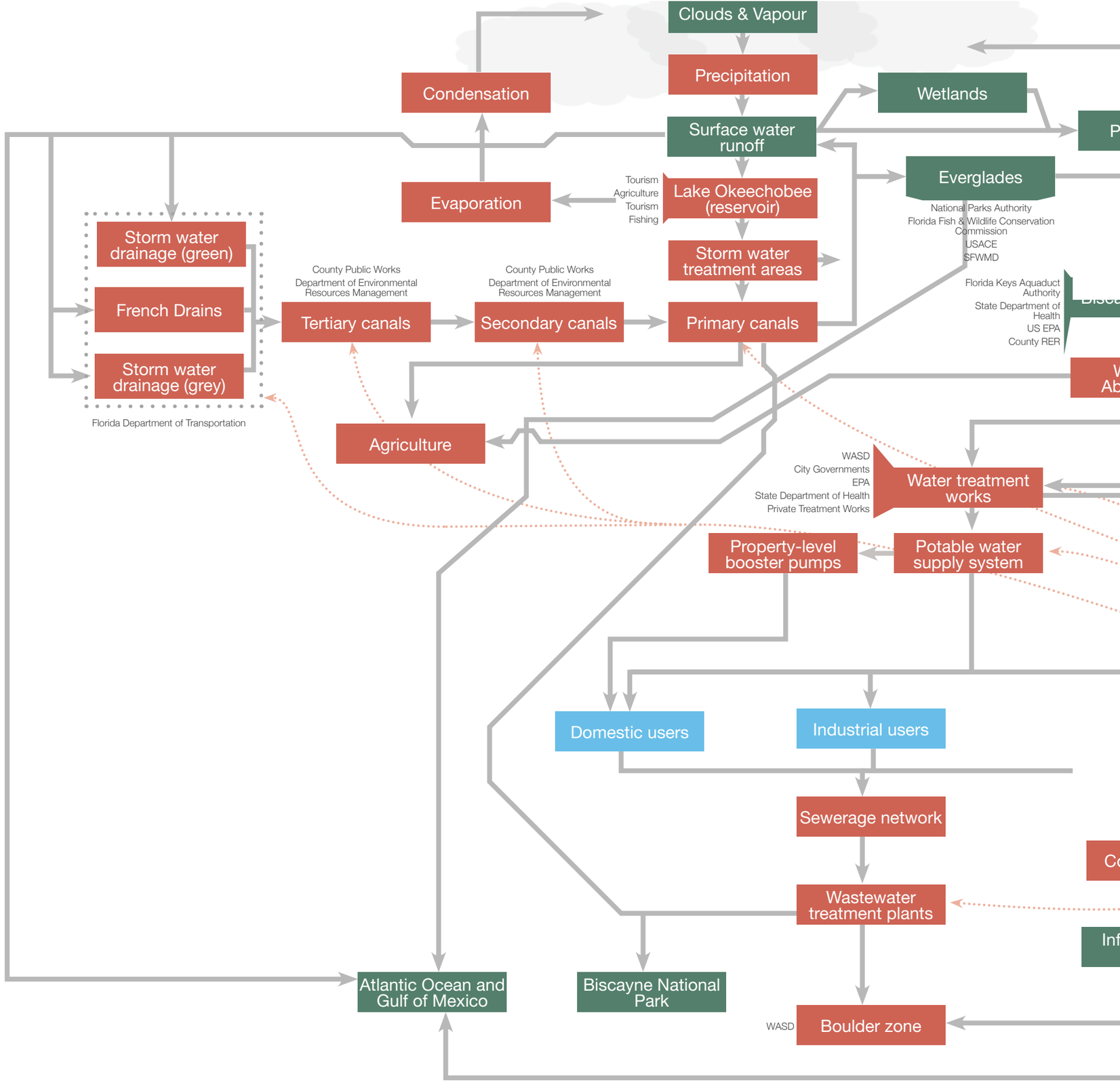
ENGAGEMENT WITH KEY STAKEHOLDERS

One of the most important aspects of understanding an urban water system, in addition to the physical catchment, is identifying which organisations are responsible for different aspects of the water system. These aspects are broken down into Basic Service Provision, Risk Management, the Environment, and Economic & Social-Cultural.



For complete diagram see Annex A

STAKEHOLDER COMMENTARY

BASIC SERVICE PROVISIONS

The State of Florida's Department of Environmental Protection (DEP) has a Division of Water Resource Management (DWRM) responsible for implementing state laws to protect the quality of Florida's drinking water, groundwater, and rivers. The Miami-Dade Water and Sewer Department (WASD), provides direct service to customers throughout the county. In addition, the WASD delivers water and wastewater services to MDC unincorporated areas, wholesale water service to fifteen municipalities, and wholesale wastewater service to fourteen municipalities.

ECONOMIC AND SOCIO-CULTURAL

The federal Department of the Interior's National Park Service manages the Everglades National Park and the Biscayne National Park. DEP's DWRM is responsible for the reclamation of mined lands; the quality of the wetlands, estuaries, rivers, groundwater, and lakes; and the preservation of the state's beach and dune systems. Miami-Dade County Environmental Resources Management (DERM) implements monitoring, education, restoration, regulatory and land management programmes to protect water quality, drinking water supply, air quality, and natural resources that are vital to the health and well-being of all MDC residents, visitors, and the ecosystem. DERM also manages the secondary canal system.

RISK MANAGEMENT

The South Florida Water Management District (SFWMD) is responsible for managing and protecting the water resources of South Florida by balancing and improving flood control, water supply, water quality, and natural systems. It has an overlapping responsibility with the USACE. Miami-Dade County Planning provides services related to sound growth management, historic preservation, urban planning, sustainability planning, and transportation development through the Comprehensive Development Master Plan (CDMP) and related activities. The municipalities operate tertiary stormwater systems; they contribute funding towards maintenance of secondary stormwater systems.

KEY PROGRAMMES

Miami-Dade County is actively engaged in numerous programmes and initiatives focussed on improving resilience. Principally these efforts are coordinated through the County's Office of Resilience.

RESILIENT GREATER MIAM & THE BEACHES	The County's Office of Resilience also leads MDC's role in Resilient Greater Miami and the Beaches (GM&B) as a member of the 100 Resilient Cities Programme, in partnership with the City of Miami and City of Miami Beach.
SOUTHEAST FLORIDA REGIONAL COMPACT CLIMATE CHANGE	The Regional Climate Action Plan (RCAP) is the Southeast Florida Regional Climate Change Compact's guiding tool for coordinated climate action in Southeast Florida to reduce greenhouse gas emissions and build climate resilience. The RCAP provides a set of recommendations, implementation guidelines, and shared best practices for local entities to act in-line with the regional agenda. The Compact holds an annual Summit which Miami-Dade hosted in 2010 and 2014, and will host October 24-25, 2018.
MIAMI-DADE COUNTY greenPrint Our Design for a Sustainable Future	The Office of Resilience coordinates the implementation of the County's Sustainability Plan, GreenPrint. GreenPrint establishes a framework "to achieve a resilient future through a vibrant economy, healthy urban environments, smart mobility, and environmental stewardship." (GreenPrint, n.d.)
Resilient Utility Coalition	Miami-Dade Water and Sewer Department has taken a leadership role in founding the Resilient Utility Coalition (RUC). RUC provides leadership in assessing and adapting utility operations and strategies and improving water management decision-making in the face of climate uncertainty.
BUILDING EFFICIENCY 305 BE305	Additionally, the Office is currently developing Building Efficiency 305 (BE305), a county-wide water and energy efficiency strategy for existing large public and private sector buildings.

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CHARACTERISING RESILIENCE

US National Park Service

CRITICAL INTERDEPENDENCIES

The fieldwork for Miami-Dade County highlighted some of the interdependencies between the water system and other critical urban systems. The top four interdependencies are listed below.

WATER AND SANITATION

When talking with water and environmental professionals, the principal interdependency was recognised as being between the water systems themselves—again a function of the lack of boundary between the systems. Changes in surface water, groundwater, and coastal water quantity and quality play out directly between each other.

ENERGY

Due to the geographical flatness of the water system, energy plays a constant role in conveyance and treatment—of potable water, wastewater, and surface water. Also, cooling water of sufficient quality and quantity is essential to operate the Florida Power & Light (FPL) Turkey Point power station that supplies much of South Florida with electricity.

ENVIRONMENT

The management of the water system is essential for the health of the prestigious and economically important natural environments around MDC like the Everglades and Biscayne Bay.

ECONOMY

Appropriate management of water quantity is necessary to support MDC's economic activity for both urban and agricultural development.

KEY SHOCKS AND STRESSES

Fieldwork conversations noted how, fundamentally, the MDC water system is one that operates on extremely low tolerances—both in terms of water quantity and quality. As a result, there is limited 'buffer' capacity, which could otherwise contribute substantially to 'resilience' of the system.

A major challenge is the uncertainty around how future shocks and stresses will play out (i.e. sea level rise, changing rainfall patterns, urban activities) and how these shocks/stresses will impact the seamlessly interconnected water systems within Miami-Dade. It is difficult to make decisions about a system when – due to the lack of boundary conditions—its future parameters are unknown.

Miami-Dade County developed a Threat and Hazard Identification and Risk Assessment (THIRA) that includes numerous natural, technological, crime/terrorism and public health hazards that Miami-Dade County could experience (Miami-Dade Office of Emergency Management, 2017).

Ecosystem degradation

A lack of boundaries between water systems presents challenges for pollution control. There is a lack of a structure/framework to promote source water protection activities between different stakeholders. Maximising returns on high land tax is a key finance stream for the county. This finance stream can conflict with land-use change that could mitigate impact of changing climate and prevent ecosystem degradation. In some cases, communities have resisted actions to restore the ecosystem because they will experience loss of amenity (e.g. restoration of coastal wetlands reduces visual amenity and access to beaches).

Hurricanes

The 100 RC Preliminary Resilience Assessment, THIRA, and the fieldwork workshop identified hurricanes, which are a regular threat, as a significant shock for Miami.

Shortfall of critical infrastructure

The failure of utility infrastructure poses a real risk to the water system. A flat system means more actively managing drainage to control hydraulic gradients. Infiltration and inflow further blur the traditional boundaries between water and wastewater supply and surface/groundwater management. The maintenance and funding regime for infrastructure does not recognise changing operating conditions for infrastructure.

Monitoring practices need to provide useful data to inform operation and management of a changing water system, i.e. consider monitoring water quality parameters previously not considered relevant. There was concern that insufficient data and analysis had been carried out when determining that a sewer outfall programme should be implemented to address water quality concerns in the Biscayne Bay and less scrutiny was placed on the canal system. The challenge around maintaining technical skills in the industry and within the agencies was identified as a direct challenge to modelling.

Sea level rise

This risk, related to climate change, results in salt water intrusion, environmental impact,

and various forms of flooding for Miami-Dade County. It can also lead to septic tank contamination and put additional stress on ageing infrastructure. For example, with more sea level rise, the inflow and infiltration of surface water (often saline) increased the volume and worsened the quality of wastewater requiring treatment by WASD. Sea level rise also means increased pumping and more electricity used to generate that pumping. This shock was identified by the 100 RC Preliminary Resilience Assessment, THIRA, and the fieldwork workshop.

Pluvial (surface water) flooding

Surface water flooding is the result of changing precipitation and sea level rise. This type of flooding reduces water quality and requires increased pumping. This shock was identified by the 100 RC Preliminary Resilience Assessment, THIRA, and the fieldwork workshop.

Coastal flooding

Storm surges and sea level rise cause coastal flooding, which can result in damage to coastal properties and ecological environments.

Groundwater flooding

The geographical flatness of the water system along with elevated groundwater present challenges for water storage. Essentially the result means flooding of streets and homes when there is no rain falling. Sea level rise also contributes to this 'sunny day flooding' that has become common in Miami. Managing this stress could play a role a flood protection and source water management.

Water quality

Decreased water quality is both the result of salt water intrusion from a combination of stresses (sea level rise, abstraction of groundwater, over drainage, and environmental degradation of areas such as wetlands). The water quality is also degraded through agricultural nutrient pollution, urban pollution, and emerging contaminants.

It was noted that current water pricing does not consider external costs (e.g. impact of sea level rise, saltwater intrusion). WASD has been faced with a huge bill for re-use and high-quality treatment that is not reflected in current water pricing. There is a mis-match between surface water quality management and wastewater quality management because addressing surface water quality has been put off as too difficult.

A cultural difference between quality control and tolerances in the energy and wastewater sectors has meant that treated effluent supplied for cooling frequently did not meet the required standards of the energy sector.

Poor governance and poor planning

There are numerous challenges to water governance and politics. When basing a campaign on the actual cost of utilities politicians tend to experience difficulties; it is easier to defer costs and unpopular to increase them as part of a candidate's campaign. A significant aspect of poor planning and governance was the lack of communication and coordination among agencies within the water system. Water in a regional system has not yet been managed within a regional plan. Decisions are made without consulting other agencies—not everyone has a seat at the table. There is a need for more collaborative management of surface water infrastructure between agencies.

For example, the Comprehensive Everglades Restoration Plan (CERP) has been lauded as successful for meeting mutual state and federal interests. However, one of the reasons CERP has exceeded its original timeframe is the misalignment of agencies' availability of funds.

Another aspect of poor planning has been the lack of data monitoring used for planning and the lack of its being shared among agencies. The need for effective monitoring—of water quality, but also of assets—and for access to the associated data and feedback of data outputs into decision making processes was highlighted. The development of tools and models should consider the potential for engaging other stakeholders in expanding models and/or the decision-making other stakeholders undertake.

Skills and planning may be the first to be cut in times of austerity, which can have a longer-term damaging impact given the types of shocks and stresses that MDC is facing.

The strong development rights of the private sector limit municipalities' ability to implement changes in land use (e.g. sea wall upgrades). The high cost of land makes it unaffordable for government agencies to purchase.

Lack of investment

Generally insufficient investment in infrastructure was cited as a negative factor and was described as disjointed and inconsistent.

Of particular note was the massive investment MDC must make to comply with the ocean outfall legislation passed by the Florida Legislature in 2008. Despite potential evidence that the substantial fund being invested to comply with that legislation could better benefit the overall water system (including Biscayne Bay) if focussed elsewhere, funding must go towards meeting this legislation. Participants noted that excessive investment in uncertain outcomes cannot be allowed, and that intermediate steps are needed to demonstrate results and build confidence. Difficult conversations and trade-offs are necessary; needing communication and understanding of value regarding investments.

One point was that in MDC, project timeframes are inconsistent with political timeframes. Worryingly, when fewer shocks occur, there is pressure to reduce funding/contingency regarding resilience. When agencies need to collaborate on funding, project like CERP can drag along due to timeline and funding issues. In general, participants expressed serious concerns around funding timelines, highlighting the need for long-term funding to fully develop and implement projects.

Case study

The invading seas

Across South Florida, the threat faced by sea level rise is serious. The editorial boards of the South Florida Sun Sentinel, Miami Herald, Palm Beach Post, and WLRN Public Media have come together to enhance public awareness. Termed 'The Invading Seas', this partnership will enable these media outlets to use their collective power to routinely and frequently identify the undeniable threat faced by the rising sea level with the goal to help businesses and communities understand what is at stake by engaging experts, citizens, businesses and political leaders on the tough choices ahead. The hope is to begin and expand a call to action that cannot be ignored. (Miami Herald, The Palm Beach Post and SunSentinel, 2018)

KEY FACTORS OF RESILIENCE

The following themes have been developed from the various conversations and discussions held during the fieldwork—drawing on the perspectives of diverse stakeholder groups.

DATA MANAGEMENT - MODELLING AND MONITORING

Participants regularly commented on the need for and benefit of comprehensive technical modelling and monitoring of the water system. Generating appropriate data that can be used to inform investment decisions to yield the greatest benefit over the appropriate timeframe—modelling and monitoring of natural and man-made systems and assets—is fundamental.

Modelling

The vulnerability of the C&SF canal system to the 'triple whammy' of sea level rise, variable precipitation, and king tides has required the SFWMD to pursue modelling of non-stationary systems to explore possible future scenarios. Given the inherent uncertainty in the models, decision-making under deep uncertainty is another area being focussed on.

WASD is working with U.S. Geological Survey (USGS) to develop a series of numerical models/tools to evaluate the surface water and groundwater flows and exchanges. This work should help MDC evaluate the potential effect(s) of changing wellfield operations and/or canal management on groundwater levels and surface water discharges. The models should also evaluate the effect increased sea levels could have on saltwater interface.

Two key benefits of the co-development approach were cited: shared and consistent resourcing and objective independent credibility through partnering with the scientific community.

Consistent guidelines and codes

Given the multi-layered governance and design guidance/regulation between the state, county and municipalities, the need for consistent design guides and codes has also been highlighted. This is a key theme within the Living With Water Discovery Area. In the case of surface water drainage, there is the potential for drainage improvements in one area to create or exacerbate flood issues in another area.

The collaboration through the Climate Compact to develop the Unified Sea Level Rise Projection was cited as an excellent example of developing consistent guidance. Figure 3 presents this guidance.

EMERGENCY PREPAREDNESS

Unsurprisingly, resilience factors for coping with hurricane and flooding shocks came through in most conversations.

The county's Local Mitigation Strategy (LMS) was cited as raising awareness of hazards and mitigation (Miami-Dade Office of Emergency Management, 2017). In the event of a hazard, the Emergency Operations Centre (EOC) is activated and communicates in a coordinated way. The term 'hardening' was referenced often regarding preparations needed in case of an emergency—such as elevating critical infrastructure, providing secure alternative energy/fuel supplies, burying infrastructure such as power cables, and providing SCADA systems that enable vulnerable plants to be operated remotely. FPL noted their work with the EOC to prioritise hardening related to electricity in case of a hurricane by coordinating with other stakeholders (Miami-Dade Office of Emergency Management, 2018). Similarly, the SFWMD works through the EOC to manage surface water levels in the canal drainage canal system. Coordinated approaches for 'safe to fail' assessments between interdependent infrastructure/utilities should be carried out.

ROBUST FUNDING

Challenges around funding were frequently raised along with a variety of suggestions to enhance resilience financially. Scenario planning should prioritise maximum return on investment for available funds. There is a need for a risk-based decision-making tool for communities/agencies to make resilience investment decisions.

Due to MDC-WASD's large size, it has had the critical mass to invest substantially where required (e.g. in the development of the surface-ground water model).

Participants recognized the need to maintain a financial buffer as required by Public Supply Commission for immediate response in the event of a shock. However, there can be pressure to reduce the contingency after a few shocks.

Where there is substantial uncertainty about future scenarios, investment decisions should be appropriately limited to acceptable confidence in the modelling timeframes. Long-term funding models for technical skills including planning would be beneficial.

Case study

Comprehensive Everglades Restoration Plan

The Comprehensive Everglades Restoration Plan (CERP) is the largest environmental restoration program in history. It builds upon and complements other state and federal initiatives to revitalize south Florida's ecosystem. The plan, submitted to Congress in 1999, is composed of a series of projects designed to address four major characteristics of water flow: quantity, quality, timing, and distribution. Upon Congressional authorization the following year, the federal government and the state of Florida entered into a 50/50 partnership to restore, protect, and preserve water resources in central and southern Florida, including the Everglades. The U.S. Army Corps of Engineers (USACE) is the lead federal agency, and the SFWMD is the lead state agency. This plan will not only provide significant lasting environmental benefits but will also enhance water supplies and maintain flood protection for the region. (Comprehensive Everglades Restoration Plan (CERP), n.d.)

There are interesting alternative methods to 'find' funding. Self-funding of infrastructure can be a viable alternative such as when the City of Miami released a $400 million general obligation bond to raise roads, pumps etc. (Miami Forever, 2017) Another suggestion was regional mitigation banks through which wetland mitigation credits could be purchased. Requiring developers to invest in public benefit funds as an offset for not achieving resilience goals would be another avenue.

Utilities can be bolder in their mandate by lobbying, dealing with 'one water', and prioritising projects with the greatest wider benefit.

There were some important observations in relation to the costs and funding as perceived by the community. Financing of household level mitigation measures is difficult—housing is already unaffordable. There is a high tariff collection rate because water could be turned off in event of no payment. Insurance pay-outs are very slow and late – creating cashflow problems. Community safety nets are considered a positive factor to mitigate in case government cannot respond quickly. However, there is concern about uninformed self-insurance by community.

INTEGRATED MANAGEMENT

Due to the inherently integrated nature of the MDC water system, integration of systems could yield multiple benefits through virtuous cycles—reducing inflow and infiltration and enhancing water quality management; reducing pumping, treatment costs, and energy; and improving environmental water quantity and quality.

Even if integrating systems is a step too far, there are several aspects of the system that need to be integrated to respond to the system's interdependencies. These changes would also involve redistributing and aligning funds among agencies to tackle mutual challenges. Data should be managed and monitored to reflect integrated challenges. Additionally, the review and alignment of operational structures and strategies should reflect integrated challenges. Sharing both technical and financial resources has been demonstrated to work and is crucial for MDC where both are limited. A One Water action coordination group—similar to the LMS Work Group—could be created to focus alignment of interest and agencies' programmes.

The Local Mitigation Strategy (LMS) highlights integration efforts related to reducing vulnerability—recognizing the value of such work. The LMS Working Group's mandate includes reviewing and working to integrate policies and guidance towards this goal. (Miami-Dade Office of Emergency Management, 2017). It is possible that even just promoting an informal network of stakeholders could help break down barriers and improve coordination.

LAND MANAGEMENT

The need for better and more integrated land-use planning was a key theme throughout the fieldwork in Miami. Land-use change is recognised as both being key to mitigation as well as limiting further environmental degradation. It was considered critical to understand the land-water interface. Land-use management should be seen as economic investments, particularly regarding the ecosystem. For example, an investment in beach nourishing is key to the tourism industry. One critical component of land-use management is maintaining or achieving social equity—limiting how climate gentrification plays out. CERP was noted as being 'the best adaptation strategy' and is discussed in the Case Study section of this report.

- Various land-related adaptation/ compensation programmes exist that are currently siloed and could benefit from more concerted alignment.
- Environmentally Endangered Lands—voluntary 'willing seller' programme.
- Adaptation Action Areas—encourages technical assistance and provides funding opportunities while demonstrating co-benefits.
- Flood Mitigation Assistance––coordinates purchasing of vulnerable land.

Certain types of land-use adaptation were evident during the fieldtrip to the agricultural areas where, for example, developing agricultural processes included hydroponics, groundwater tolerant crops, and fish farming to make use of the unique characterises of the Biscayne and Floridan aquifers.

COMMUNITY ENGAGEMENT AND COMMUNICATIONS

To advance resilience, MDC needs to engage with public opinion while being aware of language and cultural differences within cities and communities. Risks must be communicated in a tangible/understandable way. Risk management jargon and the insurance paperwork (e.g. filling in compensation claims) are 'too complex' for normal citizens. Communities struggle to connect the dots between day-to-day issues (e.g. mould) and macro challenges like sea level rise. Participants suggested that messaging to communities should be tailored to empower them to hold elected officials to account.

Communities need to understand the importance of governance, how their vote counts, and how local governance can respond to the daily challenges their communities face. Those who understand these governance points are empowered (on the ground champions) to help communities and government proactively plan and act against climate change (e.g. WASD, 100RC).

Communications continues to be an area of focus for all agencies; however, not all agencies invest significantly in communications. A positive example is WASD where water conservation and demand management was noted as a success with measured results. (Miami-Dade County, 2018) SFWMD communications are also substantial.

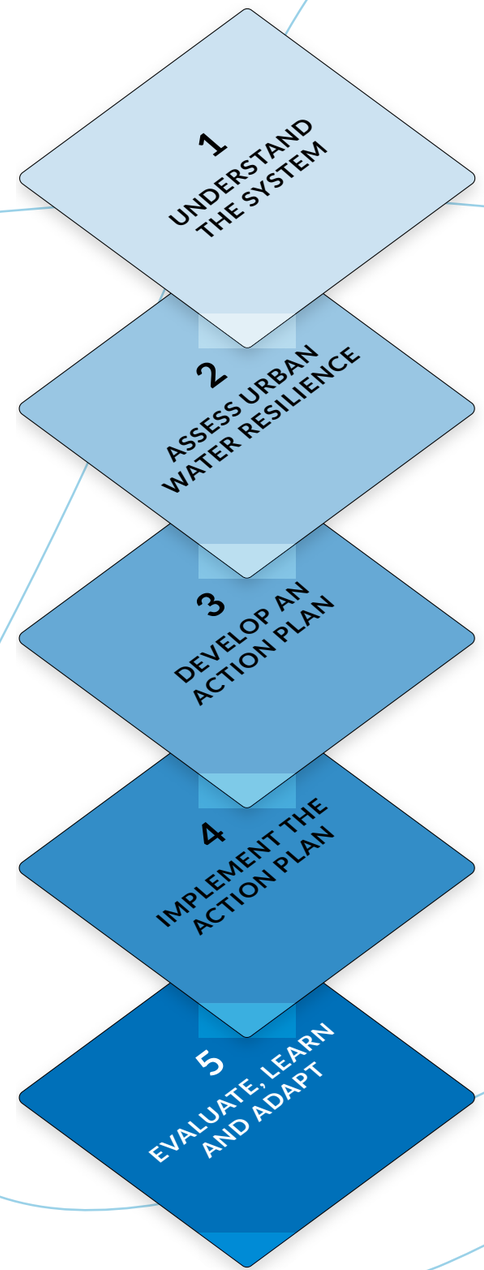
LOBBYING

There is a need for increased consistency of communications about integrated water systems that are sent to elected officials. Particularly in Miami-Dade, water (and green infrastructure) needs to be front and centre in policymakers' minds. This means communicating the value of resilience. The Southeast Florida Regional Climate Compact's unified messaging around climate change has been hailed as a success.

6

REFLECTIONS ON THE CITY WATER RESILIENCE APPROACH

Miami's unique geography, hydrogeology, and exposed climate vulnerability provides invaluable perspective for the City Water Resilience Framework's (CWRF) development—looking at diverse water related risk and resilience in urban watersheds. Similarly, the extensive investments and efforts made by Miami-Dade stakeholders to confront these challenges provides tremendous learning opportunity for the framework.



PERSPECTIVES ON THE CWRF

Generally, the concept of the City Water Resilience Framework was well received by stakeholders. During the various interviews and focus groups, participants discussed the potential framework and the role it might play in building resilience. A key benefit of such a tool was to create consensus by building a shared vision with everyone working towards a common goal. Facilitating conversations, breaking down silos, and enhanced understanding between diverse stakeholders was also valuable. It also provided an opportunity for dialogue leading to consensus-based decisions in a transparent and objective way and to help balance competing demands between stakeholders.

A good example of this collaborative work was the governance stakeholder mapping exercise. The value of the maps was the process of developing an infographic for commissioners to understand the connections, links, responsibilities, and co-dependence in terms of shocks and stresses on the systems.

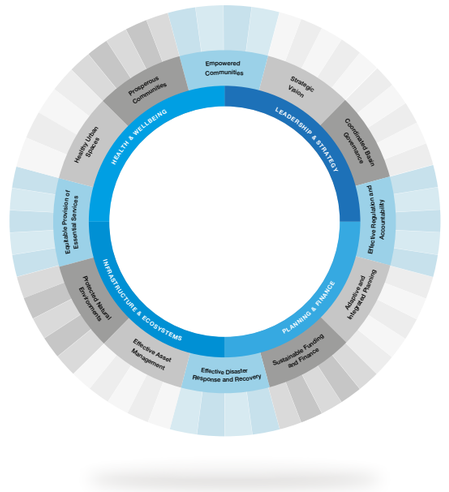
PERSPECTIVES ON CWRF DIMENSIONS AND GOALS

Participants felt MDC failed to meet the CWRF Goals of Integrated Development Planning, Transparent Governance, Effective Organisation and Community Engagement, and Effective Management of Interdependencies. Half the stakeholders scored MDC as performing 'poor' on the goal of Integrated and Effective Basin Management, while the other half scored MDC as 'good'. Results could be indicative of participants' primary concern around land-use planning and its relationship to the water system, rather than of the management of the water system itself. MDC scored well in Effective Provision of Critical Services and medium in Reduced Exposure and Fragility, perhaps suggesting MDC's ability to provide services despite regular shock occurrences, tempered with concern about its exposure and fragility in the face of sea level rise.

During the workshop, participants were invited to suggest alternative goals for the early draft of the CWRF. These are listed below and informed later development of the CWRF.

- Governance
  - Protection of environmental policies
  - Proactive funding
- Health and Wellbeing
  - Drinking water quality
  - Wastewater services
- Economy and Society
  - Social equity on environmental issues
  - Fair sharing of risks & benefits
  - Increased awareness / understanding
- Infrastructure & Ecosystem
  - Environmental protection
  - Water conservation
  - Redundancy

A lot of focus on the suggested goals centred on environmental protection, a topic very relevant in MDC and which needs to be addressed in collaboration with a variety of stakeholders. There was also significant focus on water quality and water conservation. For economy and society, improving social equity and sharing the burden of future challenges was a key theme.



PERSPECTIVES ON WATERSHARE

The water system map was well received. It allowed the workshop participants to understand the interlinkages of the system.

To investigate the application of the digital app, the system was submitted to one stress and one shock: sea-level rise and hurricanes, respectively. Under the applied shock and stress, the interdependencies between the assets of the system became even more clear to the participants. The participants found it difficult to identify the institutions in charge of water system assets since institutional mandates relate to roles and responsibilities, not specific assets. This insight was valuable in clarifying MDC roles and responsibilities.

One idea from the participants focused on how to enhance the chances of rapidly obtaining an agreed-upon full picture of the water scheme and stakeholder mapping. Potentially, each water organisation could receive a draft mapping of the water system and be asked to focus on the system assets they oversaw. Then each stakeholder would make linkages with other system assets and identify the organisations that manage them. Having institutions working on the system assets they oversee would allow for a good level of details at asset level and the simultaneous aspect would minimize the time required.

ACKNOWLEDGEMENTS

The Arup team would like to make pay particular thanks to Debbie Griner at the Resilience office of WASD, without whose tireless efforts the fieldwork would not have occurred.

In addition, the guidance and support of Hardeep Anand and Jose Cueto at WASD.

The 100RC city relationship managers (Eric Wilson and Peter Jenkins) coordinated engagement with Resilient Greater Miami and the Beaches team. During the mission the participation of the Chief Resilience Officers and Deputy Chief Resilience Officers, and their partners AECOM, broadened the reach of the CWRF agenda.

We would also like to thank all participants who gave up their time to share their experiences through the focus groups and workshops and in particular all who provided key informant interviews.

We enjoyed two fascinating field-trips and would like to thank Charles LaPradd for hosting a tour of the agricultural lands in South Miami-Dade as well as Wayne Myers for hosting a visit to the South District Wastewater Treatment Plant.

Specialist interviews:

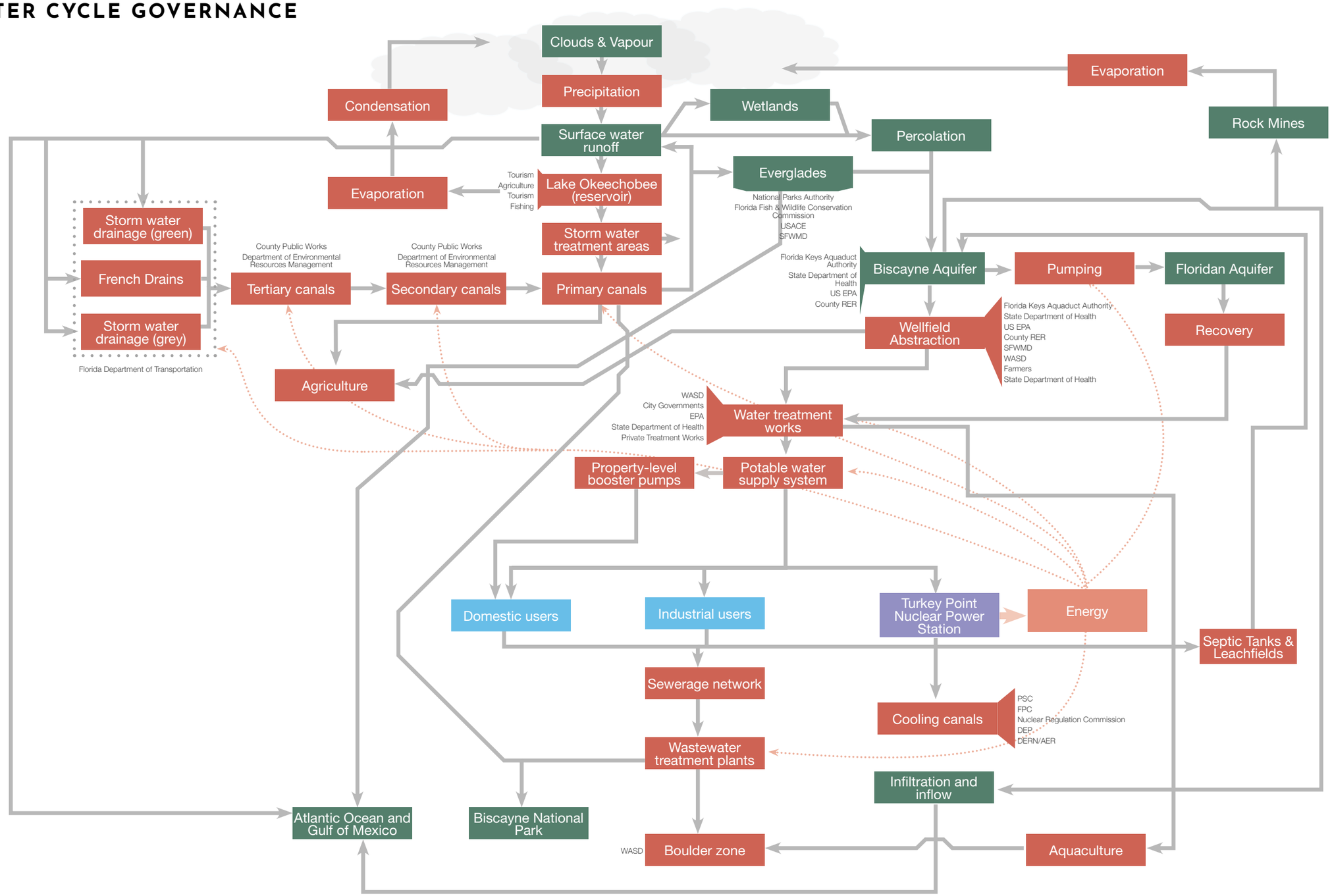
- Dr Jayantha Obeysekera – Director of the FIU Sea Level Solutions Center, Former chief modeller at the South Florida Water Management District
- Dr Virginia Walsh – Senior Professional Geologist at Miami-Dade WASD
- Lee Hefty – Director of Miami-Dade Division of Environmental Resources and Management (DERM)
- Steve Scroggs – Florida Power & Light Senior Director, Project Development
- Doug Yoder – Deputy Director, Miami-Dade Water and Sewer Department
- Mike Sukop & Jessica Bolson – Florida International University, Urban Water Innovation Network UWiN
- Hardeep Anand & Jose Cueto (Miami-Dade WASD)

MDC's engagement has been led by the Resilience office of the MDC Water and Sewer Department (WASD). WASD's leadership of the engagement was very valuable as it is apparent they are a key partner in most resilience related activities in the region as well as being a key partner of the 100RC programme and in particular the Living With Water Discovery Area. This ensured diverse stakeholder engagement prior to and during the field mission.

There was notable collaboration with the Resilient Greater Miami and the Beaches 100 Resilient Cities coalition (http://resilient305.com/) who, at the time of the field mission, were progressing the Discovery Areas leading into the Resilience Strategy aiming for launch in Fall 2018.

ANNEX A

MIAMI'S WATER CYCLE GOVERNANCE



KEY

- Natural Features
- Critical Infrastructure
- Artificial Features
- Consumers

STAKEHOLDERS

- South Florida Water Management District
- US Coast Guard
- US Department of Homeland Security
- US Army Corps of Engineers
- Florida Department of Health
- Miami-Dade County
- Florida Public Service Commission
- Florida Power & Light
- US Environmental Protection Agency
- Florida Department of Environmental Protection
- State of Florida

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