Columbia Law School | COLUMBIA CLIMATE SCHOOL SABIN CENTER FOR CLIMATE CHANGE LAW

February 1, 2023

Mathew C. Blum Acting Administrator for Federal Procurement Policy Office of Federal Procurement Policy Office of Management and Budget Washington, D.C. 20503

Re: Federal Acquisition Regulation: Disclosure of Greenhouse Gas Emissions and Climate-Related Financial Risk; FAR Case 2021-015, Docket No. FAR-2021-0015, Sequence No. 1

Dear Chairman Blum and Members of the Federal Acquisition Regulatory Council,

Columbia Law School's Sabin Center for Climate Change Law ("Sabin Center") and the undersigned climate scientists and other experts studying the effects of climate change respectfully submit these comments to the Department of Defense, General Services Administration, and National Aeronautics and Space Administration—collectively, the Federal Acquisition Regulatory Council (the "FAR Council")¹—in response to their request for comments on the proposed rule titled "Disclosure of Greenhouse Gas Emissions and Climate-Related Financial Risk."²

The Sabin Center and the undersigned climate scientists and experts offer the comments below to explain how scientists know that human activities are driving global warming, and to highlight climate tools and data that companies use to evaluate climate-related risks to their businesses.

There is overwhelming scientific consensus on the fundamental reality of climate change: human activities are increasing atmospheric greenhouse gas ("GHG") concentrations, which is causing global average temperatures to rise. In a 2021 report, the Intergovernmental Panel on Climate Change ("IPCC") concluded that "[i]t is unequivocal that human influence has warmed

The Federal Acquisition Regulatory Council ("FAR Council") is comprised of the Administrator for Federal Procurement Policy, the Secretary of Defense, the Administrator of National Aeronautics and Space, and the Administrator of General Services, or their designees. *See* 41 U.S.C. § 1302(b).

Federal Acquisition Regulation: Disclosure of Greenhouse Gas Emissions and Climate-Related Financial Risk, 87 Fed. Reg. 68312 (November 14, 2022) [hereinafter the "Proposed Rule"].

the atmosphere, ocean and land."³ The IPCC found that "[e]ach of the last four decades has been successively warmer than any decade that preceded it since 1850."⁴ The extent of future temperature increases will depend, in large part, on future GHG emissions. However, "warming above 2 degrees Celsius is "very likely" unless emissions decline rapidly prior to 2050.⁵ Rising temperatures are already increasing the frequency and severity of many types of weather extremes, such as heatwaves and floods, and contributing to sea-level rise and other slow-onset phenomena.⁶

Numerous studies confirm that climate change poses significant financial risks to corporate entities and the financial system more generally. For example, a 2019 study by the CDP found that 215 of the largest companies globally face almost \$1 trillion in potential financial risk from climate change, with approximately half of that risk identified as likely or nearly certain to materialize within five years. More recently, in its 2021 report on Climate-Related Financial Risk, the Financial Stability Oversight Council ("FSOC") noted that "[t]he intensity and frequency of extreme weather and climate-related disaster events are increasing and already imposing substantial economic costs." The FSOC recognized that, as the magnitude of climate hazards and associated costs increases in coming years, so too will risks to the financial system. Thus, according to the FSOC, "climate-related financial risks are an emerging threat to the financial stability of the United States." The Climate-Related Market Risk Subcommittee of the Commodity Futures Trading Commission ("CFTC") has similarly concluded that climate-related risks "are already impacting, or are anticipated to impact, nearly every facet of the U.S. economy."

The financial risks associated with climate change are typically divided into two broad categories: (1) physical risks arising from the impacts of climate change on companies' assets, operations, and supply chains; and (2) transition risks arising from government and market

Intergovernmental Panel on Climate Change ("IPCC"), Summary for Policymakers, in CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS. CONTRIBUTION OF WORKING GROUP I TO THE SIXTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 4 (V. Masson-Delmotte et al., eds, 2021).

⁴ *Id.* at 5.

⁵ *Id.* at 13-15.

⁶ *Id.* at 15.

See Financial Stability Oversight Council, Report on Climate-Related Financial Risk (2021), https://perma.cc/6V34-EU4F; Commodity Futures Trading Commission Climate-Related Market Risk Subcommittee of the Market Risk Advisory Committee, Managing Climate Risk in the U.S. Financial System (2020), https://perma.cc/6RHX-XTW7; Board of Governors of the Federal Reserve System, Financial Stability Report (2020), https://perma.cc/6RHX-XTW7; Board of Governors of the Federal Reserve System, Financial Stability Report (2020), https://perma.cc/2VWA-67LV.

⁸ CDP, MAJOR RISK OR ROSY OPPORTUNITY: ARE COMPANIES READY FOR CLIMATE CHANGE? (2019), https://perma.cc/XVL3-YF7T.

FINANCIAL STABILITY OVERSIGHT COUNCIL, *supra* note 7, at 10.

¹⁰ *Id*.

¹¹ Id

COMMODITY FUTURES TRADING COMMISSION CLIMATE-RELATED MARKET RISK SUBCOMMITTEE OF THE MARKET RISK ADVISORY COMMITTEE, *supra* note 7, at 11 & 28.

responses to climate change. These comments discuss the science of climate change detection and attribution—the body of research that helps to characterize the role of human activity in climate change—as well as how models are used to develop climate change projections. The goal of these comments is to explain how scientists know that anthropogenic GHG emissions are driving global warming which is, in turn, leading to other climate hazards (e.g., more severe heatwaves, droughts, and floods) that create risks for companies. The comments also highlight climate tools and data that companies can, and already do, use to evaluate climate-related risks to their assets, operations, work force, and supply chains. The sections below further explain these key points:

- There is a robust and growing body of evidence that establishes a causal connection between rising atmospheric GHG concentrations and physical climate hazards and associated impacts (e.g., water shortages, crop losses, and lost labor hours due to extreme heat).
- Climate models can be used to project future climate change hazards. Modeling climate change
 under different plausible GHG emissions scenarios provides a better method of estimating
 climate change impacts than incorrectly assuming that the climate of the recent past will simply
 continue unchanged into the future.
- Downscaled climate models can be used to refine projections from global climate models to finer scales (e.g., reflecting local climate hazards). Downscaled projections are available to companies and can be used by companies to identify climate hazards that may affect their assets, operations, work force, and supply chains. For example, using downscaled temperature projections, a company could identify potential risks to temperature-sensitive assets, such as natural gas generating plants. By comparing temperature projections to a generating plant's design reference temperature, a company could evaluate the potential for plant de-rates or outages in the future. Temperature projections could similarly be used with crop models to evaluate the potential for future crop losses. Sea level rise projections could also be overlaid on companies' asset maps to identify facilities at risk of nuisance flooding or permanent inundation.
- Some companies are already using downscaled climate projections to evaluate and disclose physical climate-related risks to their assets, operations, work force, and supply chains. Several examples are provided in Part 4 of this letter.

1. Climate Change Detection and Attribution

Attribution science refers to the body of research that explores the link between human activities and climate change. 13 According to the IPCC, distinguishing between the effects of

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Delliang Chen et al., *Framing, Context, and Methods, in* CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS. CONTRIBUTION OF WORKING GROUP I TO THE SIXTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL OF CLIMATE CHANGE 204 (V. Masson-Delmotte et al., 2021).

external influences and internal climate variability requires the direct comparison of observed changes in the climate system and those that are expected to result from external forcings, such as anthropogenic GHG emissions.¹⁴ Formal detection and attribution studies use objective statistical tests to determine whether observations contain evidence of the expected responses to external forcing that is distinct from variability generated within the climate system itself.¹⁵

Attribution research can be broken down into four broad categories:

- 1. Climate change attribution examines how rising concentrations of GHGs and other pollutants in the atmosphere affect many other aspects of the global climate system, including global and regional mean temperatures, sea level, and sea ice extent. Attribution studies have identified human-caused "fingerprint" patterns in literally dozens of different independently monitored variables. In fact, since the mid-1990s, these "pattern-based 'fingerprint' studies have been the primary and most rigorous tool for disentangling the complex causes of recent climate change." Thingerprinting relies on numerical models of the climate system to provide estimates of both the searched-for fingerprint—i.e., the climatic response to a change in one or several forcing mechanisms—and the background "noise" of natural internal climate variability. The internal and physical consistency of fingerprint results provides compelling scientific evidence of human effects on climate.
- 2. *Extreme event attribution* examines how human-induced changes in the global climate system have affected the probability, severity, and other characteristics of observed extreme events, such as hurricanes and heat waves. For example, one recent study used the Community

See also, Michael Burger, Jessica Wentz, and Radley Horton, The Law and Science of Climate Change Attribution, 45 COLUM. J. ENVTL. L. 57, 64 (2020).

¹⁸ *Id.* at 1.

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G.C. Hegerl, et al., *Understanding and Attributing Climate Change*, in CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS. CONTRIBUTION OF WORKING GROUP I TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (S. Solomon et al., eds., 2007). *See also*, NAT'L ACAD. OF SCI., ENGINEERING, AND MEDICINE, ATTRIBUTION OF EXTREME WEATHER EVENTS IN THE CONTEXT OF CLIMATE CHANGE (2016).

Hegerl, et al., *supra* note14, at 667. Detection is the process of demonstrating that the climate has changed in some defined statistical sense, while 'attribution' refers to the process of establishing whether and to what extent human activities are the cause of the detected change. *See id.* at 667-668.

See, e.g., Yang Chen, et al., Future Increases in Arctic Lightning and Fire Risk for Permafrost Carbon, 11 NAT. CLIMATE CHANGE 404 (2021); Lauren J. Vargo et al., Anthropogenic Warming Forces Extreme Annual Glacier Mass Loss, 10 NAT. CLIMATE CHANGE 856 (2020); Qiaohon Sun et al., A Global, Continental, and Regional Analysis of Changes in Extreme Precipitation, 34 J. CLIMATE 243 (2020).

Benjamn D. Santer, et al., *Human and natural influences on the changing thermal structure of the atmosphere*, 110 PROC. NAT'L ACAD. SCI. 17235 (2013).

Atmospheric Model ("CAM")¹⁹ to analyze how human-induced climate change affected rainfall rates during the 2020 hurricane season, which is estimated to have resulted in more than \$40 billion in damages.²⁰

- 3. *Impact attribution* examines how changes in the global climate system affect human and natural systems. Impact attribution studies analyze localized physical climate change impacts, such as floods, droughts, and sea level rise, and the corresponding effects on infrastructure, public health, ecosystems, agriculture, and economies.²¹
- 4. *Source attribution* is a distinct but related body of research that aims to identify the relative contributions of different sectors, activities, and entities to global climate change.²²

Climate change attribution, extreme event attribution, and source attribution are mature fields of research, with studies having been performed since the 1990s. Impact attribution is a newer, but rapidly developing, field of research. All four fields of research provide useful insights into how human activities affect the climate system which, in turn, informs modeling of future climate change.

2. Climate Modeling

This section describes the process of using climate models to generate knowledge of climate hazards. Modeling allows researchers to simulate and understand interactions between climate variables using physically-based representations of the climate system in numerical form. Through models, scientists can explore the effect of changes to external factors, like atmospheric GHG concentrations, on specific climate variables (e.g., surface temperatures) and the types of hazards associated with such GHG-induced effects (e.g., changes in rainfall patterns). Developing an understanding of the type of climate hazards present (e.g., in a given region, affecting a specific company, etc.) is a critical first step in assessing potential impacts of climate change. Using climate hazard data, companies can evaluate potential climate-related risks to their assets, operations, work force, and supply chains.

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All raw CAM model output is publicly available on the National Center for Atmospheric Research Globally Accessible Data Environment. *See* Nat'l Ctr. Atmospheric Research, *Data Services: Access, Tools & Guidance*, https://perma.cc/Y3ZX-ZX7G (last visited Dec. 5, 2022).

See Kevin A. Reed et al., Attribution of 2020 Hurricane Season Extreme Rainfall to Human-Induced Climate Change, 13 NATURE COMM, 1905 (2022).

As an example, one recent impact attribution study examined how increases in the number of wet days and in extreme daily rainfall affect economic growth rates. *See* Maximillian Kotz et al, *The effect of rainfall changes on economic production*, 601 NATURE 223 (2022).

Source attribution studies have, for example, assessed the cumulative GHG emissions attributable to specific oil, natural gas, coal, and cement producers (among others). *See, e.g.*, RICHARD HEEDE, CARBON MAJORS: ACCOUNTING FOR CARBON AND METHANE EMISSIONS 1854–2010: METHODS & RESEARCH REPORT (2014), https://perma.cc/448G-SYUA.

Research shows that past model predictions (e.g., of global average temperatures) have been highly accurate. One way to assess model accuracy is to compare previous model projections made years or decades ago to actual climate observations—a process referred to as "hindcasting." One recent study used hindcasting to assess the performance of climate model projections published between 1970 and 2007.²³ The authors found that the climate models were "skillful in predicting subsequent GMST [global mean surface temperature] changes, with most models examined showing warming consistent with observations" and that there was "no evidence that the climate models [...] systematically overestimated or underestimated warming over their projection period."²⁴ Another study analyzed global temperature and sea-level data over the past several decades and compared those records with projections published in the IPCC's Third and Fourth Assessment Reports. The analysis showed that "global temperature continues to increase in good agreement with the best estimates of the IPCC, especially if we account for the effects of short-term variability due to the El Niño/Southern Oscillation, volcanic activity, and solar variability."²⁵

2.1. Types of Climate Models

Each component of the climate system—or a combination of components—can be represented by models of varying degrees of complexity.²⁶ There are three classes of climate models:

- 1. Energy balance models, which are the oldest and simplest type of climate model, estimate changes in the climate system from an analysis of the Earth's energy budget (i.e., the balance of energy entering and leaving the Earth).²⁷
- 2. Intermediate complexity models, which are similar to energy balance models but incorporate the effect of changes in the Earth's land, oceans, and ice features on the climate.²⁸ Intermediate complexity models are used to project changes in climate over long time scales and large spatial scales.²⁹
- 3. Comprehensive climate models (General Circulation Models and full Earth System Models), which are more sophisticated than energy balance and intermediate complexity models.³⁰

Zeke Hausfather, et al., Evaluating the Performance of Past Climate Model Projections, 47 GEOPHYSICAL RES. LETTERS 1 (2020).

Id. at 1, 7-8.

Stefan Rahmstorf, et al., *Comparing climate projections to observations up to 2011*, 7 ENVTL. RES. LETTERS 4 (2012).

²⁶ *Id*.

Lauren Harper, *What are climate models and how accurate are they?* STATE OF THE PLANET BLOG (May 18, 2018), https://perma.cc/3QJ6-Q2UR.

²⁸ *Id*.

²⁹ *Id*.

³⁰ *Id*.

General Circulation Models are based on physical laws that describe the fully-coupled dynamics of the atmosphere and ocean, expressed through mathematical equations.³¹ Earth System Models, also referred to as coupled carbon-cycle climate models, are similar to General Circulation Models but also incorporate the dynamics of the land surface, vegetation, the carbon cycle, and other elements of the climate system.³² Both General Circulation Models and Earth System Models are built upon the fundamental laws of physics or the empirical relationships established from observations and, when possible, are constrained by fundamental conservation laws.³³

There are more than forty scientific institutions worldwide that develop climate models.³⁴ In order to facilitate comparison of model results across these institutions, the Coupled Model Intercomparison Project ("CMIP") serves as a framework for climate model experiments, allowing scientists to compare and assess climate models in a systematic way.³⁵ The most recent, sixth phase of CMIP model runs ("CMIP6") provided many different types of simulations that were evaluated by the IPCC's Sixth Assessment Report. As part of CMIP6, there are twenty-two specialized experiments—called Model Intercomparison Projects ("MIPs")—which prescribe standardized experiment designs, time periods, output variables or observational reference dates to better facilitate the direct comparison of climate models.³⁶

2.2. Climate Model Projections

The first step in simulating and quantifying the climate response to past, present, and future human activities is to simulate historical and/or present climate for extended simulation periods, typically across multiple decades or several centuries. Models can be used to simulate a previous climate before anthropogenic GHG emissions became prominent, as well as to simulate the effect of natural factors (e.g., volcanic activity and changes in the Sun's energy activity) and human activities on the climate.³⁷ Two general types of simulation are typically performed to make projections of future changes in the climate system:

1. Equilibrium simulations involve changing the CO₂ concentrations (e.g., doubling the CO₂ level) and running the model again until it reaches a new equilibrium. Modelers can then

Chen, et al., *supra* note 16, at 215.

³² *Id*.

³³ *Id*

Zeke Hausfather, *CMIP6: The next generation of climate models explained*, CARBON BRIEF (Dec. 2, 2019, 8:00 AM), https://perma.cc/F69B-R3U6.

Zeke Hausfather, *Q&A*: *How do climate models work*? CARBON BRIEF, https://perma.cc/8LVD-HZ4Y (Jan. 15, 2018, 8:30 AM).

Chen, et al., *supra* note 16, at 182.

E. Ahlonsou et al., *The Climate System: An Overview, in* CLIMATE CHANGE 2001: THE SCIENTIFIC BASIS, CONTRIBUTION OF WORKING GROUP I TO THE THIRD ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 95 (J.T. Houghton et al., eds., 2001).

estimate the corresponding changes to the climate based on the doubling of CO₂ emissions by calculating the differences between the climate statistics in the "doubled CO₂" and "pre-industrial CO₂" simulations.³⁸

2. Transient simulations involve forcing the model with a specific scenario of future changes in GHG emissions, particulate pollution, and land surface properties. For example, the IPCC has developed a set of scenarios that represent different time-dependent "storylines" of GHG and aerosol concentrations based on differing assumptions regarding population growth, energy intensity and efficiency, and economic growth.³⁹ (Climate modeling using emissions scenarios is discussed further in Part 2.3 below.)

2.3. Climate Modeling Using Emission Scenarios

Representative Concentration Pathways ("RCPs") were used in simulations of future climate change that were assessed in the IPCC's Fifth Assessment Report. RCPs provide four different scenarios for GHG emissions in the 21st Century, as well as for air pollutant emissions and changes in land use. Each RCP is defined by its emissions pathway and total radiative forcing⁴⁰ by 2100.⁴¹ Broadly speaking, the RCP scenarios consist of a stringent GHG emissions mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0), and one high emissions scenario (RCP8.5).

The RCP scenarios were assessed by the IPCC using Integrated Assessment Models ("IAMs"). IAMs typically incorporate simple climate models (such as the Energy-Balance Models described above), carbon cycle models, and social science models that consider demographic, political, and economic variables that influence GHG emission scenarios. ⁴² Each RCP was generated using IAMs to estimate the changes in radiative forcing through 2100 associated with each of the four "storylines."

RCP data are publicly available for download and use to make 21st century climate change projections under different emission scenarios.⁴³ Many different entities, including management consulting firms such as McKinsey & Company, already use climate models driven by RCPs to

Radiative forcing is a cumulative measure of human-caused perturbations to Earth's energy balance, expressed in Watts per square meter.

³⁸ *Id*.

³⁹ *Id*.

IPCC, Representative Concentration Pathways (RCPs), DATA DISTRIBUTION CENTRE, https://perma.cc/3475-P4JY.

IAMs differ from General Circulation Models, which focus solely on modeling the physical climate system. *See* CENTER FOR INTERNATIONAL EARTH SCIENCE INFORMATION NETWORK, THEMATIC GUIDE TO INTEGRATED ASSESSMENT MODELING OF CLIMATE CHANGE (1995), https://perma.cc/R57L-7KGP.

See RCP Database, Version 2.0.5, https://tntcat.iiasa.ac.at/RcpDb/dsd?Action=htmlpage&page=download.

assess the physical risks of climate change. For example, in a recent report by the McKinsey Global Institute ("McKinsey Report"), the authors used RCP8.5 in their analysis of future physical climate risks. They found that by 2050:

- global average temperatures are expected to warm by 2.3 degrees Celsius relative to the preindustrial baseline;
- the time spent in drought is projected to increase such that, in some areas (e.g., parts of the Mediterranean, Africa, and the Americas), drought conditions could occur up to eighty percent of each decade; and
- the likelihood of extreme precipitation events is expected to increase more than fourfold along the east coast of North America (compared to the period from 1950-1981).⁴⁴

This information can then be used to estimate the socioeconomic impacts of climate change associated with different emissions trajectories. For example, the McKinsey Report identified "the socioeconomic risk from acute hazards, which are on-off events like floods or hurricanes, as well as from chronic hazards, which are long-term shifts in climate parameters like temperature" from 2020 to 2030 and from 2030 to 2050.⁴⁵ Among other things, the report found that temperature increases associated with RCP8.5 will mean that:

"By 2030 [...] between 250 million and 360 million people could live in regions where there is a non-zero probability of a heat wave exceeding the threshold for survivability for a healthy human being in the shade (a measure of livability, without factoring in air conditioner penetration). The average probability of a person living in an at-risk region experiencing such a lethal heat wave at least once over the decade centered on 2030 is estimated to be approximately 60 percent[.] By 2050, the number of people living in regions exposed to such heat waves could rise further, to between 700 million and 1.2 billion [...] The global average number of working hours that could be lost due to increasing heat and humidity in exposed regions (a measure of workability impacts) could almost double by 2050, from 10 percent to 15 to 20 percent." 46

The IPCC's Sixth Assessment Report highlights a newer set of illustrative scenarios, derived from five Shared Socio-economic Pathways ("SSPs"), which encompass a range of possible future developments with respect to anthropogenic drivers of climate change.⁴⁷ Each pathway is built upon an internally consistent, plausible, and integrated description of a socio-economic future.⁴⁸ They include quantitative projections of socio-economic drivers, including

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JONATHAN WOETZEL, ET AL., MCKINSEY GLOBAL INSTITUTE, CLIMATE RISK AND RESPONSE: PHYSICAL HAZARDS AND SOCIOECONOMIC IMPACTS 10 (2020), https://perma.cc/55NE-TVTU.

⁴⁵ *Id.* at 2.

Id. at 23 (Internal citations omitted).

⁴⁷ Chen, et al, *supra* note 16, at 230.

⁴⁸ *Id.*

population, gross domestic product, and urbanization. The five SSPs represent: "sustainability" (SSP1), a "middle-of-the-road" path (SSP2), "regional rivalry" (SSP3), "inequality" (SSP4), and "fossil fuel-intensive" development (SSP5). The narratives and drivers underlying each SSP were used to develop scenarios of energy use, air pollution control, land use, and GHG emissions using IAMs.⁴⁹

Like RCPs, SSPs yield information about the approximate radiative forcing level in 2100. This information is encoded in the name of the SSP (SSPX-Y, where 'X' represents the Shared Socio-economic Pathway family (1-5), and 'Y' represents the approximate radiative forcing level in 2100). These combinations are widely used in the climate impact studies assessed in the IPCC Sixth Assessment Report. ⁵⁰ For example, the IPCC describes SSP5-8.5 as a "high reference scenario with no additional climate policy. CO₂ emissions roughly double from current levels by 2050" in SPP5-8.5. ⁵¹ According to the IPCC, the SSP and RCP scenarios "are designed to span a plausible range of future pathways," and can be used to develop projections of future climate conditions in various possible futures. ⁵²

2.3. Downscaling Climate Models

General circulation models generally divide the world up into grids in order to perform calculations. A typical model might have a grid cell size of sixty miles or more for one side of the cell, resulting in coarse-resolution projections that cover large geographic areas. These projections may not be sufficiently granular to enable companies to fully assess the impacts of climate change on specific assets and operations. Downscaling the output from global climate models to finer spatial scales can partially bridge this information gap. There are two main approaches to downscaling:

- 1. Dynamical downscaling uses higher spatial resolution regional climate models to directly simulate regional climate processes and regional responses to global change.⁵³ The regional models usually cover a selected domain (such as the continental United States) and receive information from more coarsely resolved general circulation models at the boundaries of the regional domain.
- 2. Statistical downscaling uses historically-based statistical relationships between the large-scale and local-scale climate to estimate future changes in local climate from large-scale general circulation model projections.⁵⁴

50 *Id.* at 231.

⁵² *Id.* at 196.

⁴⁹ *Id*.

⁵¹ *Id*.

Aristita Busuioc, *Empirical-statistical downscaling: Nonlinear statistical downscaling*, OXFORD RESEARCH ENCYCLOPEDIA OF CLIMATE SCIENCE (2021).

⁵⁴ *Id.* at 1.

Downscaling climate models can reveal useful information about a company's exposure to acute and slow-onset climate changes. Information regarding where climate hazards are likely to be felt may allow a company to assess which of its physical assets, operations, and supply chains are located in areas known to be vulnerable to climate hazards. Such an assessment may enable the company to better understand the nature and extent of any climate-related vulnerabilities. Companies can use climate models that produce a probabilistic assessment of hazards within a given area to identify risks to assets in the affected region. This would enable the company to disclose, for example, that its principal place of business is situated within a geographic area that scientists have concluded is *very likely* [90-100% outcome probability] to experience flooding exacerbated by climate change.

Downscaled climate projections have been published by various governmental and academic institutions:

- The Department of Energy, National Aeronautics and Space Administration, and National Oceanic and Atmospheric Administration have jointly published zip-code-level temperature projections and county-level precipitation and sea level projections.⁵⁷
- The U.S. Geological Survey has partnered with the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University to develop a "Regional Climate Change Viewer" that includes downscaled projections for over 60 climate variables, including air temperature and precipitation.⁵⁸
- The Bureau of Reclamation has partnered with multiple universities and non-governmental organizations to develop downscaled projections for temperature and precipitation at the watershed level. The projections are designed to enable assessment of climate change impacts on watershed hydrology, ecosystems, and water and energy demand across the U.S.⁵⁹

Probabilistic assessments indicate areas where, for example, models show a higher chance of above or below average temperatures or precipitation. *See* NOAA, *Climate Models*, CLIMATE DATA PRIMER, https://perma.cc/HL6K-33Y4 (last visited Dec. 4, 2022).

http://regclim.coas.oregonstate.edu/visualization/rccv/index.html (last visited Dec. 4, 2022).

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See, e.g., ISIMIP, The Inter-Sectoral Impact Model Intercomparison Project, https://perma.cc/UV5D-PBXQ (last visited Dec. 4, 2022). Utilizing climate model output at a more granular level than the model itself operates—i.e., downscaled data—requires an acknowledgment that the local risk of exposure to an extreme event may differ from what the model predicts at a larger scale.

⁵⁷ See Energy Data Gallery, U.S. CLIMATE RESILIENCE TOOLKIT,
https://toolkit.climate.gov/topics/energy/energy-data-gallery (last updated Sept. 24, 2019).

U.S. Geological Survey, Regional Climate Change Viewer,

U.S. Bureau of Reclamation et al., *Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections*, https://gdo-dcp.ucllnl.org/downscaled_cmip_projections/#Welcome (last visited Dec. 4, 2022).

- The Geospatial Innovation Facility at the University of California at Berkeley has developed Cal-Adapt, a web-based tool that provides projections for several climate variables, including temperature and precipitation, under two climate change scenarios on a 3.5 × 3.5-mile spatial grid.⁶⁰
- The Climate Impact Lab has developed the Global Downscaled Projections for Climate Impacts Research, a globally downscaled version of temperature and precipitation from the most recent CMIP6 projections, with a resolution of approximately 15 miles.⁶¹
- The Department of the Interior and National Oceanic and Atmospheric Administration have developed a Climate Mapping for Resilience and Adaptation assessment tool, which integrates information from across the federal government to help people assess their local exposure to climate-related hazards.⁶²

3. Overcoming Challenges and Uncertainties

Climate science is sufficiently robust to assess the likelihood of certain climate change hazards and evaluate their impacts on companies' assets and operations. There are, however, remaining uncertainties and limitations in how climate science can be used. As explained in this section, researchers have techniques and language to address these challenges, with the goal of ensuring that climate science remains a source of useful information about the climatic future. A particular focus of previous research has been to identify climate change responses that are robust across a wide range of different climate models, that are interpretable in terms of basic, well-understood physics (such as the decrease in snowpack associated with human-caused warming), and that have reliable multi-decadal observational records.

As noted above, scientists can assess how well a climate model functions by comparing its outputs to observational data. However, observational data may sometimes be incomplete, or entirely unavailable. Modeling climate impacts at fine geographic scales (e.g., regionally or locally) can result in additional sources of uncertainty due to downscaling or bias correction.⁶³ For example, statistical downscaling relies on the assumption that the statistical relationships used to transform global climate model output remains true under novel environmental conditions that

⁶⁰ CAL-ADAPT, About Cal-Adapt, https://cal-adapt.org/about/ (last visited Dec. 4, 2022).

Climate Impact Lab, Introducing Our New Global Downscaled Projections for Climate Impact Research, https://impactlab.org/news-insights/introducing-our-new-global-downscaled-projections-for-climate-impacts-research/ (last visited Dec. 4, 2022).

Climate Mapping for Resilience and Adaptation, *About CMRA*, https://resilience.climate.gov/pages/about/#about (last visited Nov. 28, 2022).

Bias correction refers to the correction of projected raw, daily global circulation model output using the differences in the mean and variability between general circulation models and observations over a set reference period. See Ed Hawkins et al., Calibration and bias correction of climate projections for crop modelling: An idealised case study over Europe. Agricultural and Forest Meteorology, 170 AGRICULTURAL & FOREST METEOROLOGY 19 (2013).

have yet to be observed directly.⁶⁴ One strength of using dynamical downscaling methodologies is that such models rely on explicit representations of physical principles in the atmosphere that are expected to hold true under climate change, but this method can be sensitive to large-scale biases in the downscaling models (and in the global climate models used to generate the data being downscaled).⁶⁵

Researchers can address these uncertainties by articulating the nature and extent to which local climate predictions may differ from regional predictions modeled at a larger scale. Assume, for example, that researchers want to study the future climate impacts on a particular city in North America. While regional modeling may suggest that North America will experience an increase in average surface temperatures, an individual city may experience more or less warming than the average for the continent. This variation can be investigated by analyzing regional-scale climate processes and factors such as land use, aerosol concentrations, and small-scale natural variability in the area of interest. Uncertainties in the observational data can also be studied and may influence attribution of observed climate changes and/or impacts to specific causal factors. For example, the IPCC states that the scarcity of temperature recording stations can explain the overall low confidence in changes in surface air temperatures in the Antarctic region.⁶⁶

The results of individual studies are typically expressed in terms of calibrated uncertainty and likelihood language. For example, the IPCC's Sixth Assessment Report uses a framework for applying expert judgment in the evaluation and characterization of assessment findings. This calibrated language is designed to consistently evaluate and communicate uncertainties associated with incomplete knowledge due to a lack of available information, or from disagreement regarding what is known or even knowable. ⁶⁷ This methodology assigns qualitative expressions of confidence—such as *very low, low, medium, high,* and *very high*—based on the robustness of evidence for a finding and uses quantitative expressions—such as *virtually certain* (99-100% probability)—to describe the likelihood of a finding. ⁶⁸ For example, the IPCC report states that "observed increases in areas burned by wildfires have been attributed to human-induced climate change in some regions (*medium* to *high confidence*)." ⁶⁹ Language of this kind is used to manage

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Geophysics Fluid Dynamics Laboratory, *Climate Model Downscaling*, https://perma.cc/K25U-3UYS (last visited Nov. 28, 2022).

 $[\]overline{Id}$

Nathaniel L. Bindoff, et al., *Detection and Attribution of Climate Change: from Global to Regional, in* CLIMATE CHANGE 2013: THE PHYSICAL SCIENCE BASIS. CONTRIBUTION OF WORKING GROUP 1 TO THE FIFTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (T.F. Stocker et al. eds., 2013).

Hans Pörtner, et al., *Technical Summary, in* CLIMATE CHANGE 2022: IMPACTS, ADAPTATION AND VULNERABILITY. WORKING GORUP II CONTRIBUTION TO THE IPCC SIXTH ASSESSMENT REPORT (Hans-Otto Pörtner et al. eds., 2022).

⁶⁸ *Id.* at 4.

Hegerl, et al., *supra* note 14, at SPM-8.

uncertainties in a rigorous, systematic way.⁷⁰ Of course, the language scientists have developed to address unavoidable uncertainty in this enterprise must not be confused with the reliability of the results and conclusions.

In sum: as in any scientific endeavor, some uncertainties are unavoidable, but researchers can frame results at an appropriate scale and use language that clearly communicates the extent to which modeling and observations produce results with a high level of confidence. Such techniques allow companies to effectively use model outputs to assess climate-related risks to their assets and operations. The case studies included below further demonstrate this point.

4. Case Studies

The case studies below highlight how companies can and do make use of the data and analytical techniques highlighted in these comments to assess climate hazards, evaluate potential impacts on their assets, operations, and supply chains, and communicate useful information about their exposure to physical climate related risks.

4.1. Con Ed's Climate Vulnerability Study

Following Hurricane Sandy in 2012, the Consolidated Edison Company of New York ("Con Ed") conducted a comprehensive climate change vulnerability study to evaluate the likelihood and consequences of a range of climate change scenarios.⁷¹ The study provides an example of how companies can conduct—and ultimately disclose—an assessment of physical climate-related risks and hazards.

Con Ed's vulnerability study evaluated climate change trends and potential extreme weather events across the company's service territory over three-time horizons: near (2030), intermediate (2050), and long-term (2080).⁷² The study focused on climate variables that could impact Con Ed's operations, planning, and infrastructure, namely temperature, humidity, precipitation, sea level rise and coastal flooding, extreme events, and multiple or compounding events.⁷³

For each climate variable mentioned above, the study team used a broad model ensemble—consisting of 32 global climate models—to address differences across models and to provide a more comprehensive view of future climate in the region.⁷⁴ Each global climate model was

See Elisabeth A. Lloyd et al., Climate Scientists Set the Bar of Proof Too High, 165 CLIMATIC CHANGE 55 (2021) ("[C]limate scientists have set themselves a higher level of proof in order to make a scientific claim than law courts ask for in civil litigation in the USA, the UK, and virtually all common law countries.").

CONSOLIDATED EDISON, CLIMATE CHANGE VULNERABILITY STUDY (2019), https://perma.cc/39E4-B77T. [Included as Attachment 1 to this letter]

 $[\]overline{Id. at 17.}$

⁷³ *Id*.

 $^{^{74}}$ Id

simulated using RCP4.5 and RCP8.5 to evaluate climate change hazards and account for model uncertainty under each RCP scenario.⁷⁵ In order to achieve a more accurate representation of the local climate across the New York Metropolitan Region (i.e., Con Ed's service territory), the study team bias corrected and downscaled the global climate model projections using weather station data over a 1976-2005 historical baseline from three weather stations across the service territory.⁷⁶

The Con Ed study revealed specific, actionable information about the impacts of climate change on the company's assets and operations. For example, the climate projections developed for the study showed a significant increase in the number of days with average temperatures above 86°F (up 1200 percent) and days with maximum temperatures above 95°F (up 575 percent) by 2050, which "create potential risks for Con Ed[] as they drive demand for air conditioning and stress electrical and infrastructure systems." The study further showed that Con Ed's system could be impacted by sea level rise and associated coastal flooding. According to climate projections, by 2100, 500-year flood events are expected to occur every ten years and the water-depth of present-day 100-year floods is expected to increase by up to fifty percent. The vulnerability study determined that, with this increase in flood height, at least seventy-five of Con Ed's electric substations would be vulnerable to flooding during a 100-year storm. Con Ed would need to spend \$636 million to harden those seventy-five substations.

Where quantitative results were not available for specific climate-related risks, the study described those risks in qualitative terms. For example, the study notes that "the percentage of very strong and destructive (i.e., Categories 4 and 5) hurricanes is projected to increase in the North Atlantic basin. It can therefore be argued that climate change could make it more likely for some of these storms to impact the New York Metropolitan Region, although the most dominant factor will remain unpredictable climate and weather variability."81

Based on the findings of the vulnerability study, Con Ed was able to identify specific assets that face physical climate risks and develop a plan to manage those risks (e.g., by replacing or hardening assets). After completing the vulnerability study, Con Ed developed a Climate Change Implementation Plan that explains how it "will incorporate climate change projections for heat, precipitation, and sea level rise from the [...] study into its operations to mitigate climate change risks to its assets and operations and establishes an ongoing process to reflect the latest science in the Company's planning."⁸² The Implementation Plan identifies 5-, 10-, and 20-year actions that

⁷⁶ *Id*.

⁷⁵ *Id*.

⁷⁷ *Id.* at 19-20.

⁷⁸ *Id.* at 23-24.

⁷⁹ *Id.* at 44.

⁸⁰ *Id*.

⁸¹ *Id.* at 24-25.

CONSOLIDATED EDISON, CLIMATE CHANGE IMPLEMENTATION PLAN 1 (2020), https://perma.cc/A32Z-JPGS.

Con Edison will take with respect to load forecasting, load relief planning, reliability planning, asset management, system planning, emergency response activities, and worker safety protocols.⁸³ The actions include elevating new critical electrical infrastructure in floodplains by three-feet to account for sea level rise and reduce the risk of inundation during coastal storms.⁸⁴

In summary, the Con Ed vulnerability study serves as a representative example of how companies can use the techniques highlighted in this letter to identify, evaluate, and ultimately disclose physical climate-related risks to their assets and operations.

4.2. UNEP FI's Climate Risk Landscape Assessment

A 2021 report from the United Nations Environment Programme Finance Initiative ("UNEP FI") illustrates the range of data and analytical techniques available to assess climate hazards; evaluate potential impacts on assets, operations, and supply chains; and communicate useful information about exposure to physical climate-related risks.

The report, titled *The Climate Risk Landscape* ("Landscape Report") surveyed various climate risk assessment tools used by financial institutions to evaluate and disclose physical and transition risks associated with climate change. ⁸⁵ The Landscape Report reviews nineteen commercially-available tools for assessing physical climate risk and eighteen commercially available transition risk assessment tools. ⁸⁶ With respect to the former, the Landscape Report finds that existing tools can be used to evaluate acute risks associated with extreme weather events, flooding, wildfires, and landslides, as well as chronic risks associated slow onset climate change impacts, such as sea level rise. ⁸⁷ The Landscape Report further notes existing tools are "being constantly updated to allow for more granular analysis that takes into account a broader, more plausible set of scenarios," and enables financial institutions to "provide consistent and market-ready disclosures." According to the Landscape Report, physical risk data is becoming easier to access in formats that are "easily usable by financial institutions." ⁸⁹

Following release of the 2021 Landscape Report, UNEP FI ran a pilot program in which forty-eight global banks and investors were given an opportunity to learn about, and trial, twelve

⁸³ *Id.* at 2.

⁸⁴ *Id.* at 8.

PAUL SMITH, UNEP FI, THE CLIMATE RISK LANDSCAPE: A COMPREHENSIVE OVERVIEW OF CLIMATE RISK ASSESSMENT METHODOLOGIES (2021), https://www.unepfi.org/publications/banking-publications/the-climate-risk-landscape/. [Included as Attachment 2 to this letter]

⁸⁶ *Id.* at 15 & 29.

⁸⁷ *Id.* at 32.

⁸⁸ *Id.* at 35 & 37.

⁸⁹ *Id.* at 37.

commercially available climate risk assessment tools. 90 The tools modeled impacts under several RCP scenarios.

The program participants included TD Asset Management Inc. ("TDAM"), which manages \$434 billion in assets on behalf of 3 million investors. TDAM trialed emissions analysis, climate scenario alignment analysis, transition risk analysis, and physical risk analysis tools made available by Institutional Shareholder Services ("ISS") ESG. ESG. We focus here on the physical risk analysis tool, which TDAM used to "measure[] the potential financial impact of the six most costly natural climate hazards such as floods, droughts or wildfires on the value of" a global equity portfolio that held 195 securities from over thirty countries. TDAM's analysis showed that physical climate risks are projected to result in a 1.6 percent and 2.8 percent change in portfolio value by 2050 under the most likely and worst-case RCP scenarios, respectively, and that "80% of the climate value-at-risk of the portfolio can be attributed to just 30 securities." TDAM also used the ISS ESG tool to evaluate the financial risks posed by specific climate impacts and found that wildfires and heat stress presented the greatest risk to its portfolio.

Another participant in the pilot program was Intesa Sanpaolo, an Italian bank that serves 13.5 million customers and has €341 billion in assets under management. ⁹⁶ Intesa Sanpaolo worked with Risk Management Solutions, Inc. ("RMS"), which has developed over 300 catastrophe risk models that can be used to assess "how frequently a given location can be expected to be impacted" by a particular hazard (e.g., flooding in excess of six feet), as well as "the frequency and severity of the economic impact caused by" the hazard. ⁹⁷ RMS used the models to quantify the flood risk of a sample of Intesa Sanpaolo's mortgage portfolio in regions throughout Italy under RCP6.0 and RCP8.5. ⁹⁸ Using RMS data, Intesa Sanpaolo calculated the impact on Loss Given Default and the Probability of Default to range from five to thirty-nine percent of the initial values. ⁹⁹ Intesa Sanpaolo further estimated, under RCP8.5, the average annual loss would increase fifty percent over the baseline in the provinces of Rome and Naples by 2040. ¹⁰⁰

⁹⁰

DAVID CARLIN & ALEXANDER STOPP, UNEP FI, THE CLIMATE RISK TOOL LANDSCAPE: 2022 SUPPLEMENT (2022), https://www.unepfi.org/publications/the-climate-risk-tool-landscape-2022-supplement/. [Included as Attachment 3 to this letter]

TD Asset Management, *About Us*, https://perma.cc/8AR9-AXPN (last visited Dec. 6, 2022).

⁹² CARLIN & STOPP, *supra* note 91, at 38-39.

⁹³ *Id.* at 39.

⁹⁴ *Id.* at 42.

⁹⁵ *Id.* at 43.

Intesa Sanpaolo, *Business, About Us*, https://perma.cc/QU5L-VXT2 (last Dec. 6, 2022).

⁹⁷ CARLIN & STOPP, *supra* note 91, at 26 & 62.

⁹⁸ *Id.* at 64.

⁹⁹ *Id.* at 66.

¹⁰⁰ *Id.* at 65.

A third pilot program participant was Desjardins Group, a financial cooperative with over seven million members and customers, and over \$397 billion in assets. ¹⁰¹ Desjardins partnered with The Climate Service ("TCS"), which used its Climanomics platform to evaluate physical and transition risks across fifty of Dejardins' real assets. ¹⁰² The Climanomics platform models absolute climate risk, measured in millions of USD and relative climate risk, reported as percent of asset value. ¹⁰³ The analysis of Dejardins' assets revealed that fluvial flooding is the greatest physical risk to the assets under both RCP4.5 and RCP8.5 scenarios. ¹⁰⁴ Drought was identified as the second greatest physical risk to the assets. ¹⁰⁵ Desjardins was able to conduct asset-level risk analyses. For example, the analysis showed that a dairy farm located northeast of Montreal, Canada, would "face a modeled average annual loss (MAAL) of 6.7% to 8.5% for RCP4.5 and RCP8.5, respectively." ¹⁰⁶ The analysis further showed that "[t]he highest risks faced are from temperature extremes, followed to a lesser degree by fluvial flooding and drought at both RCP4.5 and RCP8.5 scenarios. The largest difference among the two is temperature extremes representing a 5.7% MAAL in RCP8.5 and 3.9% MAAL in RCP4.5." ¹⁰⁷

The above examples demonstrate how companies can use existing tools to evaluate, and ultimately disclose, the physical risks they face from flooding, drought, and other climate change impacts. As UNEP FI has noted, climate risk assessment methodologies are advancing rapidly, and new tools are becoming available. UNEP FI predicts that physical risk models will continue to improve and provide increasingly "granular" data that will "allow [] more accurate risk analysis." 109

4.3. Rio Grande Project EIS

The Bureau of Reclamation's Final Environmental Impact Statement ("EIS") for the Rio Grande Project provides another example of how private companies can use climate science to understand and communicate the physical risks of climate change. 110

The Rio Grande Project supplies irrigation to about 178,000 acres of land and provides electrical power for communities and industries in the area. Physical features of the project include

104 *Id.* at 84.

106 *Id.* at 85.

Desjardins Group, *Quick facts about Desjardins*, https://perma.cc/7HHX-XPXQ (last visited Dec.

¹⁰² CARLIN & STOPP, *supra* note 91, at 80.

¹⁰³ *Id*.

¹⁰⁵ *Id*.

¹⁰⁷ *Id.* at 85.

Id. at 8; SMITH, *supra* note 86, at 35.

SMITH, *supra* note 86, at 37.

BUREAU OF RECLAMATION, FINAL ENVIRONMENTAL IMPACT STATEMENT: CONTINUED IMPLEMENTATION OF THE 2008 OPERATING AGREEMENT FOR THE RIO GRANDE PROJECT, NEW MEXICO AND TEXAS (2016), https://perma.cc/K3YN-8C5T. [Included as Attachment 4 to this letter]

the Elephant Butte and Caballo dams, as well as hundreds of miles of canals and associated infrastructure, and a hydroelectric plant. The project's climate impact analysis was designed to understand how the management of this system would operate under future climate conditions through 2050. Therefore, the EIS used climate model output generated from an ensemble of 112 statistically downscaled projections and developed three possible scenarios—a drier scenario, a median or "central tendency" scenario, and a wetter scenario. Hydrology models were then used to simulate changes in runoff and streamflow across the river basin of the Rio Grande using these three precipitation scenarios.

In the EIS, the study authors were able to isolate "worst case" scenarios for various regions across the river basin. For example, the wetter scenario represented a worst case for species that inhabit the Elephant Butte reservoir, while the drier scenario is the worst case for species located downstream of the Caballo dam. This study further demonstrates the techniques outlined in this letter, such as employing qualitative narratives as appropriate and using ensemble data from multiple climate models, can produce critical information that characterizes the climate risk to a company's physical assets.

5. Conclusion

As the IPCC has recognized, it is "unequivocal" that human activities are warming the planet, leading to "widespread and rapid changes" that pose significant economic and other risks. Using the methods described above, companies can assess, and ultimately disclose, their exposure to the physical risks of climate change. As the case studies demonstrate, private companies and others are already successfully employing available climate tools and data to generate critical information to inform their own decision-making and that of regulators.

Sincerely,

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¹¹¹ IPCC, supra note 3, at 4.

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Attachments (4):

- (1) Consolidated Edison, Climate Change Vulnerability Study (2019)
- (2) Paul Smith, UNEP FI, The Climate Risk Landscape: A Comprehensive Overview of Climate Risk Assessment Methodologies (2021)
- (3) David Carlin & Alexander Stopp, UNEP FI, The Climate Risk Landscape: 2022 Supplement (2022)
- (4) Bureau of Reclamation, Final Environmental Impact Statement: Continued Implementation of the 2008 Operating Agreement for the Rio Grande Project, New Mexico and Texas (2016)

ATTACHMENT 1

Consolidated Edison, Climate Change Vulnerability Study (2019)



Climate Change Vulnerability Study

December 2019



Climate Change Vulnerability Study December 2019



In partnership with:



Lamont-Doherty Earth Observatory COLUMBIA UNIVERSITY | EARTH INSTITUTE

With contributions from O'Neill Management Consulting, LLC, The Risk Research Group, Inc., and Jupiter Intelligence Inc.

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Executive Summary

In its 2013 rate case filing after Superstorm Sandy, Con Edison proposed \$1 billion in storm hardening investments to build additional resiliency into its energy systems. Con Edison worked with a Storm Hardening and Resiliency Collaborative to recommend optimal investments for the proposed storm hardening funds, including the recommendation that Con Edison conduct a Climate Change Vulnerability Study (Study). As described by the New York State Public Service Commission, the purpose of this Study is to aid in the ongoing review of the Company's design standards and development of a risk mitigation plan.¹ Over the course of the Study, Con Edison regularly convened a stakeholder group to provide feedback, consisting of many of the same participants from the Storm Hardening and Resiliency Collaborative. The findings from the Study equip Con Edison with a better understanding of future climate change risks and strengthen the company's ability to more proactively address those risks.

This Study describes historical and projected climate changes across Con Edison's service territory, drawing on the best available science, including downscaled climate models, recent literature, and expert elicitation. Con Edison recognizes the global scientific consensus that climate change is occurring at an accelerating rate. The exact timing and magnitude of future climate change is uncertain. To account for climate uncertainty, the Study considered a range of potential climate futures reflecting both unabated and reduced greenhouse gas concentrations through time and evaluated extreme event "stress test" scenarios.

This Study evaluates present-day infrastructure, design specifications, and procedures against expected climate changes to better understand Con Edison's vulnerability to climate-driven risks. This analysis identified sea level rise, coastal storm surge, inland flooding from intense rainfall, hurricane-strength winds, and extreme heat as the most significant climate-driven risks to Con Edison's systems. Con Edison has unique energy systems, and vulnerabilities vary across those systems. The utility's electric, gas, and steam systems are all vulnerable to increased flooding and coastal storms; workers across all commodities are vulnerable to increasing temperatures; and the electric system is also vulnerable to heat events.

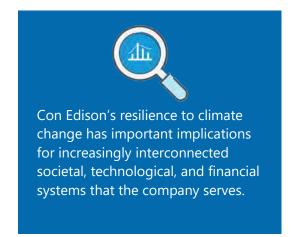
While Con Edison already uses a range of measures to build resilience to weather events, the vulnerabilities identified in this Study guide the company to pursue additional strategies to mitigate climate risks. The Study establishes an overarching framework that can work to strengthen Con Edison's resilience over time. While many adaptation strategies focus on avoiding impacts altogether, a comprehensive resilience plan also requires a system that can reduce and recover from impacts, particularly following outages.

Over the course of 2020, Con Edison will develop and file a Climate Change Implementation Plan, which will specify a governance structure and a strategy for implementing adaptation options over the next 5, 10, and 20 years. While this Study assesses vulnerabilities within Con Edison's present-day systems to a future climate, the implementation plan must also consider the evolving market for energy services, and potential changes to services and infrastructure driven by customers, government policy and external actions over time.

¹ Cases 13-E-0030, 13-G-0031, 13-S-0032, Order Adopting Storm Hardening and Resiliency Collaborative Phase Three Report Subject to Modifications (January 25, 2016).

The Need for a Study

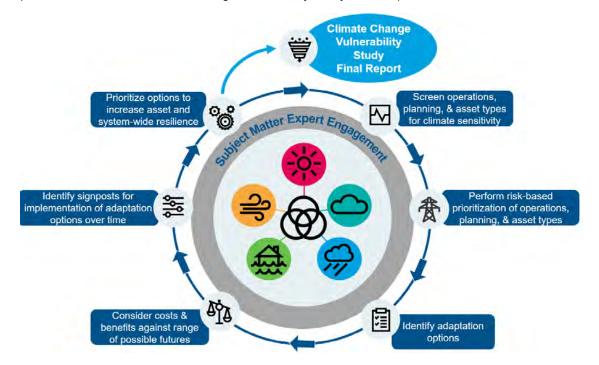
The New York State Public Service Commission approved an Order and funding for Con Edison to conduct a Climate Change Vulnerability Study, with a requirement for delivery by the end of 2019. The Con Edison Department of Strategic Planning undertook this Study with support from more than 100 subject matter experts throughout the company and in collaboration with ICF's climate adaptation and resilience experts and Columbia University's Lamont-Doherty Earth Observatory. The Study was designed to meet three primary goals:



- Research and develop a shared understanding of new climate science and projected extreme weather for the service territory.
- 2. Assess the risks of potential impacts of climate change on operations, planning, and physical assets.
- **3.** Review a portfolio of operational, planning, and design measures, considering costs and benefits, to improve resilience to climate change.

The Study used an integrated approach to achieve these goals, as shown in Figure 1.

Figure 1 ■ General approach overview: The process cycles through the steps for each climate hazard, beginning with 'Screen operations, planning, and asset types for climate sensitivity'. The process results in the Climate Change Vulnerability Study Final Report.



A New Understanding of Climate Science and Extreme Weather

Con Edison will face new challenges from a rapidly changing climate through the 21st century. To better understand these challenges, the Study characterized historical and projected changes to climate hazards within the service territory to estimate the magnitude and timing of potential climate vulnerabilities. Climate variables that present outsized impacts to Con Edison include temperature, humidity, precipitation, sea level rise, and extreme events, such as rare hurricanes and long-duration heat waves.

Temperature

Average and maximum air temperatures are projected to increase throughout the century relative to historical conditions. Assuming unabated greenhouse gas concentrations, Con Edison could experience up to 23 days per year in which maximum temperatures exceed 95°F by 2050 relative to 4 days historically. Heat waves with 3 or more days when *average* temperatures exceed 86°F in Central Park are projected to occur up to 5 and 14 times per year by 2050 and 2080, respectively, relative to 1 heat wave every 5 years historically.

Humidity

The frequency of very high heat index thresholds, which combines both temperature and humidity, is projected to increase dramatically through the century. The number of days per year where the heat index equals or exceeds 103°F could increase by 7 to 26 days by 2050, compared with only 2 days historically. In addition, Con Edison evaluates the relationship of system load to an index called temperature variable (TV), which is similar to a heat index, but considers the persistence of heat and humidity over several days. Looking forward, TV thresholds that historically occur only once per year (e.g., 86°F) are projected to become common occurrences within a generation, occurring between 4 and 19 times per year by 2050 and between 5 and 52 times per year by 2080 based on reduced and unabated greenhouse gas concentrations, respectively.

Precipitation

Con Edison's service territory experiences rainfall, downpours, snowfall, and ice. Climate change is projected to drive heavier precipitation across these event types. For example, the heaviest 5-day precipitation total could be 11.8 inches at Central Park by 2050, which represents a 17% increase over the historical reference period. Ultimately, projections point to a future defined by more frequent heavy precipitation, likely accompanied by smaller increases in the frequency of dry or light precipitation days.

Sea Level Rise

Sea levels are very likely to rise between 0.62 and 1.94 feet by 2050. In turn, rising sea levels will have profound effects on coastal flooding, as sea level rise increases both the frequency and height of future floods. For example, the flood height associated with the 1% annual chance flood (i.e., the so-called 100-year flood) in New York City is projected to increase from 8.3 feet to as much as 13.3 feet by 2100 relative to mean sea level at the Battery tide gauge. By the end of the century, today's annual chance flood could occur at every high tide.

Extreme Events

Extreme events are low-probability and high-impact phenomena, such as hurricanes and long-duration heat waves. While difficult to simulate in climate models, a growing body of evidence suggests that many extreme events will increase in frequency and intensity as a result of climate warming. This Study considers high impact "worst-case" extreme event scenarios, including a prolonged heat wave, a Category 4 hurricane, and an unprecedented nor easter, to understand these changes and their impacts on Con Edison.

Characterization of Con Edison's Vulnerabilities to Climate Risks

Heat and Temperature Variable

The core electric vulnerabilities to increasing temperature and TV include increased asset deterioration, decreased system capacity, increased load, and decreased system reliability. Since the internal temperature of electric power equipment is determined by the ambient temperature as well as the power being delivered, higher ambient temperatures increase the internal operating temperature of equipment.

Higher internal operating temperatures increase the rate of aging of the insulation of electric equipment such as transformers, resulting in decreased total life of the assets. Higher internal temperatures, resulting from higher average and maximum ambient temperatures, also reduce the delivery capacity of electric equipment such as transformers. In addition, higher ambient temperatures increase the operating temperature of overhead transmission lines, causing increased sagging. One remedy is to decrease the operational rating of the assets to reflect the new operating environment. However, derating the system due to increasing temperatures would effectively decrease the capacity of the system, and Con Edison will need to make investments to replace that capacity if it is needed.

Similarly, higher TV can cause higher peak loads due to increases in demand for cooling. Increases in load may also require investments in system capacity to meet the higher demand. The combination of decreased capacity and increased load is best addressed through Con Edison's existing 10- and 20-year load relief program. Addressing this combined risk is estimated to cost between \$1.3 billion and \$4.6 billion by 2050 (based on future projections using Representative Concentration Pathway (RCP) 4.5 10th and RCP 8.5 90th percentiles, respectively).

Increases in heat waves are expected to affect the electric network and non-network systems by decreasing reliability. Con Edison uses a Network Reliability Index (NRI) model to determine the reliability of the underground distribution networks. The Study's forward-looking NRI analysis found that with an increase in the frequency and duration of heat waves by mid-century, between 11 and 28 of the 65 underground networks may not be able to maintain Con Edison's standard of reliability by 2050, absent adaptation.

Outdoor worker safety may be a concern across all Con Edison commodities if heat index values rise as projected. When needed, Con Edison can implement safety protocols (e.g., shift modifications and hydration breaks) already practiced in mutual aid work that the company provided in hotter locations such as Florida and Puerto Rico. Similarly, to supply sufficient cooling in 2080, Con Edison's heating, ventilation, and air conditioning (HVAC) capacity will have to increase by 11% due to projected increases in dry bulb temperature. These systems have a roughly

² "Worst-case" scenarios are meant to explore Con Edison system vulnerabilities related to rare extreme weather events and formulate commensurate adaptation and resilience strategies. Scenarios represent one plausible permutation of extreme weather and the severity of actual events may exceed those considered.

15-year life span and therefore can be upgraded during routine replacements with minimal cost increases.

Flooding from Precipitation, Sea Level Rise, and Coastal Storms

All underground assets are vulnerable to flooding damage (i.e., water pooling, intrusion, or inundation) from precipitation events, sea level rise, and coastal storms. Following Superstorm Sandy in 2012, Con Edison protected all infrastructure in the floodplain against future 100-year storms and 1 foot of sea level rise (e.g., submersible infrastructure, flood walls, pumps, elevation). Sea level rise projections suggest that Con Edison's 1 foot of sea level rise risk tolerance threshold may be exceeded as early as 2030 and as late as 2080.

Electric substations, overhead distribution, underground distribution, and the transmission system are sensitive to precipitation-based hazards, although the design of Con Edison's assets already mitigates some of these risks. For example, flooding from increased intense precipitation can damage non-submersible electrical equipment, although Con Edison designs all underground cables and splices to operate while submerged in water. In addition, all underground distribution equipment installed in flood zones and all new installations are submersible.

To assess future asset vulnerability to sea level rise and storm surge, the Study team analyzed the exposure of Con Edison's assets to 3 feet of sea level rise, while keeping the other elements of Con Edison's existing risk tolerance constant (i.e., a 100-year storm with 2 feet of freeboard). Of the 324 substations (encompassing generating stations, area substations, transmission stations, unit substations, and Public Utility Regulating Stations), 75 would be vulnerable to flooding during a 100-year storm if sea level rose 3 feet. In addition, 32 gas regulators and five steam generation stations would be exposed. Hardening all of these assets would cost approximately \$680 million.

Both the gas and steam distribution systems are vulnerable to water entry, which can reduce system pressure and limit distribution capacity. In the gas system, low-pressure segments³ are particularly vulnerable to this risk. In addition, the steam system is susceptible to "water hammer" events when a high volume of water collects around a manhole, causing steam in the pipes underneath to cool and condense. Interaction between steam and the built-up condensate may cause an explosion, both damaging the steam system and putting public safety at risk.

Across all commodities, increased winter precipitation can wash salt from city roads, causing an influx of salt-saturated runoff into manholes and percolation into the ground. Salt can cause equipment degradation, arcing, manhole fires or explosions, and failure of underground assets.

Extreme and Multi-Hazard Events

The Study team reviewed the vulnerabilities of Con Edison's electric, gas and steam systems to future extreme events based on specific, worst case extreme event narratives (Category 4 hurricane, a strong nor'easter, and a prolonged heat wave) designed to stress-test these systems.

Storm surge driven by an extreme hurricane event (i.e., a Category 4 hurricane) has the potential to flood both aboveground and belowground assets. In addition, wind stress and windblown debris can lead to tower and/or line failure of the overhead transmission system and damage overhead distribution infrastructure, which could cause widespread customer outages.

³ The Con Edison gas system contains piping operating at three pressures: low, medium, and high.

An extreme nor'easter may cause significant damage to assets across all commodities. During nor'easters, accumulation of radial ice can cause tower or line failure of the overhead transmission system. Similarly, snow, ice, and wind can damage the overhead distribution system.

Con Edison's systems are vulnerable to exceeding system capacity during extreme temperatures; gas systems may experience overloading during extreme cold, and electric systems during extreme heat.

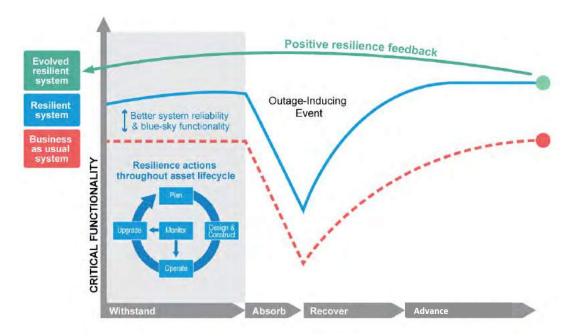
On an operational level, the increasing frequency and intensity of extreme weather events may exceed Con Edison's currently robust emergency preparedness efforts. Con Edison's current "full-scale" response, which calls for all Con Edison resources and extensive mutual assistance, is initiated when the number of customers out of service reaches approximately 100,000. However, low-probability extreme events can increase customer outages and outage durations by orders of magnitude, outpacing current levels of emergency planning and preparedness.

Resilience Management Framework

A resilience management framework will help Con Edison build resilience over time.

To conceptualize how to systematically address vulnerabilities, the Study team developed a resilience management framework (Figure 2). The framework encompasses investments to better withstand changes in climate, absorb impacts from outage-inducing events, recover quickly, and advance to a better state. The "withstand" component of this framework prepares for both gradual and extreme climate risks through resilience actions throughout the life cycle of the assets. As such, many adaptation strategies fall under this category. Investments to increase the capacity to withstand also provide critical co-benefits such as enhanced blue-sky functionality and reliability of Con Edison's systems. The resilience management framework facilitates long-term adaptation and creates positive resilience feedback so that Con Edison's systems achieve better functionality through time. To succeed, each component of a resilient system requires proactive planning and investments.

Figure 2 ■ Conceptual figure representing a resilience management framework designed to withstand changes in climate, absorb and recover from outage-inducing events, and advance to a better state. Most resilience actions should occur systematically throughout the asset life cycle to enhance the ability to withstand changes in climate, while also enhancing system reliability and blue-sky functionality. Resilient systems also adapt so that the functionality of the system improves through time (green line). Each component of a resilient system requires proactive planning and investments.



Adaptation Measures to Address Vulnerabilities

Con Edison already has undertaken a range of measures to build resilience; this Study identified additional adaptation options to address vulnerabilities under a changing climate.

Con Edison has already undertaken a range of measures to increase the resilience of its systems. For example, lessons learned and vulnerabilities exposed during past events, including Superstorm Sandy (2012) and the back-to-back nor'easters (winter storms Riley and Quinn, 2018), resulted in significant capital investments to harden the system. Looking forward, as Con Edison is investing in the system of the future—one with greater monitoring capabilities, flexibility, and reliability—it is simultaneously building a system that is more resilient to extreme weather events and climate change. In addition to new investments, Con Edison also conducts targeted annual updates to its system to ensure capacity and reliability, which help the company keep pace with recent changes in temperature and humidity.

Withstand Gradual Changes in Climate and Extreme Events

Resilience actions should occur systematically throughout an asset's life cycle to enhance the ability to withstand changes in climate while also enhancing system reliability and blue-sky functionality. This can be accomplished through planning, designing, and upgrading assets in a resilient manner, with ongoing monitoring throughout.

Plan

Incorporating climate change projections into Con Edison's routine planning processes will help identify capital needs and help the systems gradually adjust to changes in climate. Some of the types of planning processes and tools that may benefit from consideration of climate change include the following:

- Load and volume forecasting for all commodities
- Load relief planning for the electric system, which should include reduced system capacity and higher load due to warmer temperatures
- Working with utilities in other environments to understand how they plan and design their system for the climate Con Edison will experience in the future
- Long-range planning for all commodities
- Network reliability modeling and planning

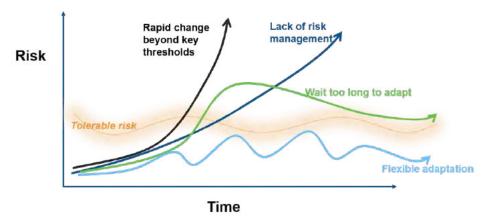
Design

The key to designing resilient infrastructure is to update design standards, specifications, and ratings to account for likely changes in climate over the life cycle of the infrastructure. While there is uncertainty as to the exact changes in climate an asset will experience, selecting an initial climate projection design pathway allows engineers to design infrastructure in line with Con Edison's risk tolerance. The Study team suggests an initial climate projection design pathway that follows the 50th percentile merged RCP 4.5 and 8.5 projections for sea level rise and high-end 90th percentile merged RCP 4.5 and 8.5 projections for heat and precipitation.

Upgrade

Changing design standards will influence the construction of new assets but does not address the vulnerability of existing assets. A flexible and adaptive approach to managing and upgrading assets will allow Con Edison to manage risks from climate change at acceptable levels, despite uncertainties about future conditions. The flexible adaptation pathways approach allows Con Edison to adjust adaptation strategies as more information about climate change and external conditions that may affect Con Edison's operations is learned over time. Figure 3 depicts how flexible adaptation pathways are based on flexible management to maintain tolerable levels of risk.

Figure 3 ■ Flexible adaptation pathways in the context of tolerable risk and risk management challenges to non-flexible adaptation. Adapted from Rosenzweig & Solecki, 2014.



As conditions change over time, Con Edison will need to consistently track these changes to identify when decision making for additional or alternative adaptation strategies is required. This approach relies on monitoring indicators, or "signposts," that provide information which is critical for adaptive management decisions. Broad categories of signposts that Con Edison should consider monitoring include climate variable observations and best available climate projections; climate impacts; and policy, societal, and economic conditions. Predetermined thresholds for these conditions signal the need for a change in action, which support decisions on when, where, and how Con Edison can take action to continue to manage its climate risks at an acceptable level. The body of this report provides many specific examples of proactive investments in resilience and their signposts; a few selected examples are provided in Table 1.

Table 1 ■ Examples of adaptation strategies to upgrade existing infrastructure and signposts to trigger action

Strategy	Signpost
Implement electric reliability strategies, such as: Split the network into two smaller networks. Create primary feeder loops within and between networks. Install a distribution substation. Incorporate distributed energy resources and non-wires solutions. Design complex networks that consider combinations of adaptation measures.	Forward-looking network reliability index exceeds 1 per unit
Upgrade HVAC systems.	End of the existing asset's useful life
Retrofit ventilated equipment with submersible equipment to eliminate the risk of damage from water intrusion.	Expanded area of precipitation-based flooding; better maps of areas at risk of current and future precipitation-based flooding
Replace limiting wire sections with higher rated wire to reduce overhead transmission line sag during extreme heat wave events. Alternatively, remove obstacles or raise towers to reduce line sag issues.	Increased incidence of line sag; higher operating temperatures
Strategically expand program to elevate gas regulator vent line termini to include additional regulators exposed to floodplains associated with stronger storms and inland flooding.	When sea level rise exceeds 1 foot; reported or observed flooding in vicinity of asset without vent line protectors

Absorb and Recover from the Impacts of Extreme Events

It is neither efficient nor cost-effective for Con Edison to harden its systems to withstand every type of extreme event. Instead, Con Edison must use a broader suite of adaptation strategies to absorb and recover from the inevitable disruptions caused by extreme events exceeding their design

standards. Con Edison currently incorporates "absorb" into its design and operations with, for example, a limited ability to control customer demand and shed load in extreme cases. A broader suite of strategies focuses on emergency preparedness, limiting customer impact and improving customer coping, including the following:

- Supporting the creation of resilience hubs (spaces that support residents and coordinate resources before, during, and after extreme weather events (Baja, 2018) and have continued access to energy services)
- Using smart meters to implement targeted load shedding to limit the impact to fewer customers during extreme events
- Strengthening staff skills for streamlined emergency response
- Planning for resilient and efficient supply chains
- Coordinating extreme event preparedness plans with external stakeholders
- Incorporating low-probability events into long-term plans
- Expanding extreme heat worker safety protocols
- Examining and reporting on the levels of workers necessary to prepare for and recover from extreme climate events
- Investing in energy storage, on-site generation, and energy efficiency programs

Advance

Advancing to a better adapted, more resilient state after an outage-inducing event (i.e., building back better/stronger) begins with effective pre-planning for post-event reconstruction. Even with proactive resilience investments, events can reveal system or asset vulnerabilities. Where assets need to be replaced during recovery, having a plan already in place for selection and procurement of assets designed to be more resilient in the future can help to ensure that Con Edison is adapting to a continuously changing risk environment. Outage-inducing events also provide important opportunities to measure the performance of adaptation investments, helping to inform additional actions that further resilience.

Next Steps

In 2020, Con Edison will develop an implementation plan that details priority actions needed in the next 5, 10, and 20 years.

As a next step from this Study, Con Edison will develop a detailed Climate Change Implementation Plan to integrate the recommendations from this Climate Change Vulnerability Study. The implementation plan will be developed in close coordination with Con Edison SMEs and will utilize quarterly meetings with external stakeholders. The implementation plan will consider updates in climate science, finalize an initial climate design pathway, integrate that pathway into company specifications and processes based on input from subject matter experts, develop a timeline for action with associated costs and signposts, and recommend a governance structure. Some key items for consideration in the implementation plan include determining the appropriate amount of proactive investment, changes in the policy/regulatory and operating environment and the establishment of a reporting structure.



Introduction

Study Background and Objectives

Con Edison's resilience to climate change has important implications for increasingly interconnected societal, technological, and financial systems that the company serves. Developing a shared understanding of Con Edison's vulnerability to climate change is critical to ensuring the continued strength of the company over the coming century. The Con Edison Climate Change Vulnerability Study (Study) has three primary goals:

- 1. Develop a shared understanding of new climate science and projected climate and extreme weather for the territory.
- 2. Assess the risks of potential climate change impacts on Con Edison's operations, planning, and physical assets.
- **3.** Review a portfolio of operational, planning, and design measures, considering costs and benefits, to improve resilience to climate change.

The Study was conducted as an outcome of the 2013 rate case. In 2013, Con Edison worked with a Storm Hardening and Resiliency Collaborative in parallel with the rate case to provide parties with an opportunity to fully examine proposals for plans to protect against storms. In 2014, the New York State Public Service Commission approved an Order and funding for Con Edison to implement measures to plan for and protect its systems from the effects of climate change, including conducting a climate change vulnerability study. The Study was developed by the Con Edison Department of Strategic Planning, in collaboration with ICF's climate adaptation and resilience experts and Columbia University's Lamont-Doherty Earth Observatory. The members of this partnership are collectively referred to as the Study team. The Study team relied on inputs and expertise from Con Edison subject matter experts (SMEs), including engaging more than 100 SMEs through a series of in-person meetings, teleconferences, and workshops.

Guiding Principles

The Study used six key principles to efficiently meet its objectives and benefit Con Edison. The Study employed a decision-first and risk-based approach, applying the best available climate science to produce flexible and adaptive solutions and mitigate risks associated with climate change and extreme weather events. The Study process was transparent and interactive to ensure that it can be replicated and institutionalized.



Decision-first approach. The Study team used a decision-first approach, which focuses on understanding the broader vulnerabilities and constraints of the system, the objectives and needs of stakeholders, and the adaptation options available, before considering the projected changes in future climate. The Study team first identified the needs of decision makers (i.e., Con Edison leadership and SMEs) and worked from there to determine information requirements based on decision goals, instead of starting by amassing as much data as possible. This approach places a higher priority on understanding the decision-making context and providing enough information to inform those decisions, which helps to prioritize near- and long-term risks and develop effective solutions despite the existence of deep uncertainties related to future climate change.

Risk-based approach. The Study team employed a risk-based approach that considers both the likelihood and the consequence of potential changes in the climate. This involves identifying a comprehensive set of plausible future climate outcomes and assessing their probability and associated impact on Con Edison's service territory. Doing so allows Con Edison to assess its vulnerability to—and to prepare for—high-probability and low-impact, as well as low-probability and high-impact, outcomes.

Best available climate science. The Study team prioritized continuous dialogues among climate scientists, climate adaptation specialists, and Con Edison SMEs to identify which climate scenarios, time periods, hazards, variables, and thresholds are important for Con Edison's operations, infrastructure, and planning. The Study team assessed multiple lines of evidence to capture historical climate conditions in the territory and employed a comprehensive set of Global Climate Models to identify the extent to which current climate conditions may change throughout the 21st century. Ultimately, the Study team synthesized climate information into metrics relating plausible effects of climatic changes on operations, infrastructure, and planning.

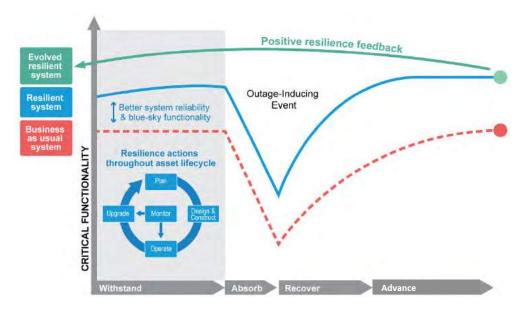
Transparent and replicable. A transparent and replicable approach allows Con Edison to institutionalize its adaptation strategy and increase its adaptive capacity over time. This will help SMEs establish their adaptation efforts into emerging policies and procedures, as well as train the next generation of SMEs in resilience building. Transparency also engenders trust with internal and external stakeholders.

Flexible solutions and adaptive implementation. A flexible and adaptive approach will allow Con Edison to manage risks from a changing climate at acceptable levels, despite uncertainties about future conditions. Adaptive implementation pathways, or flexible adaptation pathways, are a recognized approach to adaptation planning and project implementation that ensures adaptability over time in the face of uncertainty: changes in energy demand, technologies, population, and other driving factors, and refinements in the scientific understanding of future climate. Under the adaptive approach, resilience measures can be sequenced over time, allowing Con Edison to protect against near-term changes while leaving options open to protect against the wide range of plausible changes emerging later in the century.

Resilience management framework. The Study introduces a resilience management framework that allows Con Edison to mitigate risks associated with climate changes and extreme weather events most relevant to Con Edison's service territory (Figure 4). Resilient systems are composed of more than hardening measures alone, and instead consider measures that increase resilience throughout the life cycle of outage-inducing climate events. These measures include the system's capacity to "withstand," "absorb," and "recover" from climate risks and "advance" resilience. In this way, the resilient management framework is particularly important for addressing complex extreme

events with significant uncertainties and extreme thresholds to build into hardening measures alone. In turn, resilient systems offer critical co-benefits, such as improved system reliability and blue-sky functionality, reduced consequences from non-climatic risks, and more resilient customers. A resilience management framework also facilitates long-term adaptation, which enhances the critical functionality of the system through time and creates positive resilience feedback. To succeed, each measure of a resilient system requires proactive planning and investments.

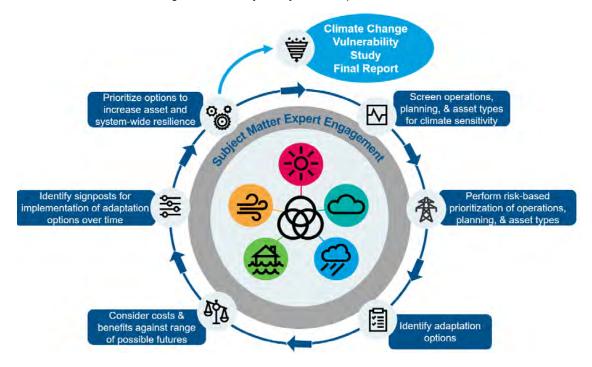
Figure 4 ■ Conceptual figure representing a resilience management framework designed to withstand changes in climate, absorb and recover from outage-inducing events, and advance to a better state. Most resilience actions should occur systematically throughout the asset life cycle to enhance the ability to withstand changes in climate, while also enhancing system reliability and blue-sky functionality. Resilient systems also adapt so that the functionality of the system improves through time (green line). Each component of a resilient system requires proactive planning and investments.



Study Methodology

The Study uses an integrated approach, with Con Edison SMEs providing support throughout the process. A rapid screen of the sensitivity of operations, planning, and assets (referred to for simplicity as "assets" throughout the rest of this document unless otherwise stated) for each climate change hazard provided the basis for a risk-based prioritization of assets. The Study team performed detailed analyses for the sensitive assets, including identifying a portfolio of adaptation options and qualitatively considering the financial costs, co-benefits, and resilience of each option. These detailed analyses will inform the development of flexible solutions and the further prioritization of assets and options to increase systemwide resilience during the creation of Con Edison's Climate Change Implementation Plan in 2020. Figure 5 depicts the Study's general approach.

Figure 5 General approach overview: The process cycles through steps for each climate hazard, beginning with 'Screen operations, planning, and asset types for climate sensitivity'. The process results in the Climate Change Vulnerability Study Final Report.



Screen operations, planning, and asset types for climate sensitivity. The Study began by establishing and confirming a clear set of climate change hazards and relevant thresholds for operations, planning, and asset types. The study team engaged SMEs to identify the extent to which each climate change hazard is a factor in asset design or operation and rate sensitivities by considering impacts from previous weather events and key climate information used in design or operation. Only assets with high sensitivity were considered in the subsequent risk-based prioritization process.

Perform risk-based prioritization of operations, planning, and asset types. Following the high-level screen for sensitivity, the Study team sought to prioritize operations, planning processes, and asset types for further analysis.

- Heat and humidity: Heat and humidity design standards vary across Con Edison assets, so the Study team used a risk workbook to guide SMEs through a structured process to identify the probability of impact (based on the probability of exceeding thresholds and the impact of threshold exceedance) and the consequence of impact. Together, these components create an overall risk score for each relevant asset and climate change hazard combination. Consequence is defined as the likely impact to the overall system given the possibility for damage or failure of the particular asset, and includes reliability, safety, environmental damage, and financial costs to the company or customers. The Study team identified several asset types and variable combinations with high sensitivity and high overall climate risk to carry forward as priorities in the analysis.
- Sea level rise and storm surge: Sea level rise and storm surge is a geographically defined hazard with a common design standard across all Con Edison assets. As such, there was a need to



identify potentially exposed assets rather than prioritize among them. The Study team used Geographic Information System (GIS) modeling to evaluate the specific type and number of assets that would be exposed under various future scenarios.

- Precipitation: Very few of Con Edison's assets have design standards tied to precipitation. For the
 few that were identified, the Study team evaluated whether the assets would withstand future
 increases in the intensity of precipitation events. In addition, the Study team worked with Con
 Edison SMEs to identify and prioritize the operational impacts of precipitation on the various
 commodities.
- Extreme events: By definition, the extreme events analyzed in the study exceed all existing Con
 Edison design standards. As such, the Study team conducted a workshop with SMEs to prioritize
 extreme event risks based on the following:
 - The potential for impacts on operations, planning, and assets
 - How prior major weather events affected assets and operations
 - The preparations that Con Edison has in place for future extreme events
 - How longer or more intense events might overwhelm current preparedness efforts

Identify adaptation options. For the identified vulnerabilities, the Study team developed adaptation response options through SME engagement, review of relevant literature, and lessons learned from adaptation options implemented in regions with similar challenges. Adaptation options include strategies to withstand a changing climate, such as engineering design, operations, and planning strategies, as well as strategies to absorb and recover from extreme events. The Study team considered adaptation options that are often already in use to manage the hazard, but which may require revision or updating to deal with changing risk. The Study team also considered both short-term and long-term solutions and took steps to understand and assess the limitations of adaptation options.

Consider costs and benefits of adaptation options against a range of possible futures. The Study team worked with SMEs to develop order of magnitude costs of the various adaptation strategies, where feasible. Where possible, the Study team conducted a multi-criteria analysis of the adaptation options to compare criteria that may be difficult to quantify or monetize, or that may not be effectively highlighted in the financial analysis.

Identify signposts for implementation of adaptation options over time. Evaluation of adaptation measures in the context of a continuously changing risk environment poses a challenge to typical project planning, design, and execution. It is important to ensure that decision-making processes support flexible solutions that allow for effective risk management in the face of irreducible uncertainties in projections of future climate conditions. The Study uses an adaptive implementation pathway approach to achieve this goal. The Study team designed a framework for "signposts," which represent information that will be tracked over time to help Con Edison understand how climate, policy, and process conditions change and, in turn, trigger additional action.

Prioritize options to increase asset and systemwide resilience. Once the prior steps were completed, the Study team circulated the findings to SMEs to allow them to strike, add, or refine strategies. This process resulted in the prioritized set of strategies included in this report.



Historical and Future Climate

Con Edison in a Changing Climate

Earth's climate is not static; it changes in response to both natural and human-caused drivers. The past decade was the warmest on record, and global atmospheric warming has increased at a faster rate since the 1970s (GCRP, 2017), which the global climate science community attributes to increasing human-caused greenhouse gas emissions (IPCC, 2013).

A growing body of research reveals that a range of climate hazards will likely increase in frequency and intensity as a result of atmospheric warming (GCRP, 2017; IPCC, 2013). For example, a warmer atmosphere increases the frequency, intensity, and duration of heat waves; holds more water vapor for heavy precipitation events; and accelerates ice loss from Earth's large ice sheets, contributing to sea level rise and coastal storm surge. These climate changes highlight how changes in the global climate system affect local climatology and weather in Con Edison's service territory. Local changes include both long-term mean changes, such as gradual increases in temperature and sea level, and changes in extreme events, such as heat waves, hurricanes, and storm surge. In most cases, long-term climate change amplifies and increases the likelihood of extreme events. In turn, climate changes and baseline climate hazards cause both direct (e.g., physical damage to infrastructure) and indirect (e.g., changing customer behavior) impacts across the electric, gas, and steam systems of Con Edison's business.

Rapid climate change will bring new challenges to Con Edison through the 21st century. This Study develops climate projections to characterize these challenges. Still, conceptualizing climate change in tangible terms is notoriously difficult. Another way to describe potential climate change is through climate analogs, which match expected future climate change at a location to current climate conditions in another. Under this perspective, New York City's temperature and precipitation by 2080 could more closely resemble current conditions in southern cities such as Memphis, TN, and Little Rock, AR, if greenhouse gas emissions continue unabated (Fitzpatrick & Dunn, 2019).⁴

⁴ Climate analogs are illustrative and vary depending on the choice of evaluation metrics, decade, and climate scenario. In this case, analogs are determined using metrics for seasonal minimum and maximum temperature and total precipitation.









Con Edison's Understanding and Assessment of Climate Change

The Study team developed improved, downscaled climate projections and used best available science to understand and evaluate climate change trends and potential extreme weather events across Con Edison's service territory over near- (2030), intermediate- (2050), and long-term (2080) time horizons. This approach builds on methods used by the New York City Panel on Climate Change (NPCC) and introduces a range of benefits (see Table 2). The Study team focused on climate variables that could present outsized impacts to operations, planning, and infrastructure across the electric, gas, and steam segments of Con Edison's business. These include temperature, humidity, precipitation, sea level rise and coastal flooding, extreme events, and multiple—or compounding—events.

The primary tools for understanding future climate change are Global Climate Models (GCMs), which mathematically simulate important aspects of Earth's climate, such as changes in temperature and precipitation, natural modes of climate variability (e.g., El Niño and La Niña events), and the influence of human greenhouse gas emissions (GCRP, 2017). Over short timescales (i.e., years to decades), individual GCM projections can differ from one another due to unpredictable natural climate variability, differences in how models characterize small-scale climate processes, and their response to greenhouse gas emissions/concentration assumptions. For these reasons, future climate analyses often consider a large ensemble of GCMs to better discern long-term trends, account for uncertainty, and consider a fuller range of potential future climate outcomes. To this end, the Study team used a broad model ensemble (i.e., 32 GCMs) for each climate variable of interest to address the spread across models and provide a comprehensive view of future climate.

While GCMs use a finer spatial resolution than ever before, they still provide coarse-resolution estimates of future climate, with model grid cells typically extending approximately 100 kilometers on one side. To achieve a more accurate representation of local climate in the New York Metropolitan Region, the Study team bias-corrected and downscaled GCM projections (i.e., statistically adjusted simulations to bring them closer to observed data) using weather station data over a 1976–2005 historical reference period from three weather station locations spanning Con Edison's service territory, including Central Park, LaGuardia Airport, and White Plains Airport.⁶

GCM simulations are driven by a standard set of time-dependent greenhouse gas concentration trajectories called Representative Concentration Pathways (RCPs), developed by the Intergovernmental Panel on Climate Change (IPCC). RCPs consider different evolutions of fossil fuels, technologies, population growth, and other controlling factors on greenhouse gas emissions through the 21st century. To acknowledge uncertainty in future greenhouse gas concentrations, the Study team selected the commonly used RCPs 4.5 and 8.5 to drive each GCM, following precedent set by IPCC and NPCC. RCP 4.5 represents a moderately warmer future based on a peak in global greenhouse gas emissions around 2040. In contrast, RCP 8.5 represents a hotter future

⁶ Technical information regarding bias-correction and downscaling methods used in this Study are provided in the appendices for the relevant climate variables.











⁵ Columbia University's Lamont-Doherty Earth Observatory led the analysis of temperature, humidity, and precipitation projections and extreme event information. ICF provided insights into future climate conditions using localized constructed analog (LOCA) projections, analyzed sea level rise projections, and synthesized extreme event narratives. Jupiter Intelligence provided projections of extreme temperatures and the urban heat island effect.

corresponding to "business as usual" increases in greenhouse gas concentrations through the century.

The Study team used a model-based probabilistic framework to evaluate climate change hazards and account for model uncertainty under different RCP scenarios. Specifically, the Study team analyzed high-end estimates (e.g., the 90th percentile of projections across climate models), and mid-point (50th percentile) and low-end (10th percentile) projections for both RCPs. In doing so, the Study Team considered the range of potential climate outcomes across models and RCPs to form a comprehensive risk-based approach. Under this framework, the RCP 8.5 90th percentile approximates a stress test to characterize low probability, high-impact climate change, and its impact on Con Edison.

This Study builds on the approach used by NPCC. Table 2 provides a high-level overview of climate information advances developed as part of this Study.

Table 2 ■ Overview of climate projection methods in this Study relative to the NPCC2 (2015) climate projections of record for New York City

NPCC2 (Reference Projections)	Con Edison Study
Combined projections from two scenarios (RCPs 4.5 and 8.5)	Separate scenario projections
Four time periods (2020–2080)	Seven time periods (2020–2080) to align with planning processes
Single reference point (Central Park)	Multiple reference points tailored to the service territory (Central Park, White Plains, and LaGuardia)
Downscaling using the "delta method"	Downscaling using "quantile mapping"
Limited set of climate variables	Numerous Con Edison-specific variables and multi-variable projections (e.g., heat plus humidity)

The Study also evaluates Con Edison's vulnerability to rare and complex extreme events, such as major hurricanes and long-duration heat waves, that may increase in intensity and frequency as a result of climate change. Such events play an outsized role in shaping the public's perception of climate change vulnerability and how institutions should address its unique challenges. While the Study team uses model-based probabilistic projections to inform many climate variables, such as long-term mean temperatures and sea level, it is more challenging to project the rarest events, such as a 1-in-100-year heat wave, and multi-faceted and difficult to model events such as hurricanes. Obstacles to modeling rare and complex extreme events include the brevity of the historical record relative to the rarity of the event, and challenges associated with modeling extremes that have important features at very small space and time scales.

To address these challenges, the Study team constructed a series of extreme event narratives based on historical analogs and the best available climate science. In contrast with model-based











probabilistic projections, narratives represent plausible future worst-case scenarios⁷ meant to stress-test Con Edison's system. The narratives merge a decision-first and risk-based approach, blending best available science with decision maker-defined high impacts to develop a better understanding of Con Edison's vulnerability to rare, complex extreme events.

Overview of Climate Science Findings Relevant to Con Edison

The Study team's analysis characterized historical and future changes in temperature, humidity, precipitation, sea level rise, and extreme events within Con Edison's service territory. This information supports a risk-based understanding of potential climate-related vulnerabilities within the company's operations, planning, and physical assets. The sections below provide an overview of projected climate changes relevant to Con Edison. While projections were prepared for Central Park, LaGuardia, and White Plains as described above, this section commonly uses Central Park as a reference point due to its central location and because it currently serves as a reference point for many Con Edison operations. The report appendices contain detailed information on other locations and the full scope of climate projections and corresponding vulnerabilities developed for this Study.

Temperature

Both average and maximum air temperatures are projected to increase throughout the century relative to historical conditions (Figure 6). Climate

The timing and magnitude of climate change over the coming century remains uncertain, particularly with respect to rare and multi-faceted extreme events. This uncertainty presents challenges for institutions such as Con Edison in understanding the potential effects of climate change and the associated risks to their business, operations, and financial performance.

Scenario analysis is a proven way to address these challenges. For example, Task Force on Climate-Related Financial Disclosures (TCFD) scenarios use forwardlooking projections to provide a framework to help companies prepare for risks and opportunities brought about by climate change. The scenarios used in this Study are similarly hypothetical constructs, but differ from TCFD scenarios in that they provide quantitative details regarding future extreme event conditions (e.g., regarding specific storm characteristics) so that Con Edison can better plan for specific impacts to assets and infrastructure. Ultimately, this Study uses both climate science and stakeholder-driven perspectives to develop plausible, high impact worst-case scenarios designed to stress-test Con Edison's system.

model projections reveal significant increases in the number of days per year in which average temperatures exceed 86°F (up to 26 days per year, relative to a baseline of 2 days) and maximum temperatures exceed 95°F (up to 23 days per year from a baseline of 4 days; Figure 7) by 2050. At

⁷ Worst-case scenarios are meant to explore Con Edison system vulnerabilities related to rare extreme weather events and formulate commensurate adaptation and resilience strategies. Scenarios represent one plausible permutation of extreme weather and the severity of actual events may exceed those considered.











the same time, winter minimum temperatures are expected to fall below 50°F as many as 40 fewer times per year than in the past by mid-century, representing a 20% decrease.

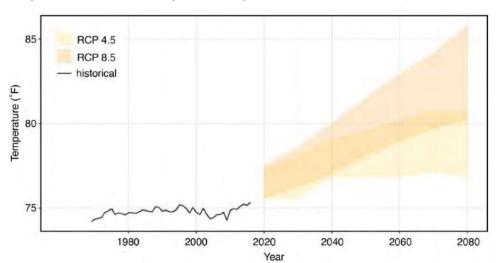
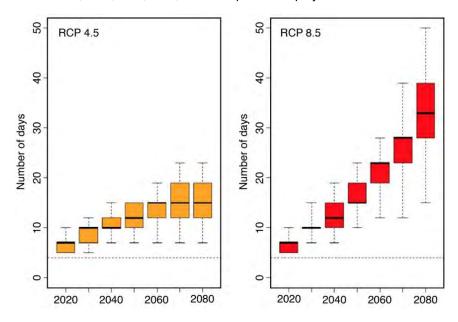


Figure 6 ■ Historic (black line) and projected (colored bands) average air temperature in Central Park during the summer under two greenhouse gas concentration scenarios (RCPs 4.5 and 8.5)

Figure 7 ■ The average number of days per year with maximum summer air temperatures exceeding 95°F in Central Park under two greenhouse gas concentration scenarios (RCPs 4.5 and 8.5). The dashed horizontal lines show the historical average number of days. Box plots correspond to the 10th, 25th, 50th, 75th, and 90th percentile projections.



Multi-day heat events, known as heat waves, create potential risks for Con Edison as they drive demand for air conditioning and stress electrical and infrastructure systems. The number of heat waves, defined here as 3 or more consecutive days when *average* temperatures exceed 86°F in Central Park, is projected to increase up to 5 and 14 events per year by 2050 and 2080, respectively, relative to 0.2 events per year historically. The magnitudes of temperature increases are projected to be greatest at LaGuardia and Central Park and smaller at White Plains.



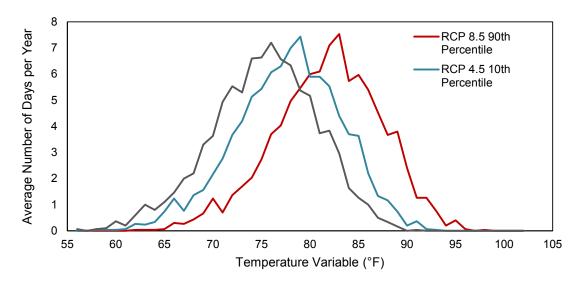




Humidity

The New York Metropolitan Region is susceptible to significant combinations of heat and humidity, which cannot be captured by temperature alone. The combination of temperature and humidity drives electric demand within Con Edison's service territory. To address this, the company currently evaluates the potential for high loads using an index referred to by Con Edison as temperature variable (TV), 8 which incorporates considerations of both temperature and humidity. Looking forward, TV thresholds that have historically occurred only once per year (e.g., 86°F), are projected to become common occurrences within a generation, occurring between 4 and 19 times per year by 2050 and 5 and 52 times per year by 2080, under the RCP 4.5 10th percentile and RCP 8.5 90th percentile, respectively, at LaGuardia (Figure 8). Smaller increases are expected at White Plains.

Figure 8 Distributions showing historical (black line) and 2050 projected (blue and red lines) summer (June–August) daily electric TV at LaGuardia Airport. The 2050 projections show both the RCP 8.5 90th percentile and the RCP 4.5 10th percentile distributions.



The heat index is a typical indicator of "how hot it feels," which considers the combined effect of air temperature and relative humidity. The index assesses health risks associated with overheating, including for Con Edison employees working under hot conditions. Looking forward, the frequency of occurrence for very high heat index thresholds is projected to increase dramatically through the century. Projections reveal that the number of days per year when the heat index equals or exceeds 103°F at LaGuardia could increase to between 7 and 26 days by 2050 under the RCP 4.5 10th percentile and the RCP 8.5 90th percentile, respectively, compared to only 2 days historically.

⁸ Temperature variable is calculated using the weighted time integration of the highest daily recorded 3-hour temperature and humidity over a 3-day period. The reference TV for Con Edison is 86°F, which approximates a heat index of 105°F.







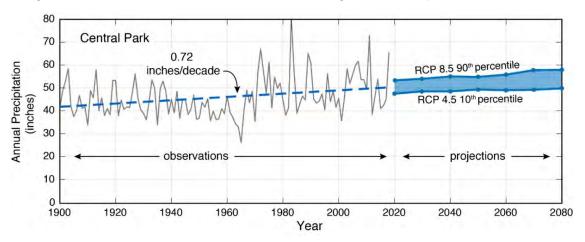




Precipitation

Con Edison's service territory experiences a range of precipitation events over a range of timescales, including rainfall, downpours, snowfall, and ice. Climate change is projected to drive heavier precipitation across these event types because a warmer atmosphere holds more water vapor and provides more energy for strong storms. Looking forward, average annual precipitation is projected to increase by 0% to 15% relative to the historical baseline in Central Park through 2050 (Figure 9).

Figure 9 Observed and projected annual precipitation at Central Park. Projections show potential annual precipitation under both the RCP 8.5 90th percentile and the RCP 4.5 10th percentile. Projections represent 30-year time averages (shown as blue circles), which reveal the long-term trend, but underrepresent year-to-year variability. The dashed line represents the linear trend though the observational record, with observed increases given in inches per decade.



Projections of heavy rainfall reveal similar increases. For example, the heaviest 5-day precipitation amount could be 11.8 inches at Central Park by 2050, which represents a 17% increase over the historical reference period. Data from the Northeast Regional Climate Center⁹ show that 25-year, 24-hour precipitation amounts at Central Park, LaGuardia, and White Plains could increase by 7% to 14% and 10% to 21% by mid- and late-century, respectively. Ultimately, projections point to a future defined by more frequent heavy precipitation and downpours, likely accompanied by smaller increases in the frequency of dry or light precipitation days (GCRP, 2017).

Projections for changes in snow and ice are more uncertain than those for rainfall. Overall, models project a decrease in snowstorm frequency corresponding to a warming climate (Zarzycki, 2018). However, while the likelihood of a given storm producing snow instead of rain will decrease in the future, if atmospheric conditions are cold enough to support frozen precipitation, then storms are expected to produce more snow (or ice) than during the present day (Zarzycki, 2018).

Sea Level Rise

A range of underlying factors, including thermal expansion of the ocean, the rate of ice loss from glaciers and ice sheets, atmosphere and ocean dynamics, and vertical coastline adjustments determine local sea level rise within Con Edison's service territory. State-of-the-art probabilistic







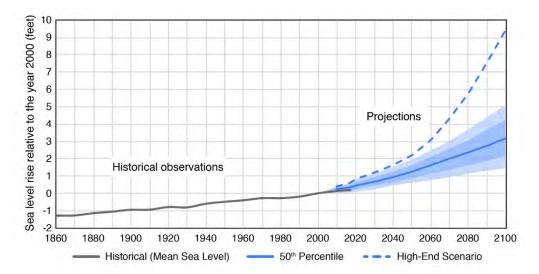




⁹ http://ny-idf-projections.nrcc.cornell.edu/

projections (Kopp et al., 2014; 2017) determined these contributions and characterized the rate of future sea level rise in the region under both RCPs 4.5 and 8.5 (e.g., Figure 10). These sea level rise projections include a unique high-end scenario driven by rapid West Antarctic ice sheet mass loss in the later 21st century (DeConto & Pollard, 2016; Kopp et al., 2017). Con Edison has always implemented anti-flooding measures. Following Superstorm Sandy in 2012, the company implemented a minimum protection design standard of "FEMA plus three feet," ¹⁰ allowing for 1 foot of sea level rise. In turn, forward-looking projections determine when sea level rise may exceed Con Edison's established risk tolerance of 1 foot of sea level rise.

Figure 10 Historical and projected sea level rise in New York City under RCP 8.5 relative to the year 2000. The grey line shows historical mean sea level at the Battery tide gage. Projections are relative to the 2000 baseline year. The solid blue line shows the 50th percentile of projected sea level rise. The darker shaded area shows the likely range (17th–83rd percentiles), while the lighter shaded area shows the very likely range (5th–95th percentiles). The blue dashed line depicts a high-end projection scenario driven by rapid West Antarctic ice sheet mass loss in the later 21st century (DeConto & Pollard, 2016; Kopp et al., 2017).



Sea level rise will very likely be between 0.62 and 1.74 feet and 0.62 and 1.94 feet at the Battery tide gauge in lower Manhattan by 2050 under RCPs 4.5 and 8.5, respectively. Projections suggest that Con Edison's 1-foot sea level rise risk tolerance threshold may be exceeded as early as 2030 and as late as 2080.

In turn, rising sea levels will have profound effects on coastal flooding, as sea level rise is expected to increase both the frequency and height of future floods (Figure 11). For example, the flood height associated with the 1% annual chance (100-year) flood in New York City is projected to increase from 10.9 feet to as much as 15.9 feet under RCP 8.5 by 2100, representing an increase of close to 50%. Similarly, today's 0.2% annual chance (500-year) flood could look like a 10% annual

¹¹ Flood values are above the mean lower low water (MLLW) datum at the Battery tide gauge. MLLW is measured as 2.57 feet below mean sea level at the Battery.







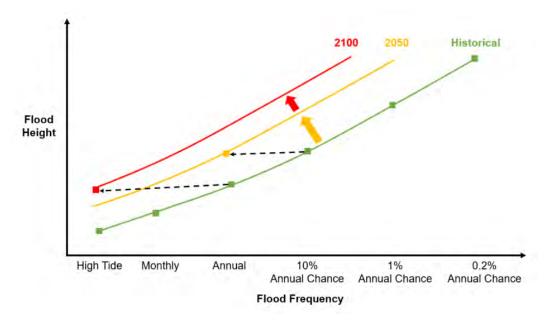




¹⁰ This includes the FEMA 1% annual flood hazard elevation, 1 foot of sea level rise and 2 feet of freeboard (to align with 2019 Climate Resiliency Design Guidelines published by the New York City Mayor's Office of Recovery and Resiliency).

chance (10-year) flood in 2100, making it 50 times more likely. At the end of the century, today's annual chance flood could occur at every high tide.

Figure 11 ■ Projected changes in the frequencies of historical flood heights as a result of sea level rise. Dashed lines represent projected changes in frequency; solid lines represent illustrative changes in flood frequency coinciding with flood heights



Extreme Events

Rare extreme events, such as strong hurricanes and long-duration heat waves, are low-probability and high-impact phenomena that pose outsized risks to infrastructure and services across Con Edison's service territory. While modeling rare extreme events remains challenging and at the forefront of scientific research, a growing body of evidence suggests that many types of extreme events will likely increase in frequency and intensity as a result of long-term climate warming.

To address these challenges, the Study team used feedback from Con Edison SMEs to prioritize a suite of extreme event narratives that combine plausible worst-case events from both climatological and impact perspectives. In turn, the narratives represent future worst-case scenarios designed to stress-test Con Edison and the local and regional systems with which it connects. The chosen narratives considered a prolonged heat wave, a Category 4 hurricane, and an unprecedented nor easter striking the region.

Best available climate science reveals that climate change will likely amplify these extremes over the coming century. For example, the mean heat wave duration in New York City is expected to increase to 13 and 27 days by 2050 and 2080, respectively, based on RCP 8.5 90th percentile projections (NPCC, 2019). At the same time, broadscale atmospheric and ocean surface temperature changes may drive stronger hurricanes and extratropical cyclones. Looking forward, while the total number of hurricanes occurring in the North Atlantic may not change significantly over the next century, the percentage of very strong and destructive (i.e., Categories 4 and 5) hurricanes is projected to increase in the North Atlantic basin (IPCC, 2013). It can therefore be









argued that climate change could make it more likely for one of these storms to impact the New York Metropolitan Region, although the most dominant factor will remain unpredictable climate and weather variability (Horton & Liu, 2014). Finally, some recent studies project a 20% to 40% increase in nor'easter strengthening (i.e., producing the types of storms with destructive winds) immediately inland of the Atlantic coast by late-century, suggesting stronger storms may more frequently impact the New York Metropolitan Region with heavy precipitation, wind, and storm surge (Colle et al., 2013)

Signposts: Monitoring and Climate Science Updates

Understanding Con Edison's vulnerabilities to climate change and adapting to those changes over time require a robust monitoring strategy. Climate change evolves through time, meaning that the current spread of potential future climate outcomes produced by models will eventually converge on a smaller set of climate realizations. To keep up with this evolution, a range of signposts are required to sufficiently gauge relevant rates of change and best prepare Con Edison for the most likely climate future.

An awareness of past and present climate conditions in Con Edison's service territory is critical for understanding the trajectory of climate change. Con Edison currently operates a number of stations that monitor climate variables and is finalizing plans to expand the number of monitoring locations. Increasing observations from monitoring stations will help measure both local climate variations and climate change through time, informing Con Edison's climate resilience planning. Citywide observations of variables, such as hourly temperatures, precipitation, humidity, wind speed, and sea level, are paramount to building a broad and usable set of guiding measurements. With accurate and up-to-date data on these variables, Con Edison can better monitor both changing conditions and potential points of vulnerability.

Con Edison can supplement monitoring through a regularly updated understanding of the best available projections as models and expert knowledge evolve over time. Climate projections continually improve as the scientific community better understands the physical, chemical, and biological processes governing Earth's climate and incorporates them into predictive models. Ultimately, Con Edison wants to draw on the best available data and projections that are driven by scientific consensus, but also are accessible and applicable to company needs. Signposts for updating climate science used to inform potential Con Edison vulnerabilities include major science advancements, such as the release of the new Coupled Model Intercomparison Project (CMIP) projections and their integration and validation in new IPCC, NPCC, and National Climate Assessment (NCA) reports. These assessments include updated probabilistic climate projections representing model advancements, the best available science regarding difficult-to-model extreme events, and literature reviews reflecting the current state of science as guided by leading experts. Such signposts could justify Con Edison updating their climate projections of record to reflect the best available science or projections that represent a significant departure from previous understanding. Historically, major scientific reports, such as the IPCC, have been released about every 6 to 7 years, which provide a potential constraint on how frequently Con Edison's understanding of climate change within the service territory might be revisited.













Existing Efforts and Practices to Manage Risks Under a Changing Climate

Although this Study is Con Edison's first comprehensive assessment of climate change vulnerabilities, Con Edison has already undertaken a range of measures to increase the resiliency of its system. Lessons learned and vulnerabilities exposed during past events, most recently Superstorm Sandy (2012) and the back-to-back nor'easters (winter storms Riley and Quinn, 2018), resulted in significant capital investments to harden the system.

In addition, as Con Edison invests in the system of the future—one with greater monitoring capabilities, flexibility, and reliability—it is simultaneously building a system that is more resilient to extreme weather events and climate change. For example, grid modernization will both increase efficiency and enhance monitoring capabilities by employing new technology and modes of data acquisition. Con Edison is planning to support numerous grid modernization initiatives that target energy storage technologies, communications systems, distributed energy resources infrastructure and management, complex data processing, and advanced grid-edge sensors (Con Edison, 2019). Con Edison additionally plans to modernize its Control Center to assume more proactive and centralized management of its complex distribution grid. Throughout these modernization initiatives, the company remains in close collaboration with the City of New York.

Con Edison also conducts targeted annual updates to its system to ensure capacity and reliability. These annual updates help the company keep pace in real time with changes in some key hazards. For example, when conducting electric load relief planning, Con Edison incorporates load forecasts that use an annually updated set of TV data. Although these forecasts are not grounded in future projections that consider climate change, they do account for the most recent climate trends and, as such, allow the company to stay in stride with the most current data.

Con Edison's previous adaptation measures have made targeted improvements in (1) physical infrastructure, (2) data collection and monitoring, and (3) emergency preparedness. The following measures are illustrative of these targeted improvements, but are not meant to be exhaustive of the efforts that Con Edison has undertaken:

Physical Infrastructure

 Adopting the Dutch approach of "defense in depth" after Superstorm Sandy to protect all critical and vulnerable system components from coastal flooding risks, including the following:











- Upgrading and increasing the number of flood barriers and other protective structures
- Reinforcing tunnels
- Replacing equipment with submersible equivalents in flood zones (e.g., targeted main replacement program, gas system)
- Installing pumps and elevating infrastructure behind flood walls
- Protecting or elevating critical electrical infrastructure to the Federal Emergency Management Agency (FEMA) 100-year flood elevation plus 3 feet to account for sea level rise and freeboard during coastal storms
- Undertaking a targeted main replacement program that addresses low-pressure gas mains in low-lying areas, as well as other potentially vulnerable gas mains
- Installing isolation devices to limit the impact of damaged infrastructure on customers by deenergizing more granular sections of the system, when necessary
- Engaging innovative technologies to reduce the impact of extreme weather on electric distribution systems and quicken the recovery, including the following:
 - Demand response technologies that more efficiently regulate load
 - Automated splicing systems that reduce feeder processing times

Data Collection and Monitoring

- Developing programs that employ machine learning and remote monitoring to identify areas of heightened vulnerability in Con Edison's systems, including the following:
 - Leak-prone areas of the gas distribution system
 - Gas system drip pots that require draining
- Initiating a more diligent inspection system that effectively assesses the functionality of assets, as well as their exposure to potential hazards (e.g., nearby vegetation), including the following:
 - Underground network transformers and protectors
 - Underground structures
 - Flushing of flood zone vaults
 - Rapid assessments of overhead feeders
 - Overhead system pole-by-pole inspection for specification compliance
- Future deployment of advanced metering infrastructure (AMI) throughout the service territory
 has the potential to both improve information flow to customers and help absorb the impacts of
 extreme events. Specifically, AMI might be able to rapidly shed load on a targeted network to
 help ensure demand does not exceed supply, which reduces potential damages and likelihood
 of network-wide outages in the event of an extreme event.











Emergency Preparedness

- Improving contractor and material bases for post-storm repair crews and equipment, including the following:
 - Expanding and diversifying spare material inventories
 - Ensuring that all spare materials are housed in safe locations
- Conducting post-event debriefings to understand the impact of weather conditions on system performance
- Engaging with major telecommunications providers and enhancing communications systems among customer networks
- Facilitating equipment-sharing programs across New York State to ensure access to supplies during emergency response

Con Edison recognizes that the drivers behind future planning operations are inherently uncertain and is committed to both closely monitoring key signposts and continuously updating company investment plans and priorities.













Vulnerabilities, a Resilience Management Framework, and Adaptation Options

Con Edison may face greater vulnerabilities due to future changes in temperature, humidity, precipitation, sea level rise, and extreme weather events. To understand this, the Study team evaluated key vulnerabilities of Con Edison's present-day electric, gas, and steam systems under a changing climate. The physical assets, operations, and planning of each system are uniquely vulnerable. In turn, building a detailed understanding of key vulnerabilities is an important step toward identifying priority adaptation measures.

Resilience Management Framework

Under a changing climate, Con Edison will likely experience the increasing frequency and intensity of both gradual climate changes and extreme events. In response, the Study team developed a resilience management framework (Figure 12) to outline how a comprehensive set of adaptation strategies would mitigate future climate risks. The framework encompasses investments to better withstand changes in climate, absorb impacts from outage-inducing events, recover quickly, and advance to a better state. The "withstand" component of this framework prepares for both gradual (chronic) and extreme climate risks through resilience actions throughout the life cycle of assets. As such, many of the adaptation strategies identified in the following sections fall under the category of systematically bolstering Con Edison's ability to withstand future climate risks. Investments to increase the capacity to withstand also provide critical cobenefits, such as enhanced blue-sky functionality and the reliability of Con Edison's system. The resilience management framework facilitates long-term adaptation and creates positive resilience feedback so that Con Edison's system achieves better functionality through time. To succeed, each component of a resilient system requires proactive planning and investments.



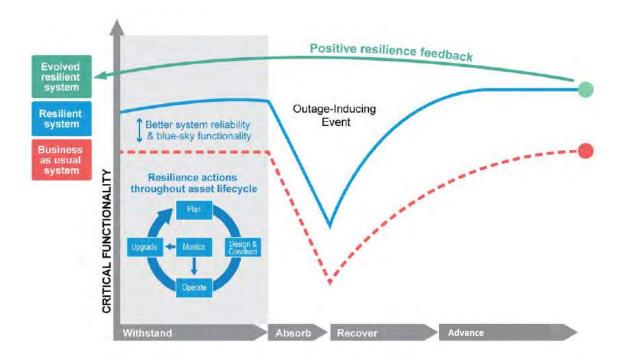








Figure 12 Conceptual figure representing a resilience management framework designed to withstand changes in climate, absorb and recover from outage-inducing events, and advance to a better state. Investing in a more resilient system (blue line) provides benefits relative to a less resilient, or business-asusual, system (red dashed line) before, during, and after an outage-inducing event. Most resilience actions should occur systematically throughout the asset life cycle to enhance the ability to withstand changes in climate, while also enhancing system reliability and blue-sky functionality. Resilient systems also adapt so that the functionality of the system improves through time (green line). Each component of a resilient system requires proactive planning and investments.



"Withstand" entails proactively strengthening the system to mitigate and avoid climate change risks and increase the reliability of Con Edison's system. "Withstand" investments are not necessarily a one-time event. Rather, the ability to withstand climate change must be integrated and revisited throughout the life cycle of Con Edison's assets. Doing so requires changes in the planning, design, and construction of new infrastructure; ongoing data collection and monitoring; and eventually investing in the upgrade of existing infrastructure, using forward-looking climate information. This life cycle approach to considering climate change is captured in Figure 13. Across Con Edison's electric, gas, and steam systems, planning for new investments in system capacity serves as a critical and strategic opportunity to integrate climate considerations. In addition, an important aspect of increasing the capacity of new investments to withstand changes in climate is maintaining strong design standards that account for gradual changes in chronic stressors and more frequent extreme events. However, since design standards do not apply to existing infrastructure, a strong monitoring program and signposts for additional adaptation investments could help ensure that Con Edison's existing infrastructure remains resilient to climate change by informing adjustments to operations and potential needs for upgrades.









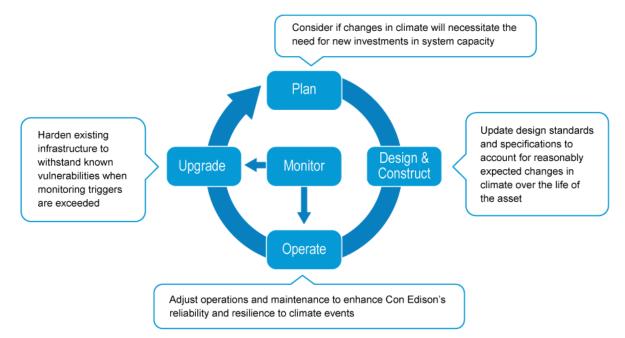


Figure 13 "Withstand" actions and investments must be revisited throughout the life cycle of Con Edison's assets.

"Absorb" includes strategies to reduce the consequences of outage-inducing events, since Con Edison cannot and should not harden its energy systems to try to withstand every possible future low-probability, high-impact extreme weather event. These actions, many of which Con Edison is already implementing, include operational changes to reduce damage during outage-inducing events and to protect exposed systems from further damage.

"Recover" aims to increase the rate of recovery and increase customers' ability to cope with impacts after an outage-inducing event. Such strategies build on Con Edison's Emergency Response Plans and Coastal Storm Plans. In addition, there is a role that Con Edison can play to increase customer coping and prioritize the continued functioning of critical services. Resilient customers are those who are prepared for outages and are better able to cope with reduced energy service—through measures such as having on-site energy storage, access to locations in their community with power, the ability to shelter in place without power, and/or prioritized service restoration for vulnerable customers.

"Advance" refers to building back stronger after climate-related outages and updating standards and procedures based on lessons learned. Even with proactive resilience investments, outage-inducing climate events can reveal system or asset vulnerabilities. Adjusting Con Edison's planning, infrastructure, and operations to new and future risks after an outage-inducing event, while incorporating learning, will allow for a more effective and efficient transition to greater resiliency. Con Edison has taken this approach in the past, including investing a billion dollars in storm hardening measures after Superstorm Sandy. Moving forward, restoring service following an outage-inducing climate event to a better adapted, more resilient state begins with effective pre-planning for post-event reconstruction. Where assets need to be replaced during recovery, having a plan already in place for selection and procurement of assets designed to be more resilient in the future can help to ensure that Con Edison is adapting to future extremes in a continuously changing risk environment.









Implementation of adaptation strategies throughout all of these phases will need to be adjusted over time to manage for acceptable levels of risk despite uncertainties about future conditions. The flexible adaptation pathways approach, described in further detail in the subsequent section, ensures the adaptability of adaptation strategies over time as more information about climate change and external conditions becomes available.

All Commodities (Electricity, Gas, and Steam)

Vulnerabilities

The Study team identified priority hazards for each of Con Edison's commodity systems (electric, gas, and steam) and found that several hazards were priorities across all three systems, although these hazards present unique vulnerabilities to the various assets within each system. The hazards common to all three systems are heat index, precipitation, sea level rise and storm surge, and extreme and multi-hazard events. These are discussed below. System-specific vulnerabilities are subsequently discussed in separate sections.

Heat Index

Worker safety may be a point of vulnerability if heat index values rise as projected. The Occupational Safety and Health Administration has set a threshold of 103°F for high heat index risk for people working under hot conditions. During the base period (1998–2017), there were 2 days per year with maximum heat greater than or equal to 103°F (but below 115°F). Under a lower emissions climate scenario (RCP 4.5 10th percentile), the 103°F threshold may be met 5 to 7 days per year by 2050; under a higher emissions scenario (RCP 8.5 90th percentile), this may occur 14 to 20 days per year by 2050. This poses a potential health threat to all Con Edison workers whose duties require outdoor labor.

Projected increases in heat index may also affect cooling equipment across Con Edison's systems, including the HVAC units for Con Edison buildings, air cooling towers for the electric system, and a water cooling tower for Con Edison's East River Steam Generating Plant. In order to supply sufficient cooling to its systems in 2080, Con Edison's HVAC systems will have to increase their capacity by 11% due to projected increases in dry bulb temperature. These systems have a roughly 15-year life span and therefore can be upgraded during routine replacements at an incremental cost of \$1.3 million for 157 units. Similarly, Con Edison's cooling towers will have to increase their capacity by 30% by 2050. Cooling towers have a 20- to 35-year life span, allowing them to be upgraded during routine replacements at an incremental cost of \$1.1 million for 19 cooling towers at 13 sites.

Precipitation

The Study team conducted an analysis of the physical and operational vulnerabilities of Con Edison's steam system, gas system, and transmission and substation components of the electric system. Findings indicated that all underground assets are vulnerable to flooding damage (i.e., water pooling, intrusion, or inundation) from heavy precipitation occurring over a short period of time. Specific vulnerabilities and their relevant thresholds vary significantly by commodity and, as such, are outlined in their respective sections.











Sea Level Rise and Storm Surge

The Study team broke down evaluation of priority vulnerabilities related to sea level rise into two components.

The first component focuses on design standards for new infrastructure. The Study team assessed Con Edison's coastal flood protection standards for robustness to projected sea level rise. Con Edison's current design standard for coastal flood protections includes the FEMA 1% annual flood hazard elevation, 1 foot for sea level rise, and 2 feet of freeboard, which aligns with New York City's Climate Resilience Design Guidelines for critical infrastructure and water elevations that Con Edison experienced during Superstorm Sandy. Under high-end sea level rise (e.g., due to either rapid ice loss from the West Antarctic Ice Sheet corresponding to Kopp et al., 2017, or RCP 8.5 95th percentile projections corresponding to Kopp et al., 2014), the existing 1 foot sea level rise risk tolerance threshold could be exceeded by 2030; however, under more likely scenarios, the current threshold could be exceeded between 2040 and 2080. The probability that sea level rise will exceed the 1-foot sea level rise risk tolerance by 2020 is under 10%; that increases to 65% to 70% by 2050, and to 100% by the 2080s.

The second evaluation component identified specific physical vulnerabilities of Con Edison's existing assets to impacts related to sea level rise, which are described by commodity below.

Extreme and Multi-Hazard Events

Assets across all systems are vulnerable to possible damage from extreme event flooding. Storm surge driven by an extreme hurricane event (i.e., a Category 4 hurricane) has the potential to flood both aboveground and belowground assets. Specific asset damage varies by commodity and is outlined in the commodity-specific sections. In addition, flooding from ice-melt and snowmelt may cause significant damage to assets across all commodities, especially if the melt contains corrosive road salts.

On an operational level, increasing frequency and intensity of extreme weather events may exceed Con Edison's currently robust emergency preparedness efforts. Con Edison's extreme weather response protocols are specified in the company's hazard-specific Emergency Response Plans and Coastal Storm Plans for electric, steam, and gas systems. Con Edison's current "full-scale" response, which calls for all Con Edison resources and extensive mutual assistance, is initiated when the number of customers out of service reaches approximately 100,000. However, low-probability extreme events can increase customer outages and outage durations by an order of magnitude, outpacing current levels of emergency planning and preparedness, as shown in Figure 14.

¹² The sea level rise projections use a baseline year of 2000. For more details on these projections and how they relate to Con Edison's design standards, see Appendix 4.



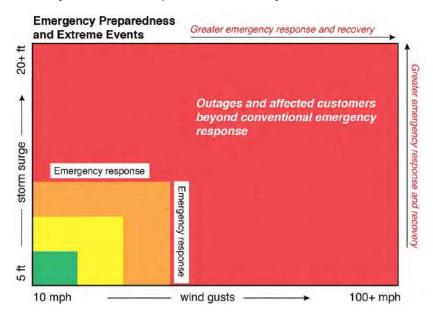








Figure 14 ■ Schematic diagram illustrating the increasing impacts during an extreme event (e.g., hurricane with extreme wind gusts and storm surge) that demands correspondingly large emergency response efforts that may exceed those experienced historically.



Adaptation Measures to Address Vulnerabilities

Several adaptation measures help address vulnerabilities across Con Edison's electric, gas, and steam systems: improved monitoring systems and capabilities to support planning and decision making, emergency preparedness and full system recovery, and improved customer coping.

Improved Monitoring Systems and Capabilities to Support Planning and Decision Making

Con Edison can collect updated and comprehensive data to further strengthen the resilience of its long-term plans and decision-making processes to climate change. Signposts guide planning and decision making, especially through informing the timing of implementation and the adjustment of adaptation measures, described in greater detail in the section below on Moving Towards Implementation.

As previously mentioned, it is important to have the latest information on climate variables and projections as the climate changes and the science improves. Monitoring local climate rates of change across the service territory can help Con Edison better track both changing conditions and potential points of vulnerability across its systems. Specific adaptation measures per commodity that are dependent on the monitoring of climate variable information are detailed in the respective commodity sections. In addition to information on climate variables, Con Edison will need to stay abreast of the latest climate science projections generated by expert organizations such as IPCC, NCA, and NPCC. The Study team suggests that Con Edison could revise its planning and decision-making processes at least every 5 years to incorporate updated climate science information.

Emergency Preparedness and Full System Recovery

Con Edison should consider a range of adaptation strategies to increase capacity for an efficient preparedness and recovery process, as defined in Table 3.











Table 3 ■ Emergency preparedness and system recovery adaptation strategies

Adaptation Strategy	Measures
Strengthen staff skills for streamlined emergency response.	 Use technology to increase the efficiency of emergency response work crews. Review the Learning Center courses to ensure that crews are developing the skills required for emergency response. Incorporate supply shortages into emergency planning exercises.
Plan for resilient and efficient supply chains.	 Develop a resilience checklist for resilient sourcing. Have a plan already in place for selection and procurement of assets designed to be more resilient in the future. Ensure that parts inventories are housed out of harm's way and in structures that can survive extreme weather events. Standardize equipment parts, where possible.
Coordinate extreme event preparedness plans with external stakeholders.	 Continue coordination with telecommunication providers, including through joint emergency response drills. Continue and strengthen collaboration with the city to improve citywide design, maintenance, and hardening of the stormwater system. For example, improved drainage could alleviate the potential impacts of flooding and increase the effectiveness of adaptation measures in which Con Edison invests (e.g., drain hardening at manholes).
Incorporate low probability events into long-term plans.	 Continue expanding the Enterprise Risk Management framework to include lower probability extreme weather events and long-term issues (e.g., 20+ years). Conduct additional extreme weather tabletop exercises informed by the future narratives outlined in this report, and consecutive extreme weather events. Consider expanding the definition of critical facilities and sensitive customers.
Track weather-related expenditures.	 Con Edison's Work Expenditures Group could track expenditures, such as the cost of outages and repairs or customer service calls. Concurrently tracking climate and cost data will enable Con Edison to perform correlation analysis over time.
Update extreme event planning tools.	 Con Edison currently uses an internal Storm Surge Calculator (an Excel workbook that determines the flood measures to be employed for coastal assets based on a given storm tide level) to help plan for coastal flooding impacts. Con Edison could adjust inputs to this program to reflect the following: Updated storm surge projection information, using high-end forecasted surge Information from coastal monitoring, such as sea level rise and coastal flooding In addition, Con Edison could regularly revisit the definition of critical equipment so that the Storm Surge Calculator can best inform prioritization of equipment upgrades.
Expand extreme heat worker safety protocols.	 Implement safety protocols (e.g., shift modifications and hydration breaks) practiced in mutual aid work in hotter locations such as Florida and Puerto Rico. Examine and report on the levels of workers necessary to prepare for and recover from extreme climate events.
Improve recovery times through system and technology upgrades.	 Consider the use of drones and other technology (satellite subscription) or social media apps for damage assessment. Use GIS system to facilitate locating and documenting damage. Expand the use of breakaway hardware and detachable service cable and equipment.

Improved Customer Coping

Extreme events can present outsized risks compared to chronic events—risks that, in some cases, also extend to larger geographic areas. For example, impacts from hurricanes can overwhelm multiple facets of Con Edison's system and surrounding communities. Con Edison is positioned at the center of increasingly interconnected societal, technological, and financial systems, making it difficult and inefficient to evaluate risks solely on a component-by-component basis (Linkov, Anklam, Collier, DiMase, & Renn, 2014). Together,











these factors necessitate different approaches to considering adaptation compared with climate changes for which probabilities are more easily assigned.

While the City of New York has primary responsibility for coordinating resident emergency response efforts, Con Edison can play a role in increased customer coping and resilience. This includes helping customers cope with reduced energy service if an extreme event leads to prolonged outages (e.g., supporting on-site energy storage, access to locations in the community with power, prioritized service restoration for vulnerable areas). Table 4 provides more specific adaptation strategies. Overall, Con Edison could consider expanding the definition of critical facilities and sensitive customers.

Table 4 ■ Improved customer coping adaptation strategies

Adaptation Strategy	Measures
Create resilience hubs (see below for more information).	 Use solutions such as distributed generation, hardened and dedicated distribution infrastructure, and energy storage so that resilience hubs can function akin to microgrids to provide a range of basic support services for citizens during extreme events. Continue to promote the pilot resilience but at the Marcus Garyey Apartments in Brooklyn, using
	 Continue to promote the pilot resilience hub at the Marcus Garvey Apartments in Brooklyn, using a lithium ion battery system, fuel cell, and rooftop solar to provide back-up power to a building with a community room that has refrigerators and phone charging.
	 Support additional deployment of hybrid energy generation and storage systems at critical community locations and resilience hubs.
	Use AMI capabilities to preserve service for vulnerable populations, if possible.
Invest in energy storage.	 Continue to enhance customer resilience through continued installation of energy storage strategies, including on-site generation at substations or mobile storage on demand/transportable energy storage system (TESS) units, and compressed natural gas tank stations.
	 Continue to explore ways to help customers install, maintain, and make use of distributed energy resource assets for power back-up, self-sufficiency, and resilience purposes.
On-site generation	 Con Edison currently supports on-site generation for customers through programs such as rebate and performance incentives for on-site residential and commercial photovoltaic solar generation, incentives for behind-the-meter wind turbines, and incentives for combined heat and power projects that Con Edison currently facilitates in collaboration with the New York State Energy Research and Development Authority.
	 On-site generation is a recommended approach for locations where resilience hubs may not be affordable or necessary.
	 Con Edison could continue to encourage on-site generation for individual businesses and residential buildings.
Energy efficiency	 Support improved passive survivability, or the ability to shelter in place for longer periods of time, through enhanced energy efficiency programs.
	 Continue to support energy efficiency programs and further expand its energy efficiency program portfolio to include additional incentives for energy-efficient building envelope upgrades.

Resilience hubs are an emerging idea in resilience planning, which focus on building community resilience by creating a space (or spaces) to support residents and coordinate resources before, during, and after extreme weather events (Baja, 2018). A key requirement for a resilience hub is continued access to energy services. The objective of a resilience hub is to be able to provide a range of basic support services for citizens during extreme events. To accomplish this, resilience hubs may require a hybrid energy solution that includes multiple generation sources (e.g., solar and natural gas generation) and energy storage (i.e., batteries), plus dispatching controls, similar to the functionality of a microgrid. Figure 15 and Figure 16 demonstrate how a fuel cell-based microgrid can be used to power key community locations during normal operating conditions and during emergency events.

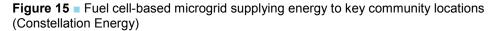












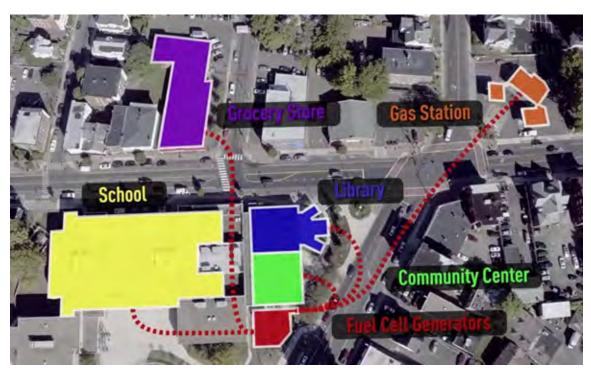
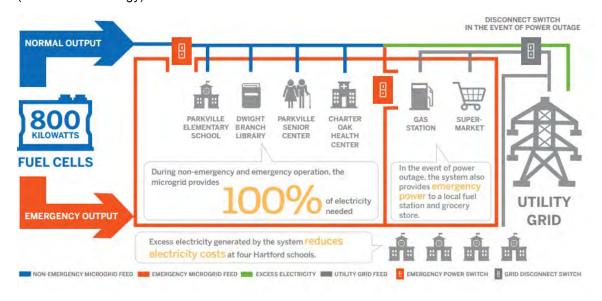


Figure 16 ■ Diagram of microgrid operations during normal and emergency operations (Constellation Energy)











Electric System

Electric System Overview

Con Edison's electric service territory includes both New York City and Westchester County, covering an area of 660 square miles and serving 3.3 million customers. Figure 17 depicts a schematic of the Con Edison electric system.

Con Edison's grid is a delivery system that connects energy sources to customers. While most electricity delivered is produced by large third-party generating stations, distributed energy resources also supply energy to the grid.

Energy produced by generating sources is delivered via the Con Edison transmission system, which includes 430 circuit-miles of overhead transmission lines and the largest underground transmission system in the United States, with 749 circuit-miles of underground cable. The system also includes 39 transmission substations. The high-voltage transmission lines bring power from generating facilities to transmission substations, which supply area substations, where the voltage is stepped down to distribution levels.

Con Edison has two different electric distribution systems—the non-network (primarily overhead) system and the network (primarily underground) system. The network system is segmented into independent geographical and electrical grids supplied by primary feeders at 13 kilovolts (kV) or 27 kV. The non-network system is designed using either overhead autoloops with redundant sources of supply, or 4-kV overhead grids arranged in a network configuration or as underground residential distribution systems designed in loop configurations.











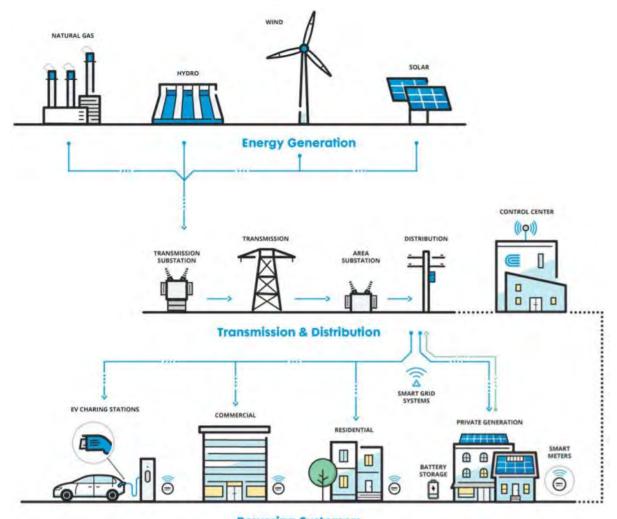


Figure 17 Diagram of the Con Edison Electric System

Powering Customers

Electric Vulnerabilities

Assets in the electric segment of Con Edison's business are most vulnerable to climate-induced changes in temperature/humidity and sea level rise. Both climate hazards have already shown their ability to bring about outages or damage assets and interrupt operations and carry the potential for future impacts. More information on specific vulnerabilities for these and other climate stressors is discussed below.

Heat and Temperature Variable (TV)

The core electric vulnerabilities for increasing temperature and TV include increased asset deterioration, decreased asset capacity, decreased system reliability, and increased load. Figure 18 illustrates how temperature-related stressors, such as maximum and average air temperature, lead to impacts on the electric system.











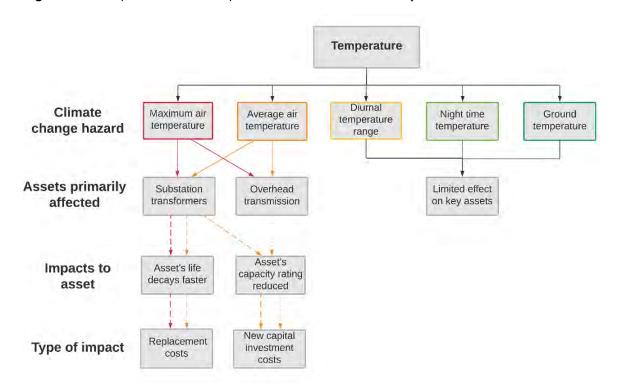


Figure 18 Temperature-related impacts on Con Edison's electric system

Increased Asset Deterioration

Increased average temperatures pose a threat to substation transformers. Within a substation, transformers are the asset most likely to be affected by projected higher temperatures since their ambient temperature design reference temperature is lower (i.e., 86°F) than that of most other assets. Higher average and maximum ambient temperatures increase the aging rate of the insulation in transformers, resulting in decreased asset life. 14

Decreased Asset Capacity

Because an asset's internal temperature is the result of the ambient temperature in which it operates, as well as the amount of power it delivers, operating in an ambient temperature above the design reference temperature decreases the operational rating of the asset. However, derating the system due to increasing temperatures would effectively decrease the capacity of the system. When the capacity of the system is decreased, Con Edison must make investments to replace that capacity. The Con Edison system is currently designed with the capacity to meet a peak summer demand of more than 13,300 megawatts (MW). Based on projected temperature increases, capacity reductions in 2050 could range from 285 MW

¹⁴ Not every excursion above the designed-for temperature will result in decreased service life. Two conditions must be met for the useful life of the transformer insulation to experience an increased rate of decay: (1) the ambient reference temperature rating must be exceeded, and (2) the transformer must be operating at the rated load, typically as a result of the network experiencing a single or double contingency.











¹³ Buses, disconnect switches, circuit breakers, and cables all have a design reference temperature of 104°F or higher.

to 693 MW for overhead transmission, switching stations, area station and sub-transmission, and network transformers. ¹⁵ This could potentially result in a capital cost of \$237 million to \$510 million by 2050.

The primary impact of increases in ambient temperatures on overhead transmission lines (assuming peak load) is increased line sag. Insufficient line clearance presents a safety risk should standard measures such as vegetation management not alleviate the risk. If standard measures cannot be applied, the lines would have to be derated and investments would be needed to replace the diminished capabilities of the line.

Decreased System Reliability

Increases in TV-related events are expected to affect the electric network and non-network systems by decreasing reliability. Con Edison uses a Network Reliability Index (NRI) model to determine the reliability of the underground distribution networks. ¹⁶ Con Edison has set an NRI value of 1 per unit (p.u.) as the threshold over which reliability is considered unacceptable. Currently, there are no networks that exceed this standard.

The Study team modeled how the NRI value of each network would change without continued investments in the system. The forward-looking NRI analysis found that with an increase in the frequency and duration of heat waves by mid-century, between 11 and 28 of the networks may not be able to maintain Con Edison's 1 p.u. standard of reliability by 2050, absent adaptation. Under the higher emissions scenario (RCP 8.5 90th percentile), projected impacts are relatively severe, even by 2030, with up to 21 total networks projected to exceed the NRI threshold by that year, absent adaptation (Figure 19). These deficiencies can be reduced by continuing to make investments to better withstand climate events, which Con Edison has done in the past through measures such as infrastructure hardening and added redundancy, diversity, and flexibility in power delivery. Such measures carry the co-benefit of improving blue-sky functionality and reliability.

Currently, Con Edison replaces paper-insulated, lead-covered (PILC) cables as an effective first line of defense against NRI increases. Con Edison is committed to continued investment in this measure, which will help reduce this heat-related vulnerability in the near term. The Study team also quantified the value of other measures to maintain network reliability, including innovative distribution designs and the use of distributed resources, which can be part of microgrids.

¹⁶ NRI is a Monte Carlo simulation used to predict the performance of a network during a heat wave. The program uses the historical failure rates of the various components/equipment that are in the network, and through probability analysis determines which networks are more likely to experience a shutdown.











 $^{^{15}}$ The assumed decrease in capacity is 0.7% per °C (0.38% per °F) for substation power transformers, and 1.5% per °C (0.8% per °F) for overhead transmission conductors (Sathaye, 2013).

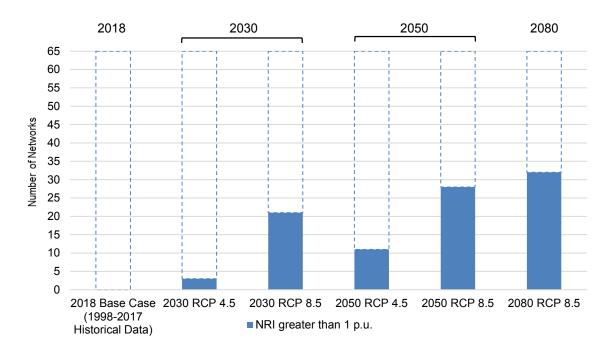


Figure 19 ■ The number of networks above the NRI threshold of 1 p.u. under both climate scenarios for 2030, 2050, and 2080

The Study team also analyzed the impact of climate change on non-network reliability, which is measured in terms of the System Average Interruption Frequency Index (SAIFI).¹⁷ The results indicate that the reliability of the non-network system is somewhat vulnerable to heat events; however, climate impacts would be negligible out to 2080. The average contribution to reliability from non-network autoloop feeder failures and 4-kV grid supply feeder failures due to increased temperatures would only contribute up to 8% of the maximum threshold SAIFI of 0.45 (i.e., a 0.035 increase in SAIFI in 2080) (New York Department of Public Service, 2018).

Increased System Load

When temperature and humidity increase, demand for electricity for cooling also increases. Therefore, higher TV in the summer can cause higher peak loads. The Study team found an increase in peak load in 2050 of 6.9% to 19.2%, as compared to historical conditions. These projected changes in load are due only to the impact of changing TV, and do not take into consideration changes in other factors (e.g., population, increased air conditioning penetration). The Study team found a decrease in winter peak electric load.

Increases in load may require investments in system capacity to meet the higher demand. This cost could be between \$1.1 billion and \$3.1 billion by 2050. The 10- and 20-year load relief investment plans use asset ratings and load forecasts as key inputs, both of which include temperature as a factor. This combination of a greater demand and a decreased capacity to fill that need will likely warrant a revision to the load relief planning process in the future (Table 5).

¹⁷ SAIFI is a measure of customer reliability. It is the average number of times that a customer is interrupted for 5 minutes or more over the course of 1 year.









Total capacity under base and Peak load during **Total additional** Incremental Incremental capacity needed future capacity current and load increase reduction due to temperature future 1-in-3 due to changes under climate conditions (MW) **Scenario** temperature events (MW) in TV scenarios (MW) Base Case 2050 13.300 0 13.525 0 RCP 4.5 10th 13,015 285 14,949 1,424 1.709 percentile 2050 RCP 8.5 90th 12,607 693 16,491 2,966 3,659 percentile 2050

Table 5 The combined impacts of increased load and asset capacity reduction in 2050

Secondary Vulnerabilities

The Study team identified additional heat and humidity-related vulnerabilities in Con Edison's system that were not flagged as priority vulnerabilities but nonetheless present risks.

- **Transmission system:** Con Edison's current transmission system is designed for the highest anticipated loads based on historical values. The Study team found that while load exceeded 90% of the peak load (presenting the possibility for thermal overload) on 1.5% of summer days historically, by 2050, this may increase to 5.2% of days under the RCP 8.5 90th percentile scenario. This shift in TV distribution may result in a small increase in the frequency of load drop from the transmission system.
- Summer operations and voltage reductions: When summer temperatures soar, Con Edison implements a set of procedures to avoid voltage and thermal stresses on the system. These procedures are triggered by a threshold (e.g., TV 86, which is the 1-in-3 peak load-producing TV). The Study team found that there could be a significant increase in the number of days with voltage reductions and summer work restrictions. However, if Con Edison continues to invest in the system to ensure operational capacity during the 2050 1-in-3 TV event, then there will be a drop in the frequency of voltage reductions and summer work restrictions, relative to today.
- Corporate Emergency Response Plan: Con Edison also uses TV thresholds to trigger elevated threat levels under its Corporate Emergency Response Plan (CERP). The Study team conducted an analysis to understand how the projected changes in TV will affect the exceedance of current CERP threat levels. The analysis indicates that TV conditions exceeding current thresholds will increase in both the lower (RCP 4.5 10th percentile) and higher (RCP 8.5 90th percentile) climate change scenario. The conditions for reaching a "Serious" threat level based on the current thresholds, for example, would increase from 0.4 days per summer, on average, to 1.8 days under RCP 4.5, and 12.8 days under RCP 8.5.
- Volume forecasting: Con Edison conducts volume forecasting to estimate the volume of energy the company needs to purchase, a portion of which is weather-sensitive. The calculation for this portion relies primarily on heating degree-days (HDDs) for the winter and cooling degree-days (CDDs) for the summer. The Study team estimated that Con Edison could experience an increase in summertime CDDs, which could result in the energy delivery increasing from 43,077 gigawatt-hours (GWh) in 2050 under the base case to 43,685 GWh under the RCP 4.5 scenario (a 1.4% increase), and to 45,394 GWh under the RCP 8.5 scenario (a 5.4% increase). The Study team found a less significant decrease in HDDs due to climate change.

Sea Level Rise

RCP 4.5 and RCP 8.5 projections indicate that sea level rise may exceed Con Edison's current design standard for coastal flood protection (i.e., a 100-year storm with 1 foot of sea level rise and 2 feet of











freeboard) between 2030 and 2080. The Study team analyzed the exposure of Con Edison's assets to 3 feet of sea level rise (i.e., the 2080 RCP 8.5 83rd percentile sea level rise projection), keeping the other elements of Con Edison's existing risk tolerance constant (i.e., a 100-year storm with 2 feet of freeboard). By summing the freeboard and sea level rise values, this equates to FEMA's 100-year floodplain elevation plus 5 additional feet.

Of the 324 electric substations (encompassing generating stations, area substations, transmission stations, unit substations, and Public Utility Regulating Stations [PURS]), 75 would be vulnerable to flooding during a 100-year storm if sea level rose 3 feet. Three of these potentially exposed substations would only require minimal modifications to protect them, 16 would require an extension of existing protections, eight would require a new protection approach (i.e., the existing protections cannot be extended), and 48 do not have existing protections because they are outside of the floodplain. Hardening all these substations is estimated to cost \$636 million.

Precipitation

The Study team found that substations, overhead distribution, underground distribution, and the transmission system are most at risk for precipitation-based hazards.

Substations may experience an overflow of water from transformer spill moats, which could release oil-contaminated water within the substation. However, the risk of such an event is low, as transformer spill moats are built at a level that is robust to all but a severe and highly improbably conjunction of events.¹⁸

The transmission and overhead distribution systems are both vulnerable to the accumulation of radial ice, which can build up on lines and towers during winter precipitation events. In extreme scenarios, accumulation of radial ice can result in unbalanced structural loading and subsequent transmission line failure, especially when accompanied by heavy winds (Nasim Rezaei, Chouinard, Legeron, & Langlois, 2015). Con Edison's current system meets the National Electrical Safety Code standard for radial ice and is robust to ice accumulation. It is uncertain whether climate change will increase or decrease the intensity of future icing events.

The underground distribution system is vulnerable to flooding and salt runoff from snowfall and ice events. Flooding can damage non-submersible electrical equipment. This risk is mitigated through Con Edison's designs: All underground cables and splices operate while submerged in water, and all underground distribution equipment installed in current flood zones (and all new installations) are submersible. Snowfall and ice require municipalities to spread salt on roads, which eventually seeps into the ground with runoff water. Road salt can degrade wire insulation and lead to insulation burning and arcing, potentially causing safety concerns and customer outages. It is currently unclear how salting frequency will change over time.

Extreme Events

Hurricanes and nor'easters present physical risks associated with heavy winds, precipitation, and flooding, which can lead to widespread system outages and, at worst, physical destruction. During hurricanes, wind stress and windblown debris can lead to tower and/or line failure of the overhead transmission system

¹⁸ In accordance with New York State code and federal Spill Prevention, Control, and Countermeasure recommendations, Con Edison's transformers are protected by moats designed to hold water from a 6-inch, 1-day storm event, in addition to the gallons of oil that may be released during a spill event and a further 50,000–60,000 gallons of fire suppression fluid. Based on this standard, Con Edison's substation transformer moats are robust to 6 inches of rain during a catastrophic emergency, and significantly more than that at all other times.











and damage overhead distribution infrastructure, which could cause widespread customer outages. Intense rain during hurricanes can also flood substations, which may cause an overflow of oil-contaminated water from transformer spill moats. A Category 4 hurricane could very likely lead to outages for more than 600,000 non-network customers and more than 1.6 million network customers.

During nor'easters, accumulation of radial ice can cause tower or line failure of the overhead transmission system. Similarly, snow, ice, and wind can damage the overhead distribution system. Indirectly, salt put down by the city to contend with snow and ice accumulation on roads could infiltrate the underground distribution system, causing arcing and failure of underground components.

Extreme heat waves present a range of effects that can contribute to failures, including a lower ampacity rating while increasing load demand, causing cables and splices to overheat, transformers to overheat, and transmission and distribution line sag. Distribution network component failures can cause Con Edison to exceed the network reliability design standard. Greater line sag can lead to flashovers and line trips.

Adaptation Options for the Electric System

Withstand

In the short term, Con Edison can work to address the vulnerabilities of the electric system by integrating climate hazard considerations into planning, collecting data on priority hazards, and updating design strategies.

There are several opportunities to integrate climate change data into planning processes. For example, Con Edison could integrate climate change projections into long-term load forecasts, consult utilities in cities with higher temperatures to refine the load forecast equation for high TV numbers, and develop a load relief plan that integrates future changes in temperature and TV into asset capacity and load projections. During load relief planning, Con Edison could also consider whether extreme events may shift the preferred load relief option—frequent extreme heat could reduce the effectiveness of demand response programs. For the transmission system, Con Edison could integrate considerations of climate change into the long-range transmission plan. For the distribution system, Con Edison could integrate climate projections into NRI modeling and install high-reliability components, ¹⁹ as needed.

Given the potential risks that temperature and heat waves pose to the electric system, the Study team suggests that Con Edison could collect data on these hazards to build greater awareness of their impacts to the system, as well as to monitor for signposts that would trigger additional action. Specifically, Con Edison could:

¹⁹ System components vary in their reliability. For example, PILC cable performs more poorly than solid dielectric cable.











- Install equipment capable of collecting, tracking, and organizing temperature data at substations to allow for location-specific ratings and operations.
- Make ground temperature data more accessible and track increases over time.
- Expand monitoring and targeting of high-risk vegetation areas.
- Continue to track line sag and areas of vegetation change via light detection and ranging (LiDAR) flyovers to identify new segments that may require adaptation.

These data could be used to routinely review asset ratings in light of observed temperatures. Con Edison could also incorporate heat wave projections into reliability planning for the network system.

Hurricanes are another priority hazard for the electric system and therefore warrant robust planning tools that capture potential changes in climate. Con Edison could complement their existing model used to predict work crews required to service weather-driven outages with an updated model that better resolves extreme weather events and extreme weather impacts on customers in the service territory.

Design standards are a way to help standardize resilience by ensuring that new assets are built to withstand the impacts of climate change hazards. The Study team suggests a variety of design standards:

- Temperature: Standardize ambient reference temperatures across all assets for development ratings.
- Precipitation: Update precipitation design standards to reference National Oceanic and Atmospheric Administration (NOAA) Atlas 14 for up-to-date precipitation data. Consider updating the design storm from the 25-year precipitation event to the 50-year event to account for future increases in heavy rain events.
- **Sea Level Rise:** Revise design guidelines to consider sea level rise projections and facility useful life. Continue to build to the higher of the FEMA + 3' level and the Category 2 storm surge levels at newbuild sites, as is current practice. Add sea level rise to the Category 2 maps to account for future changes and a greater flood height/frequency.

In addition to these systematic approaches, Con Edison can also help the electric system better withstand climate hazards through asset-specific physical adaptation measures, when needed. Table 6 illustrates these physical options.











Table 6 ■ Potential physical adaptation options for electric assets

Main Hazard(s)	Vulnerable Assets or Plan	Adaptation Option	Implementation Timeframe	Signpost or Threshold
Temperature	Grid modernization	Continue to invest in grid modernization to increase resilience to climate change through new technology and increased data acquisition. Efforts include distribution automation, grid-edge sensing (environmental, AMI), asset health monitoring, conservation voltage optimization, and targeted system upgrades.	Continuous	Change in ambient operating temperatures, including changes in science-based projections
Heat Waves	Network system, which may experience reduced reliability (and therefore increased NRI) due to heat waves	Complete PILC cable replacements.	2030	Increased frequency or duration of heatwaves
		Continue implementing load relief strategies to keep NRI ratings below 1. Options include: • Split the network into two smaller networks. • Create primary feeder loops within and between networks. • Install a distribution substation. • Incorporate distributed energy resources and non-wire solutions. • Design complex networks that consider combinations of adaptation measures.	Continuous	NRI value over 1 p.u.
	Non-network distribution system	Maintain non-network reliability in higher temperatures by implementing the following: • Autoloop sectionalizing • Increased feeder diversity	2080	Forecasted System Average Interruption Frequency Index (SAIFI) ratings (incorporating climate change projections) above established thresholds
	Overhead transmission	Replace limiting wire sections with higher rated wire to reduce overhead transmission line sag during extreme heat wave events. Alternatively, remove obstacles or raise towers to reduce line sag issues.	Continuous	Increased incidence of line sag; higher operating temperatures
		Explore incorporating higher temperature-rated conductors.	2050	Existing asset replacement
	Area and transmission substation transformers	Undertake measures that contribute to load relief, such as energy efficiency, demand response, adding capacitor banks, or upgrading limiting components, such as circuit breakers, or disconnect switches and buses.	2030/2050	Ambient temperatures exceeding asset specifications
		Gradually install transformer cooling, or replace existing limiting transformers within substations.	2050/2080	Ambient temperatures exceeding asset specifications
Precipitation	Substations	Harden electric substations from an increased incidence of heavy rain events by doing the following: Raising the height of transformer moats Installing additional oil-water separator capacity Increasing "trash pumps" behind flood walls to pump water out of substations	2080	Changes in the 25-year return period storm
	Transmission and overhead distribution	Underground critical transmission and distribution lines.	2080	Increased incidence of icing











Main Hazard(s)	Vulnerable Assets or Plan Adaptation Option		Implementation Timeframe	Signpost or Threshold
	Underground distribution	Retrofit ventilated equipment with submersible equipment to eliminate the risk of damage from water intrusion.	2050	Expanded area of precipitation-based flooding; better maps of areas at risk for current and future precipitation-based flooding
		Reduce the incidence of manhole events due to increased precipitation and salting by doing the following: Expanding Con Edison's underground secondary reliability program Accelerated deployment of vented manhole covers Replacement of underground cable with duallayered and insulated cable, which is more resistant to damage Installation of sensors in manholes to detect conditions indicating a potential manhole event	2050	Increase in the City's use of salt over the winter period; increased rate of winter precipitation
Hurricanes	Overhead transmission	Continue to expand existing programs to reinforce transmission structures; address problems with known components.	Continuous	Increased frequency/severity of heavy winds; existing asset replacement
	Overhead distribution	Invest in retrofits for open wire design with aerial cable and stronger poles.	2080	Increased frequency/severity of heavy winds; existing asset replacement
		Underground critical sections of the overhead distribution system to ensure resilience against hurricane force winds and storm surge.	2080	Increased frequency/severity of heavy winds
Nor'easters	Overhead transmission and distribution	Continue to expand programs to reinforce transmission and distribution structures and expand the number of compression fittings used to address weak points in transmission lines.	Continuous	Increased incidence of icing; existing asset replacement
	Underground distribution	Upgrade high failure rate components.	Continuous	Increased frequency/severity of nor'easter events

Of course, it is neither practical nor feasible for Con Edison to build resilience to the point that its electric system can fully withstand the impacts of all climate hazards. The Study team thus suggests that Con Edison consider the following strategies to help the electric system better absorb and recover from impacts:

Absorb

- Temperature: Increase capabilities to provide flexible, dynamic, and real-time line ratings.
- **TV:** Routinely update voltage reduction thresholds and hands-off thresholds to account for changes in climate and the changing design of the system.
- **Hurricanes:** Continue to explore and expand operational measures to increase the resiliency of the overhead distribution system by increasing spare pole inventories to replace critical lines that are compromised during extreme weather events.
- **Heat waves:** Stagger demand response consecutive event days across different customer groups to increase participation; ensure that demand response program participants understand the purpose/cause of the event; use technology to more efficiently regulate load/use AMI to rapidly shed











load on a targeted network to help ensure that demand does not exceed supply; and continue installation of energy storage strategies, including on-site generation at substations or mobile storage on demand/transportable energy storage system (TESS) units, and compressed natural gas tank stations.

Recover

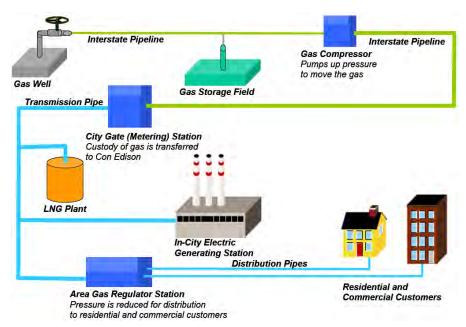
- **Heat waves:** Continue to actively engage forward-looking technologies to improve extreme recovery time for distribution systems, such as automated splicing systems to reduce feeder processing times.
- Extreme events: Support additional deployment of hybrid energy generation and storage systems at critical community locations and resilience hubs; support increasing the percentage of solar/other distributed generation projects to allow for islanding; encourage on-site generation for individual businesses and residential buildings; and increase the use of LiDAR and drones to assess damage and reduce manual labor.

Gas System

Gas System Overview

Con Edison's gas service territory covers Manhattan, Bronx, Westchester, and parts of Queens. Con Edison serves approximately 1.1 million firm customers and 900 large-volume interruptible customers who can alternate fuel sources. The natural gas system consists of more than 4,359 miles of pipe transporting approximately 300 million dekatherms (MMdt) of natural gas annually. About 56% of the system operates at low pressure, 11% operates at medium pressure, and 33% operates at high pressure. Figure 20 depicts the Con Edison natural gas delivery chain.

Figure 20 ■ Con Edison natural gas delivery chain













Gas Vulnerabilities

Most of Con Edison's gas assets are underground, and gas load peaks in the winter rather than in the summer, which means that gas assets are less likely to be damaged by subaerial extreme events, such as heat waves, lightning, and strong winds. As discussed in Con Edison's Post Sandy Enhancement Plan, Con Edison's gas assets are most vulnerable to underground water intrusion caused by flooding, and thus projected increases in the frequency of heavy precipitation and downpours, sea level rise and storm surge, and hurricanes and nor'easters pose a significant risk (Con Edison, 2013).

Water intrusion can occur if underground water enters gas pipes or mains and may result in a drop in pressure and lead to scattered service interruptions; low-pressure segments of the system and cast iron pipes are particularly vulnerable to this risk. In addition, pipe sections near open-pit construction projects may also be more vulnerable, because open excavation work can create opportunities for water intrusion if flood protection measures are not consistently used. Con Edison has already developed operational protocols that require crews working on open excavation sites to secure them to minimize water intrusion risk.

Water intrusion into gas regulators through aboveground vents may also cause damage. This intrusion could lead to water sitting on top of the diaphragm that allows each regulator to function and exerting additional pressure on the diaphragm that could, in turn, over-pressurize the regulator. Over-pressurized gas flowing through a system designed for lower pressure gas increases the possibility of tearing leaks in distribution piping, and in the worst-case scenario, could blow out pilot lights.

For the gas distribution system to function at full capacity and to be able to provide customers with desired gas supply, Con Edison must keep gas moving through the system at the intended flow rate, or pressure level, of each system segment. Once water enters the gas system, it is difficult to pinpoint the location and remove the water, which can increase the durations of resulting service interruptions.

Con Edison is currently undertaking several measures to manage underground water intrusion:

- Using drip pots to collect water at low points in the system (approximately 8,000 are currently in place)
- Developing a program to better prioritize gas infrastructure replacements. Remote sensors and
 machine learning could identify leak-prone areas to prioritize for upgrades intended to mitigate
 increasing precipitation risks in the face of climate change
- Developing a drip pot remote monitoring program using sensors, which would increase the efficiency
 of periodic emptying of drip pots and reduce the effort needed to monitor drip pots during the period
 of planned pipe replacement
- Shifting toward constructing and repairing infrastructure with more leak-resistant equipment, when possible

A climate change-driven increase in the frequency and intensity of flood events, such as heavy rain events or snow events followed by rapid snow melt, or coastal storm surge, may elevate the risk of water infiltration into the low-pressure gas system. The precipitation threshold currently used as a benchmark for monitoring and emptying drip pots is ½ inch of rain in 24 hours. Under the RCP 8.5 scenario, this threshold is projected to be exceeded 37 days per year in Central Park by the latter part of the century, which is nearly 20% more than the 31 days observed over the baseline period.

Low-probability, high-impact extreme events may also include heavy rainfall and storm surge that could increase the risk of water entering the distribution system. An increase in the frequency and intensity of extreme events may make water infiltration into the gas distribution system more likely. Con Edison's gas











system has established criteria to ensure that new equipment, such as gas regulator line vents, is resilient against a 100-year storm and 1 foot of sea level rise. After Superstorm Sandy, Con Edison upgraded two regulator stations to meet this standard. The Study team determined that to protect regulator stations against 3 feet of sea level rise, Con Edison would need to update 32 regulator stations, at a cost of \$13.8 million.

The gas transmission system is vulnerable to cold snaps associated with nor'easters, when temperatures can drop below 0°F for multiple days. Transmission system capacity is designed to meet demand projected for weather conditions at or above 0°F. Temperatures below that threshold may increase demand to a level that exceeds system capacity; in such an event, system pressure may decrease, resulting in customer service loss.

In a generally warmer climate, the gas sector could experience significant decreases in winter energy sales for heating. There could be up to a 33% decrease by 2050 and a 49% decrease by 2080. Similarly, under the RCP 8.5 scenario, winter gas peak load is projected to decrease by 144 MMdt in 2050, compared to the base case.

Adaptation Options for the Gas System

In addition to Con Edison's existing efforts, the Study team identified several additional adaptation options that the company could consider. Some measures proposed, such as remote information monitoring and analysis, address vulnerabilities in operations and planning processes. Most measures proposed address physical vulnerabilities (see Table 7), which fall within the "withstand" adaptation category.

In the short term, Con Edison could focus on expanding its monitoring capabilities, particularly through programs that use machine learning and remote monitoring to identify vulnerable areas of the distribution system, and remote drip pot monitoring sensors.

To account for changing temperatures, Con Edison could integrate climate change data on changes in the winter gas TV into gas volume and peak load forecasting so that the company is continuously planning for future changes in climate.

To address physical risks to existing infrastructure, Con Edison may need to invest in the system at strategic points in time, as described in Table 7.

Distribution system measures focus on minimizing the risk of flood water entering and depressurizing gas mains and pipes, and measures to more easily re-elevate pressure if water does enter the system.

Adaptation measures identified to address transmission system vulnerabilities primarily focus on diversifying the system and strengthening load management when capacity is constrained.











Table 7 ■ Physical adaptation options for gas commodities

Hazard	Asset	Adaptation Option	Implementation Timeframe	Signpost or Threshold	
Extreme Hurricane (Category 4)	Transmission System	Procure additional compressed natural gas tank stations.	Designing for a future Category 4 hurricane	Increased frequency and severity of storms that could cut supply, including from science-based projections	
	Gas Regulators	Install vent line protectors, extend vent lines and posts, seal all penetrations, and/or elevate key electric and communications equipment to protect vent lines.	2050	When sea level rise exceeds 1 foot, or if flooding is reported and the regulators do not have vent line protectors	
	Distribution System	Continue targeted Main Replacement Program (planned completion by 2036) to harden gas mains against depressurization by water intrusion or other concerns.	~2030 (goal to complete program by 2036)	Increase in flooding events	
Extreme Nor'easter	Transmission System	Construct additional gate stations.	Designing for a future worst-case nor'easter	More frequent or intense cold spells that drop temperatures below the design threshold for consecutive days and	
		Build larger and/or additional transmission mains.			
		Create ties between mains to diversify the transmission system.		threaten supply	
		Install remote operated valves to more efficiently isolate load for load management (temporarily disconnecting gas customers) during peak events.			

In addition, given the increasing potential for extreme events, Con Edison could consider distribution system resilience options such as exploring and implementing ways to elevate system pressure in low-flow conditions.

Steam System

Steam System Overview

Con Edison's steam system provides service to more than 3 million Manhattan residents (including approximately 1,720 metered customers) south of 96th Street. Total system capacity is about 11,676 thousand pounds per hour (Mlb/hr). The distribution system is comprised of a continuous network of pipes (steel main pipes and steel and brass service and condensate piping)—in aggregate, about 105 miles of piping. The pipes' physical location is directly correlated with the locations of generation sources and regional customer demand. Figure 21 shows the locations of several steam system assets.













Figure 21
Key assets included in the Con Edison steam system

Steam Vulnerabilities

Like the gas system, much of Con Edison's steam system is underground, and steam is also a winter-peaking rather than a summer-peaking commodity. As such, steam generation and distribution assets are generally less prone to damage by shifts and extremes in temperature, humidity, and wind, and more vulnerable to flooding, which may be caused by increased precipitation, coastal inundation, snow melt, or storm surge in extreme events. Severe flooding impacts, such as broken distribution pipes and damaged steam generation stations, can take significant time to repair, further increasing the duration of customer impacts.

Increased frequency and intensity of precipitation events may increase the vulnerability of steam system manholes to "water hammer" events. When a high volume of water collects around a manhole, steam in the pipes underneath may cool and condense. Interaction between steam and the built-up condensate may cause a rupture in a steam pipe. One such water hammer event occurred in 2007 when a steam pipe at Lexington Avenue and 41st Street exploded during a period of heavy rainfall (Figure 22). Con Edison responded to that event by implementing a precautionary rain event threshold. If more than ¾ inch of rain is forecasted to fall within 3 hours, Con Edison will begin to proactively monitor and address flooding before it can cause a water hammer event. The key measure used to address flooding to prevent water hammer events is pumping water out of manholes and into the city sewer. In turn, Con Edison's capacity to manage flooding events that threaten steam generation and distribution assets depends on the capacity of the city's stormwater









system to handle high volumes of water that Con Edison may need to pump away from assets under a changing climate.

Steam generation and distribution system assets are also vulnerable to projected increases in sea level and coastal inundation. Five out of six steam generating plants would be exposed to a 100-year storm if sea level rose by 3 feet. If water enters the steam generation system, it can degrade plant capacity or force unit or plant outages. Significant damage to steam generation systems would likely require long repair times, which could increase the duration of customer impacts. Hardening several of the generating stations to a higher level of protection would be difficult and costly. For example, at the East River Generating Station, raising mechanical equipment would require significant and costly alterations to the hydraulics of the steam system. Similarly, at East 13th Street, flood waters associated with a 100-year storm and 3 feet of sea level rise would reach the tertiary bushings on some 345-kV transformers, resulting in arcing and critical failure of the unit. The total estimated cost to harden the five steam generation plants against a 100year storm and 3 feet of sea level rise is \$30 million.

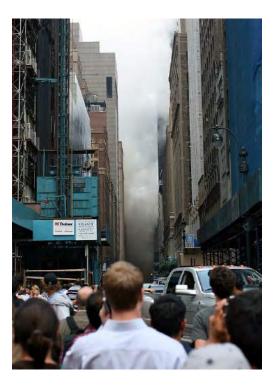


Figure 22 2007 steam pipe explosion

Con Edison has adopted storm hardening measures to protect the steam system in response to recent storms such as Superstorm Sandy. Those measures include developing location-specific plans and drills in preparation for storms, implementing physical hardening measures at steam generating stations, protecting critical equipment by waterproofing or relocating it, installing a new steam main to ensure that hospitals receive continued service, and introducing isolation valves in strategic locations to reduce the number of customers impacted by flooding in future extreme events. Because isolating steam lines is key to managing flooding impacts, Con Edison considers several potential flood sources (e.g., rainfall deluges, storm tides, water main breaks) when evaluating hardening options, and periodically reviews and updates both operational and physical risk mitigation strategies. The company is also investing in steam system resilience through measures such as waterproofing system components in the normal course of upgrades, prioritizing hardening steam mains by prior flooding issues (fewer than 10 of the original 86 locations identified are still vulnerable), and using remote monitoring to monitor manhole water level and steam trap operation (a system is currently under design and expected to be operational by 2021).

Extreme and multi-hazard events could also increase the vulnerability of the steam distribution system to salt damage and flood damage. During nor'easters and extreme ice storms, the City of New York and jurisdictions in Westchester County conduct widespread street-salting operations to mitigate ice build-up on roads and sidewalks. Rapid melt after nor'easters and extreme ice storms can lead to an influx of salt-saturated runoff into manholes, in turn causing equipment degradation and, in some cases, manhole fires or explosions.

In a generally warmer climate, the steam system could experience significant decreases in winter energy sales for heating. There could be up to a 33% decrease by 2050 and a 49% decrease by











2080. Similarly, under the RCP 8.5 scenario, winter gas peak load is projected to decrease by 891 Mlb/hr in the winter of 2050 compared to the base case.

Adaptation Options for the Steam System

To determine when to implement various adaptation strategies, Con Edison could track climate trends, including TV, precipitation, sea level rise and storm surge, and extreme events, as described in prior vulnerability and adaptation sections.

The Study team suggests that Con Edison could continue to work collaboratively with other city actors on initiatives that could help strengthen the resilience of the steam system. Specifically, the company could take measures, including the following:

- Strengthen collaboration with the city to improve citywide stormwater design to alleviate flooding impacts and make adaptation measures implemented by Con Edison, such as drain pumps at manholes, more effective.
- Discuss ways to minimize salt use during the winter.
- Incorporate considerations of New York City initiatives in coastal resiliency plans for lower Manhattan to re-evaluate Con Edison's storm response plans and stages of pre-emptive main shutoffs.

In addition to engaging in these monitoring and coordination efforts, the company could also consider taking measures to address physical vulnerabilities in existing infrastructure by strategically investing in the system. Physical measures developed by the Study team are listed in Table 8.

Table 8 ■ Physical adaptation options for steam commodities

Hazard	Asset	Adaptation Option	Implementation Timeframe	Signpost or Threshold
Extreme Hurricane (e.g., Category 4)	Generation System	Invest in additional storm hardening investment measures to protect generation sites against extreme hurricane-driven storm surge. Leverage new innovations and advancements in flood protection over time and raise moated walls around current generation sites.	2050	When sea level rise exceeds 1 foot
	Distribution System	Continue to segment the steam system to limit customer outages in flood-prone areas.	In preparation for a Category 4 hurricane	Increased frequency and severity of storms, including from science- based projections
	Distribution System	Expand programs to harden steam mains (waterproofing pipes and raising mains).	In preparation for a Category 4	Increased frequency and severity of storms, including from science- based projections
		Pre-stage a greater number of drain pumps at critical or flood-prone manholes.	hurricane	

As it is neither practical nor feasible for Con Edison to build resilience to the point that its steam system can fully withstand the impacts of extreme events, Con Edison could also consider implementing additional strategies to better absorb and recover from impacts, such as improving systems for crowd-sourcing steam system leak detection.













Moving Towards Implementation

Initial Climate Projection Design Pathway

Implementation of adaptation options to mitigate vulnerabilities requires clear climate design guidelines that incorporate forward-looking regional climate change projections. To this end, the Study team suggests that Con Edison could establish an "initial climate projection design pathway" that considers appropriate risk tolerance levels within the range of climate change projections. The initial climate projection design pathway is meant to guide preliminary planning and investments until and if Con Edison can refine the pathway to reflect new climate projections with reduced uncertainties, changes to Con Edison's operating environment, and changes in city guidance. The following section outlines an adaptive management approach that allows Con Edison to monitor, manage, and design to acceptable levels of climate risk through time.

As an initial climate projection design pathway for decisions that require it, Con Edison will follow the conservative precedent set by the city's climate resiliency design standards (e.g., Mayor's Office of Recovery and Resiliency, 2019), combined with the state-of-the-art climate projections produced for this Study. Corresponding to city guidance, the same pathway may not apply uniformly across different climate change projections and hazards. More specifically, multiple climate projection design pathways may be required to address differences in the risk tolerance and projection uncertainty associated with different climate hazards. Under this framework, initial pathways could use the 50th percentile merged RCP 4.5 and 8.5 projections for sea level rise and high-end 90th percentile merged RCP 4.5 and 8.5 projections for heat and precipitation. Climate projection design pathways will be finalized for Con Edison's Climate Change Implementation Plan.

Alternative considerations are necessary to inform pathways for rare and difficult-to-model extreme events without probabilistic projections, such as 1-in-100-year heat waves and strong, multi-faceted hurricanes. Rather than prescribing statements of probability, these types of extremes require the blending of plausible worst-case scenarios from a climate perspective with stakeholder-driven worst-case scenarios from an impact perspective. Until climate modeling can better resolve and simulate these types of rare extreme events, the union of these two perspectives is critical for determining acceptable risk tolerance levels and setting initial pathways.







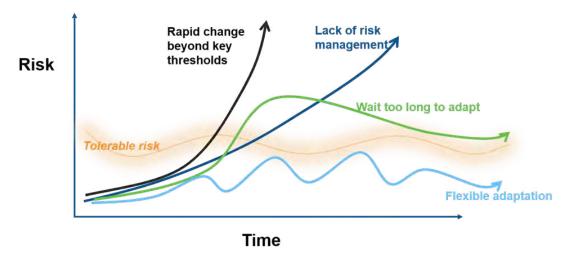




Flexible Adaptation Pathways Approach

While the initial climate design pathway can inform asset design, a complementary approach is needed to ensure resilience over the lifetime of that asset. A flexible and adaptive approach will allow Con Edison to manage risks from climate change at acceptable levels, despite uncertainties about future conditions. The flexible adaptation pathways approach ensures continued adaptability over time as more information about climate change and external conditions is learned. Figure 23 depicts how flexible adaptation pathways are used to maintain tolerable levels of risk.

Figure 23 ■ Flexible adaptation pathways in the context of tolerable risk and risk management challenges to non-flexible adaptation. Adapted from Rosenzweig & Solecki, 2014.



Con Edison will need to consistently track changing conditions over time to identify when additional adaptation strategies are required. This approach relies on (1) monitoring indicators ("signposts") related to climate conditions, climate impacts, and external conditions that affect system resilience, and (2) predetermined thresholds to signal the need for a change in risk management approaches ("transformation points"). This approach can support decisions on when, where, and how Con Edison can take action to continue to manage its climate risks at an acceptable level. Figure 24 depicts how a signpost indicator and a predefined threshold can be applied in the adaptation pathways approach to inform the timing of action given uncertainty.









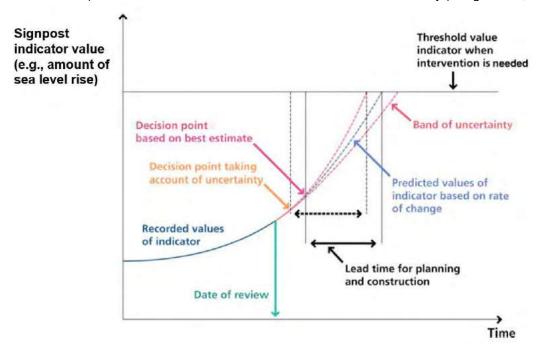


Figure 24 ■ Schematic diagram of how an indicator of change for a particular signpost (e.g., amount of sea level rise) informs decision lead times that take into account uncertainty (Ranger et al., 2012).

Con Edison is already familiar with monitoring signposts to manage planning uncertainties and guide adjustments to its Electric, Gas, and Steam Long Range Plans. ²⁰ Con Edison currently monitors signposts related to the pace of technology innovation (e.g., energy management technologies), the nature of regulation and legislation (e.g., new or revised greenhouse gas reduction policy targets), and the future of the economy (e.g., higher economic growth and impacts on demand), among others. In addition, the flexible adaptation pathways approach to manage climate change risks has been applied more widely by New York City and New York State (New York City Mayor's Office of Resiliency, 2019; Rosenzweig & Solecki, 2014) and utilities and infrastructure agencies across the United States, including San Diego Gas & Electric (Bruzgul et al., 2018; SDG&E, 2019) and Los Angeles Metro (Metro ECSD, 2019).

This flexible adaptation pathways approach allows Con Edison to develop an adaptation implementation plan in the near term, while adjusting adaptation strategies based on the actual climate conditions that emerge, thus reducing the cost of managing uncertainty. Under this adaptive approach, resilience measures can be sequenced over time to respond to changing conditions. For example, Con Edison may identify actions to implement now that protect against near-term climate changes and actions that are low and no regret, while leaving options open to protect against the wide range of plausible changes emerging later in the century. This implementation approach is preferred to implementing actions now that are optimized for present-day conditions or a single future outcome that ignores uncertainty.









²⁰ Long Range Plans are available at: https://www.coned.com/en/our-energy-future/our-energy-vision/long-range-plans

Illustrative Adaptation Pathway: Sea Level Rise Adaptation for Substation in FEMA + 3' Floodplain

Flexible adaptation pathways could be developed for guiding the management and protection of specific assets or types of assets. Here, we consider a hypothetical electric substation that is potentially vulnerable to sea level rise, as it is located within the FEMA + 3' floodplain (and, as such, is protected up to FEMA + 3' flood heights based on Con Edison's current design standards). This adaptation pathway is presented as *illustrative*; while it is grounded in the types of strategies that Con Edison would use for substation flood defense, a ready-to-implement pathway for implementation would require site-specific analysis and may differ from this configuration.

Figure 25 ■ Illustrative flexible adaptation pathway for a hypothetical Con Edison substation in a current FEMA + 3' floodplain

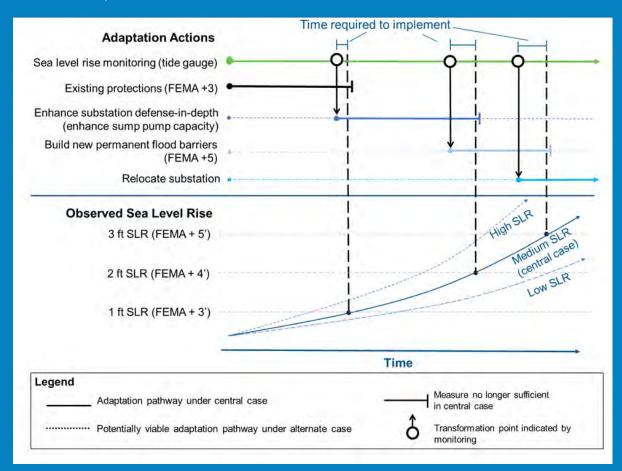










Figure 25 illustrates how the implementation of adaptation actions can be phased over time, with the implementation of new measures being triggered by observed sea level rise in excess of certain thresholds (transformation points). The timing of these transformation points is indicated by monitoring the rate of sea level rise at a local tide gauge (green line). Transformation points are set based on the point at which Con Edison needs to take action in order to implement a higher standard of protection before existing protections become insufficient.

In this adaptation pathway diagram, the implementation schedule of adaptation measures is illustrated based on a "central" sea level rise case. Measures based on this central scenario are illustrated with solid lines. If the actual pace of sea level rise deviates from the central case, monitoring of sea level rise may necessitate an accelerated or delayed implementation schedule

In this example, it is assumed that the substation already has existing protections to FEMA + 3' based on Con Edison's post-Superstorm Sandy hardening measures (black line). However, these protections will no longer be sufficient to provide the requisite 2 feet of freeboard under a 100-year flood scenario once sea level rise surpasses 1 foot.

- A trigger slightly under 1 foot leads to the first adaptation option, which is to supplement the substation's defense-in-depth strategy with additional sump pump capacity.
- The second adaptation option is triggered when sea level rise approaches 2 feet, and includes building new permanent flood barriers to a FEMA + 5' level.
- The final adaptation option, relocating the substation entirely, is triggered when sea level rise approaches 3 feet.

Each trigger is far enough in advance of the critical risk threshold (each foot of sea level rise, in this case) to have time for full implementation of the adaptation option.

Such a flexible adaptation pathway can allow Con Edison to better manage the costs of adaptation in the face of uncertainty, facilitating a prudent approach that avoids adapting too early or too late.











Signposts provide information that is critical for adaptive management decisions. Broad categories of signposts that Con Edison could consider monitoring include:

- Climate variable observations and best available climate projections: An awareness of recent and present climate conditions and their rates of change are key when determining potential asset exposure and risk. As described above, Con Edison currently operates a number of stations that monitor climate variables and is finalizing plans to expand the number of monitoring locations. Furthermore, access to the most recent and best available climate projections and expert knowledge is critical when updating plans for potential future scenarios as the science advances. In some cases, thresholds for action under climate variable and projection signposts may be determined by how quickly changes in climate conditions are approaching existing design or operational specifications.
- **Climate impacts:** Con Edison is already experiencing extreme weather and climate impacts to assets, operations and internal processes, and customers. Recognizing the risks, Con Edison is already conducting monitoring to identify areas of heightened vulnerability in its systems. Continued monitoring and evaluation of highest risk assets for impacts or near impacts can provide information about when and where additional adaptation options may be required.
- Policy, societal, and economic conditions: Evolving external conditions may affect climate-related
 decision making and areas of need throughout the service territory. Con Edison is already monitoring
 signposts for external conditions related to policies, society, and economies as part of its long-range
 plans. Additional external conditions may shift with a changing climate, such as adaptation strategies
 and investments led by the city.

The Study team identified a set of example signposts within each category, summarized in Table 9. Con Edison could consider coordinating with the city on NPCC's proposed New York City Climate Change Resilience Indicators and Monitoring System (Blake et al., 2019), where overlap and efficiencies in monitoring signposts may exist.

Table 9 ■ Example signposts for a flexible adaptation pathways approach

Category	Example Signposts
Climate variable observations and best available climate projections	 Chronic variables: Rate of change in TV, cooling degree-days, heating degree-days, sea levels, etc. relative to historical Extreme weather variables: Number of days overheat index thresholds, storm surge levels, frequency of various storm types in the greater region, wind speeds, heat wave intensity and duration, intense precipitation levels, etc. Updates to the best available climate projections: NPCC, IPCC, National Climate Assessment, etc.
Climate impacts	 Assets: Extent and magnitude of the costs of keystone asset damages (e.g., substations or power lines downed), damages incurred by events with different combinations of extreme weather, etc. Operations and internal processes: Frequency of heat-related contingencies in the network and non-network systems, etc. Customers: Number, spatial extent, and duration of outages caused by extreme weather, especially noting outages experienced by critical infrastructure and interdependent systems, etc.
Policy, societal, and economic conditions	 Policy: Updates to New York City design guidelines, etc. Societal: Community-scale flood protection strategies led by New York City (e.g., East Side Coastal Resiliency Project), population shifts (e.g., retreat), etc. Economic: Insurance prices and availability, etc.









Selecting Cost-Effective Solutions

As outlined in this Study, adapting to climate change will require investments in infrastructure and processes. Although some adaptation will be achieved through co-benefits from investments that Con Edison makes under existing processes, such as using distributed energy resources to meet growing electricity demand, other adaptation will require investments over and above those previously planned. The costs of those investments will ultimately be reflected in customers' bills. In order to minimize the financial impact of adapting to climate change, a cost-effective resilience planning process should identify a target level of resilience along with associated metrics, strike a balance between proactive and reactive spending, consider both the costs and benefits to customers, and select adaptation strategies that provide optimal benefit at the lowest cost.

As the energy industry grapples with how best to build resilience to the changing climate, the issue of how to quantify the resilience of energy systems is front and center. There is currently no standard *set of metrics* for the resilience of energy systems. A 2017 report from the National Academies of Sciences, Engineering, and Medicine found that "there are no generally agreed-upon resilience metrics [for the electricity sector] that are widely used today," also noting a contrast with the well-established set of electricity reliability metrics (NAS, 2017).

While there are a wide variety of energy resilience metrics that have been proposed or piloted in various contexts, most of these metrics fit within one of two broad categories. *Performance-based* metrics seek to quantify the resilience of the system through measurement of infrastructure performance during actual or modeled disruptive events. *Attribute-based* metrics, on the other hand, measure the presence of characteristics or features that are known or predicted to increase resilience performance in the event of a disruption. (Vugrin, Castillo, & Silva-Monroy, 2017).

Con Edison's storm hardening investments after Superstorm Sandy were guided by a combination of performance-based metrics, such as "past performance" in the selective undergrounding of feeders, and attribute-based metrics, such as "reducing the number of customers served by a single circuit to fewer than 500 customers," and adding "isolation devices to spurs and sub-spurs with open wire that are more than 2 spans in length" (Con Edison, 2013). Since the development of metrics is an active area of research and discussion, Con Edison could keep abreast of industry advances in resilience metrics for energy systems and incorporate those advances, where applicable, into its planning framework.

Even after a resilience metric(s) is selected, the question of exactly *how much* to spend on resilience or what the *right* level of resilience is, remains. One approach is to compare the societal cost of an outage against the cost of resiliency measures to shorten that outage. The total cost curve developed by ICF's Mihlmester and Kumaraswamy (Figure 26) is one example of such an approach (Mihlmester & Kumaraswamy, 2013). It shows for a hypothetical utility the post-outage time needed to restore service to 90% of customers, known in the industry as "CR-90." In this case, the lowest total costs, combining customer outage and grid-hardening costs, would be about \$169 million for a 65-hour CR-90 restoration time. The graph also shows that getting the CR-90 time to less than a day would cost more than twice that amount.

For Con Edison, the "right" level of resiliency investment will be strongly linked to the climate projection design pathway selected for each of the climate stressors identified for resiliency planning.











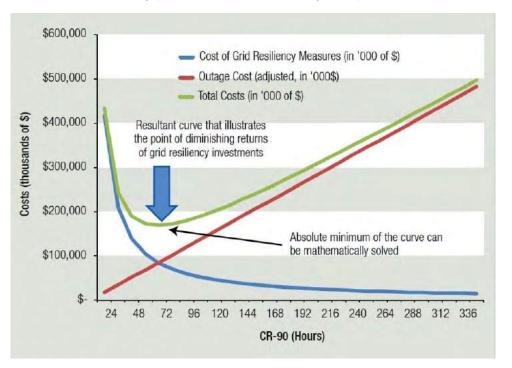


Figure 26 Total cost of resiliency (Mihlmester & Kumaraswamy, 2013)

Utilities have historically *reacted* to events, primarily because they lacked relevant climate projections and clear guidance or best practices for a methodology necessary to inform *proactive* adaptation and resiliency investments in infrastructure (California Energy Commission, 2018). Similarly, prior to conducting this study, Con Edison had limited information to guide proactive investments. The U.S. Department of Energy's North American Energy Resilience Model (U.S. DOE, 2019) highlights the need to "transition from the current reactive state-of-practice to a new energy planning and operations paradigm in which we proactively anticipate damage to energy system equipment, predict associated outages and lack of service, and recommend optimal mitigation strategies."

The Study team has described an overarching resilience management framework in Figure 12, designed to minimize the impacts of extreme events throughout asset life cycles. The framework considers how the system can withstand, absorb, recover, and adapt to risks posed by extreme events. To succeed, each measure of a resilient system requires *proactive planning and investments*.

Consideration of the *costs and benefits to customers* is a key component in the selection of adaptation options. Con Edison's capital budget cycle currently considers costs and benefits through an investment optimization and management process that compares the wide array of capital investments the company makes across its various business units. The process calculates a "strategic value" for each project to compare the benefit of investing in one capital project or program over another and to ensure that spend is in alignment with the company's corporate strategy. The strategic value is conveyed by a set of strategic drivers, each with relative weights, based on the company's long-term objectives. The strategic value of each capital project is assessed against that of other projects, and an optimized portfolio of capital projects is generated. While the strategic drivers include *reliability* and customer satisfaction components, the drivers do not include or consider the *resiliency* benefit of a project.









Con Edison developed and used a cost-benefit calculation model to prioritize storm hardening investments after Superstorm Sandy. The model estimated "the vulnerability of individual electric system assets based on the impact of electric system damage to customers and supporting critical infrastructure, the duration of an electric service outage, the likelihood of those assets being affected by either flooding or wind damage, and the reduction in vulnerability of those assets because of storm hardening initiatives." (Con Edison, 2014)

Con Edison's current distribution system planning process includes an evaluation of customer benefits resulting from investments. Con Edison's Distributed System Implementation Plan (DSIP) (Con Edison, 2016) includes the consideration of distributed energy resources as one option to meeting growing demand. As part of Con Edison's DSIP, the company has developed a Benefit Cost Analysis (BCA) Handbook that describes how to calculate individual benefits and costs. The BCA includes consideration of the unit cost of a particular option, per megawatt of delivery capacity, as well as an option's "social cost." Social cost accounts for the monetization of air pollution and carbon dioxide, using 20-year forecasts of marginal energy prices, the cost of complying with regulatory programs for constraining these pollutants, and the price paid for renewable energy credits. The social cost metric also qualitatively accounts for avoided water and land impacts. Beyond these environmental aspects, social cost accounts for net avoided restoration and outage costs to Con Edison, as well as net non-energy benefits (such as avoided service terminations, avoided uncollectable bills, and avoided noise and odor impacts).

This Study illustrates the use of multi-criteria analysis to compare criteria that may be difficult to quantify or monetize, or that may not be effectively highlighted in the financial analysis. This process identified additional complementary metrics that could be included in Con Edison's planning and budget prioritization process to account for uncertainty in climate outcomes. These metrics fall into two categories: co-benefits and adaptation benefits. Under a non-stationary climate, co-benefits (environmental, reputational, safety, and customer financial benefits) can help planners more comprehensively evaluate response options considering the additional challenges that climate change can pose on the system. In addition, consideration of adaptation benefits (flexibility, reversibility, robustness, proven technology, and customer's resilience) support long-term planning under climate uncertainty. These metrics allow for effective implementation of adaptation measures over time to achieve resilience. Con Edison's current processes include some of the metrics identified in the multi-criteria analysis (environmental and safety) but not others (customer's resilience and reversibility). Con Edison could work to incorporate this wider set of metrics as it incorporates resiliency planning into its broader capital budgeting process.

Key Issues to Be Addressed for Effective Implementation

Changes in the Policy/Regulatory and Operating Environment

Changes in the policy/regulatory and operating environment other than climate change were not accounted for in this Study but will be an important consideration when moving toward implementation. For example, the prioritization of adaptation strategies, and even the understanding of vulnerabilities, will need to consider these other drivers of change. Likewise, as Con Edison undertakes studies on how these factors will impact its business, climate change impacts could be factored into those studies. Some examples of possible changes in Con Edison's operating environment include:

Climate change and clean energy targets: New York State and New York City have both adopted
ambitious greenhouse gas emissions reduction targets (State of New York, 2019; City of New York, 2014),
which will drive changes in the adoption of renewables, transportation electrification, energy storage, and











so forth. It will also impact relative demand across the commodities (e.g., decreasing gas demand and increasing electricity demand).

- **Technological advances:** Advances in solar photovoltaics, energy storage, electric vehicles, and electrification of space heating are changing how and where electricity is generated and used.
- Customer response to climate change impacts: Customers will also have to respond to climate
 change impacts. This may include shifting away from flooded coastlines (depending on city-scale
 investments in coastal protection) and, with it, shifting demand away from portions of Con Edison's
 system.

Coordination with External Entities

Another critical need for effective implementation is coordination with external entities, including the City of New York and Westchester County, industry groups, equipment manufacturers, and others. Con Edison has limited authority to address certain vulnerabilities, such as the capacity of the city's stormwater system, so coordination is necessary for developing a more resilient system. In addition, coordination is needed to ensure that Con Edison is not over-investing in locations that the city plans to protect or retreat from. This project seeded the necessary relationships; however, the continuation of the interactions will need to be specified in the governance section of the upcoming implementation plan.

Establishing a Reporting and Governance Structure

Con Edison will need a continuing approach to updating stakeholders on climate risk management progress. Of the various reporting options, many companies are opting to follow the relatively new framework outlined by the Task Force on Climate-Related Financial Disclosures (TCFD).²¹ This framework emphasizes the need to assess both the physical risks of climate change, which is covered in this study, as well as the risks and opportunities presented by transition to a low-carbon economy. It requires consideration of the financial implications of the risks and opportunities, as well as a measurable risk management plan that is integrated with a strong governance structure.

Two risks that were not explored in this study, but would fit well in the TCFD framework, include:

- Costs and penalizations from service failure and outages: Costs associated with an outage event include restoration; collateral damage; customer claims; penalties, fines, audits, remediation, and reporting; and the financial impact of lost confidence. For example, in 2007, Con Edison was penalized \$18 million for its 2006 service disruptions, which included a 9-day blackout in western Queens.
- **Credit rating:** Increasingly frequent and intense extreme weather events could also impact credit rating risks and insurance liabilities. Credit rating agencies like Standard & Poor's and Moody's have added "resiliency" as a component of their rating criteria, indicating the relevance of climate risk for creditworthiness (Shafroth, 2016). Similarly, utilities may be increasingly choosing to retain a higher level of insurance to cope with more frequent and destructive weather-related events. However, a higher level of insurance protection leads to higher costs that may ultimately be reflected on customers' bills. Thus, while not as visible as physical asset or planning vulnerabilities, climate risks related to credit and insurance can have an impact on the utility.

Establishing a governance structure will be crucial for the successful continuation of Con Edison's climate change adaptation work. The governance structure can be used to encourage and track progress on the implementation of adaptation strategies (i.e., performance against set metrics and targets), ensure specific

²¹ For more information on the Task Force on Climate-Related Financial Disclosures, see https://www.fsb-tcfd.org/











people are on point for monitoring and implementing various strategies, and establish a frequency and process for reporting on risks and adaptation actions from individual employees to senior managers to Con Edison's board of directors.

Next Steps

As a next step from this Study, Con Edison will develop a detailed Climate Change Implementation Plan to operationalize the suggestions from this Climate Change Vulnerability Study. The implementation plan will:

- Review the Study and investigate whether recent progress in climate science may warrant inclusion.
- Select climate change pathway(s) to incorporate into design standards and procedures.
- Establish life cycle tables that provide timeframes of reference climate variables through 2080.
- Aggregate input from subject matter experts on changes required for specifications/procedures and choices for risk mitigation measures.
- Develop a timeline and written plan for the implementation of risk mitigation measures.
- Identify the scope and cost within the 5-year capital plan and 10- and 20-year long-range plans.
- Establish signposts for the re-evaluation of measure installation schedules.
- Conduct periodic progress meetings for external stakeholders.
- Recommend a governance structure for climate change monitoring and updating.











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APPENDICES

Appendices

To inform the conclusions of this Study, the Study team undertook a series of in-depth vulnerability assessments corresponding to the climate hazards representing outsized risks to Con Edison: temperature, humidity, precipitation, sea level rise, and extreme events. These are included as appendices. Each appendix includes detailed historical and projected climate conditions; corresponding climate-driven vulnerabilities to operations, planning, and infrastructure across the company's electric, gas, and steam systems; and potential adaptation strategies to mitigate vulnerabilities.

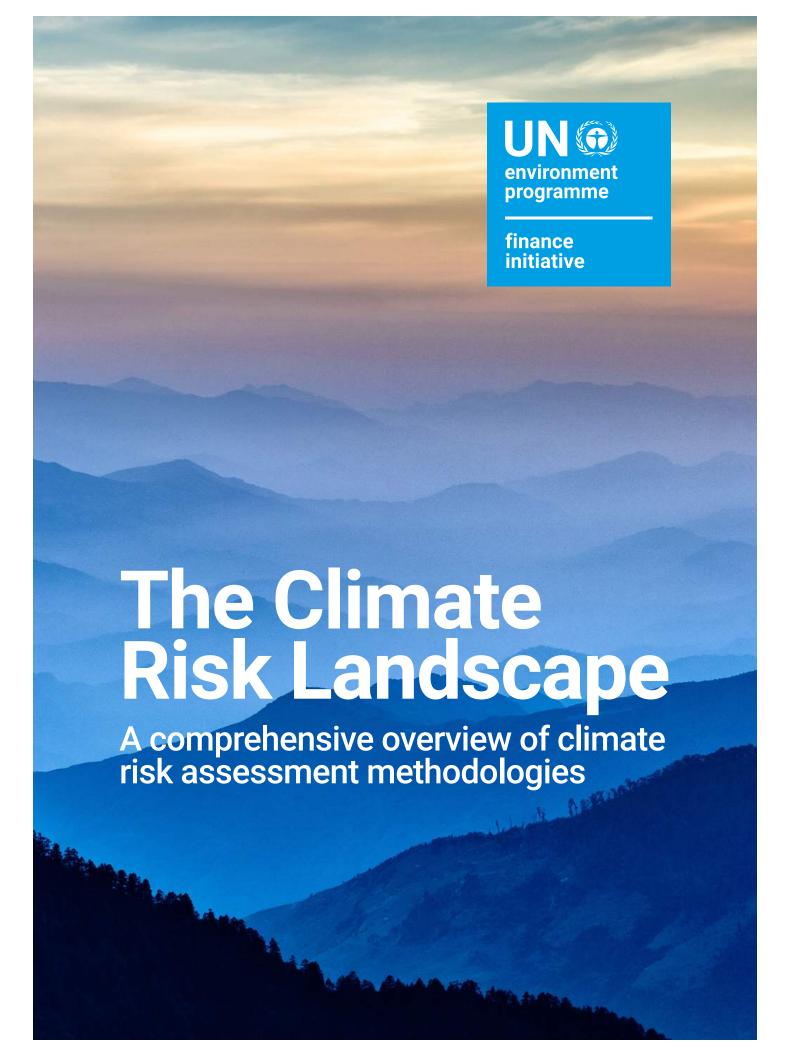
For each hazard, the Study team collaborated with Con Edison subject matter experts to conduct a rapid screen of the sensitivity of operations, planning, and infrastructure to support a risk-first approach. Vulnerabilities were then selected for more detailed analyses, which focused on understanding asset vulnerabilities to climate change and, in turn, relevant adaptation options and evaluation of their costs and co-benefits. These analyses informed the development of flexible solutions and signposts to guide implementation of potential adaptation options through time.

Ultimately, the five appendices provide key context for the climate science, vulnerabilities, and adaptation strategies discussed in this report, and as such, can be referenced for more comprehensive information in each subject area.

- Appendix 1 Temperature: Identifies how projected gradual trends in increasing temperature may affect operations, planning, and infrastructure across the electric, gas, and steam segments of Con Edison's business.
- Appendix 2 Humidity, Temperature Variable, and Load: Addresses climate
 variables—humidity (expressed through wet bulb temperature), heat waves, cooling degreedays, heating degree-days, and the combination of projected changes in wet and dry bulb
 temperatures—that have a direct effect on system loads and reliability. These variables are also
 specifically addressed in specifications and procedures associated with upgrading system
 capacity and maintaining system reliability.
- Appendix 3 Changes in Precipitation Patterns: Discusses the potential for climatedriven changes in rainfall and frozen precipitation in Con Edison's service territory, and the potential impacts of those changes on Con Edison's assets and operations.
- Appendix 4 Sea Level Rise and Changes in Coastal Storm Surge Potential: Examines the ways in which changes in sea level may affect operations, planning, and infrastructure across the electric, gas, and steam segments of Con Edison's business.
- Appendix 5 Extreme Events: Describes how extreme weather events (hurricanes, nor'easters, and heat waves), as well as concurrent or consecutive extreme events, may become more frequent and severe due to climate change, and considers their potential impact on operations, planning, and infrastructure across the electric, gas, and steam segments of Con Edison's business over the coming century.

ATTACHMENT 2

Paul Smith, UNEP FI, The Climate Risk Landscape: A Comprehensive Overview of Climate Risk Assessment Methodologies (2021)



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Disclaimer

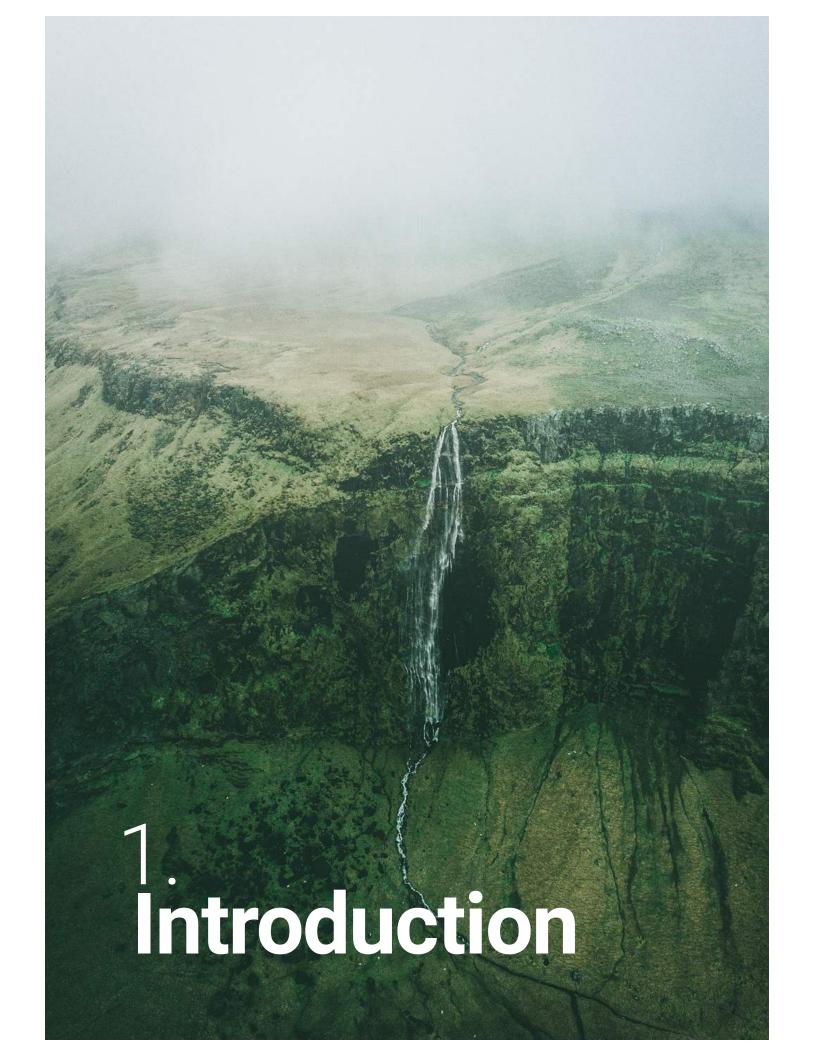
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The forward-looking nature of climate risk assessments imply a myriad of assumptions, baselines, inputs and modelling choices that result in a great diversity of methodologies and tools available to financial institutions. This in turn leads to some difficulties for banks and investors to make transparent, informative choices on climate risk modelling approaches, while standardisation is hampered by the great uncertainty over the most appropriate model choices in a forward-looking risk assessment.

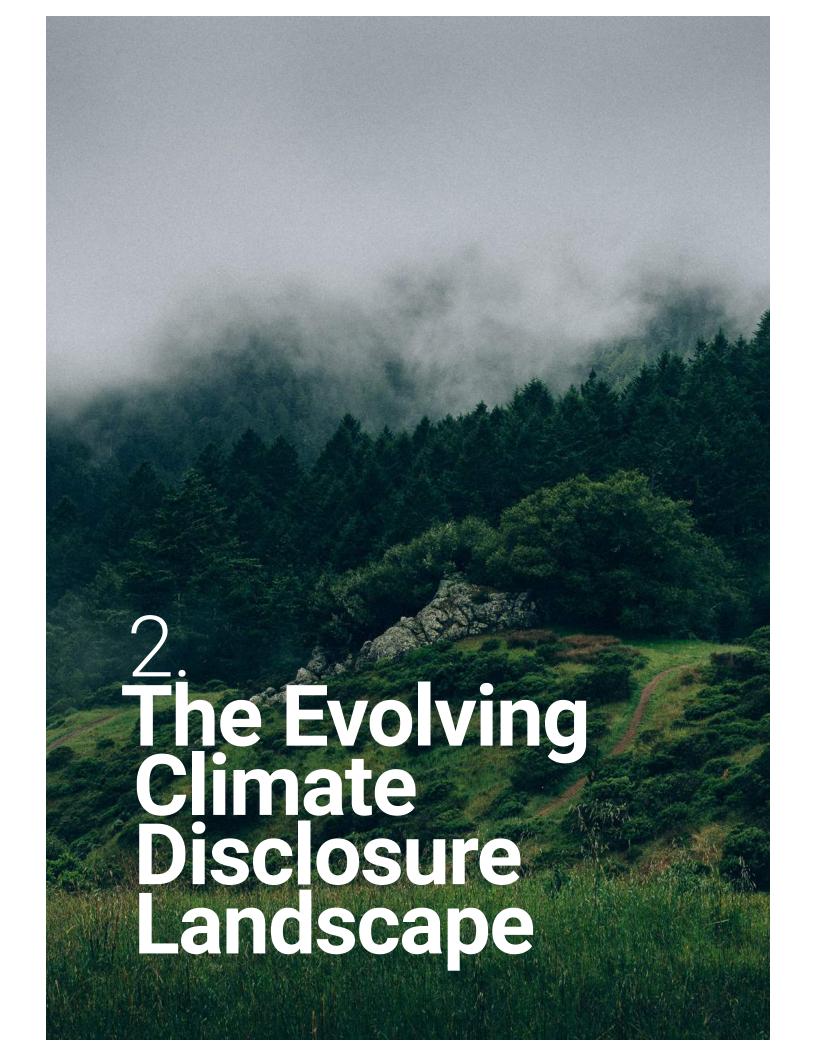
Since the publication of UNEP FI's 'Changing Course' report in May 2019, the tools available to financial institutions that wish to use scenario analysis to reinforce their climate-related risk assessments and disclosures have developed and expanded rapidly. This report is intended, not to provide a comprehensive guide to scenario analysis and risk assessment, but rather a summary of the key developments of the climate risk assessment landscape since May 2019, including new and updated scenarios, methodological tools, key guidelines, as well as an overview of the changing regulatory landscape and potential developments into 2021.

This report covers both physical and transition risks, though the headline results on physical risks have incorporated the results of an analysis of physical risk methodologies and data sources in chapters 2 (Data portals) and 4 (Methodologies) of Acclimatise's recently released report, 'Charting a New Climate' (2020) developed for UNEP FI's TCFD Banking Pilot Project Phase II. This overview has adopted a two-step process by engaging with methodology developers to provide information on their tools and methodologies, which have been subsequently verified through objective research.

The report opens with a chapter on the evolving landscape of climate disclosure since May 2019, taking a brief look at how new regulations and reporting guidelines have emerged, and the increasing regulatory push for climate stress-testing, as well as the development of portfolio temperature assessments.

The second and third chapters provide a broad overview of the landscape of scenario analysis methodologies for the estimation of transition and physical risks from climate change. The intention here is not to provide an endorsement of one methodology over another but to present some of the key strengths and differences in approaches.

The report concludes with an overview of advances in scenario development, a review of emerging trends and what financial institutions should look out for in 2021.



2.1 Recent developments in regulation

Over the past year, the number of climate risk reports has increased in quality and number (Carlin, 2020). However, as highlighted in 'Changing Course' and in the TCFD's own 2019 Status Report, scenario analysis remains far from commonplace aside from larger, more climate-aware institutions in leading countries (UNEP FI, 2019). Despite the relatively high interest – as of September 2020, 739 financial institutions had signed up as supporters of the recommendations of the TCFD (Mitchell et al, 2020) – very few financial firms are actively disclosing. Those institutions that do disclose have not been able to follow harmonised standards while the difficulty of accessing robust, high-quality data and scenarios has compromised the quality and usefulness of their disclosures. The COP26 Secretariat's Financial Coalition Coordination Mechanism is encouraging financial firms to conduct scenario analysis and implement climate-risk reporting, while the Principles for Responsible Investment (PRI, 2020) have made reporting on certain climate indicators mandatory – though disclosure remains voluntary.

2.1.1. Risk disclosure mandates

With the voluntary disclosure framework only providing piecemeal disclosures and limited data on the financial impacts of climate change so far, regulators, central banks and ratings agencies are increasingly under pressure to introduce mandatory climate risk disclosure frameworks. Mark Carney, the former chair of the Financial Stability Board and catalyst for the establishment of the TCFD, has advocated for a mandate (TCFD, 2019), while Ceres has called on the SEC to implement more stringent climate-related reporting (Ceres, 2020). The Basel Committee on Banking Supervision (BCBS) established the Task Force on Climate-related Financial Risks (TFCR) in February 2020, to maintain the stability of global financial systems in the face of climate-related risks, commencing with a stocktake of member initiatives on climate-related financial risks. In September 2020, the government of New Zealand became the first country to announce mandatory climate-related financial disclosures for publicly listed companies and large banks, investors and insurers (NZMFE, 2020). The following table gives a flavour of the status of the climate-related reporting mandates and voluntary initiatives in selected jurisdictions worldwide:

USA	2020	Commodity Futures Trading Commis- sion (CFTC)	Establishment of Climate-related Market Risk Subcommittee (CRMS) and release of the Managing Climate Risk in the U.S. Financial System report (2020) urging financial regulators in the U.S. to "move urgently and decisively to measure, understand, and address these risks", taking advantage of "existing statutes".
	2019	New York State Department of Financial Services (NYDFS)	Non-binding expectations of insurers to consider "the financial risks from climate change into their governance frameworks, risk management processes, and business strategies" and to "start developing their approach to climate-related financial disclosure." (NYDFS, 2020)
UK	2019	Bank of England, Prudential Regula- tion Authority (PRA)	PRA supervisory statement <u>SS3/19</u> , "Enhancing banks' and insurers' approaches to managing the financial risks from climate change"
	2019	Department for Business, Energy and Industrial Strat- egy (BEIS)	Green Finance Strategy: Expectation for all companies to disclose in line with TCFD recommendations by 2022 (BEIS, 2019).
	2020	HM Treasury	Interim Report of the UK's Joint Government Regulator TCFD Taskforce, publishes a roadmap towards mandatory climate-related disclosures by 2025, with the majority of measures implemented by 2023.
European Union	2020	Non-Financial Reporting Directive (NFRD)	Targeted consultation on strengthening reporting of sustainability and climate-related information in the NFRD (2014/95/EU).
	2019	European Banking Authority (EBA)	Article 98.8 of the Capital Requirements Directive (CRD5) requires EBA to assess the inclusion of ESG risks in performance & evaluation.
France	2016	Article 173	Non-mandatory financial reporting, including climate.
Hong Kong	2020	HKEX	Mandatory ESG governance and reporting
New Zealand	2020	Ministry for the Environment	Mandatory climate risk reporting legislation to be presented to Parliament following 2020 general election. Disclosure by all registered banks, credit unions, building societies, managers of investment schemes, and licensed insurers with total assets of more than NZ\$1bn and all equity and debt issuers listed on the NZX by 2023.
Canada	2020	Bank of Canada	Discussion / exploratory paper on scenario analysis.
		Canada Develop- ment Investment Consortium (CDEV)	TCFD reporting mandatory for companies receiving emergency funding during the pandemic: <u>Large</u> <u>Employer Emergency Financing Facility (LEEFF)</u> (CDEV, 2020)
Japan	2019	Japan TCFD Consortium	The Consortium is a public-private partnership to promote TCFD disclosure. This has led to higher voluntary corporate TCFD reporting than in any other country (lkeda, S., 2020).

Switzerland	2019	Federal Office for the Environment (BAFU)	Legal opinion shows that climate-related risks need to be taken into account according to existing law (Eggen & Stengel, 2019)
			Switzerland became a supporter of the TCFD in January 2021 and has launched a consultation on mandatory climate-related risk disclosure.
Australia	2020	Australian Prudential Regulation Authority (APRA)	2021 Climate Risk Vulnerability Assessment, for major banks (Australia's largest deposit-taking institutions, ADIs). Climate risk disclosure remains voluntary, however (APRA, 2020).

Table 1: Overview of mandatory and voluntary disclosure recommendations on climate-related risk from a selection of regulators and policy makers

Some private investors are starting to move the dial, particularly in jurisdictions where there has been relatively little regulatory guidance on climate risk disclosure in recent years, such as in the United States. BlackRock, the world's largest asset manager, has requested TCFD-aligned climate-related risk disclosures from all their investee companies by the end of 2020, holding board members of those companies directly accountable for reporting (Fink, 2020). To give one high profile example of this new approach, BlackRock issued a statement voting against Exxon Mobil directors for not taking sufficient action on TCFD-aligned risk disclosure (BlackRock, 2020). State Street Global Advisors are also threatening voting action against major publicly listed investees that fail to improve poor sustainability ratings, based on SSGA's proprietary R-Factor rating, including climate-related risk (SSGA, 2020).

2.1.2. Risk disclosure standards and guidelines



Figure 1: CDP's 'Building blocks' report showing how CDSB and CDP guidelines allow for the development of TCFD-standard reports

Whether mandated or not, climate-related reporting has come under criticism for its lack of standardisation, making it difficult to compare disclosures. Voluntary reporting frameworks remain the norm in an absence of mandates. In September 2020, several reporting standards organisations, including CDSB, SASB, CDP, GRI and IIRC¹ jointly committed to align their sustainability reporting requirements (CDP, 2020a), building on CDP's work with CDSB to integrate the recommendations of the TCFD (CDP, 2020b). This is certainly a step in the right direction, as they form the basis of voluntary reporting for global financial firms. In parallel, the Network for Greening the Financial System (NGFS) has developed technical guidelines to help its members integrate climate-related and environmental risks into prudential supervision (NGFS, 2020a), as well as working closely with scenario developers to issue a set of standard scenarios (NGFS, 2020b), built on existing well-developed Integrated Assessment Models (IAMs),² allowing for assessment of both transition and physical risks. The following table outlines some of the guidelines and standards that have been developed in a handful of jurisdictions, often to accompany mandatory or voluntary reporting:

USA	2010	Securities and Exchange Commission (SEC)	Guidance on Disclosure Related to Climate Change. No recent climate-related risk disclosure updates despite recent amendments to risk disclosure rules (Herren Lee, 2020)
European Union	2020	Disclosures Directive	Regulation 2019/2088 requires annual disclosure standards.
	2020	European Central Bank (ECB)	Draft guide on incorporating climate-related and environmental risks into existing risk framework (ECB, 2020)
		European Insurance and Occupational Pensions Authority (EIOPA)	EIOPA is currently holding a consultation on its expectations of national competent authorities to supervise the integration of climate changes scenarios in their 'Own Risk and Solvency Assessments' (ORSAs).
Singapore	2020	Monetary Authority of Singapore (MAS)	Introducing guidelines on climate risk disclosure, currently under consultation (MAS, 2020).

Table 2: Overview of standards and guidelines on climate-related risk from a selection of regulators and policy makers

Leading climate finance groups such as the Climate Safe Lending Network, suggest that even mandating climate risk disclosure is not enough and financial institutions need to disclose their impact on systemic or planetary climate risks (Vaccaro, 2020) – in other words an "inside-out" risk assessment rather than an "outside-in" assessment.

¹ CDSB: Climate Disclosure Standards Board; SASB: Sustainability Accounting Standards Board; GRI: Global Reporting Initiative; IIRC: International Integrated Reporting Council

² GCAM, MESSAGEix GLOBIOM and REMIND MAgPIE

2.1.3. Stress testing

A handful of central banks are integrating climate change into stress tests to assess the stability of the financial system to these more systemic, longer-term risks:

- The Bank of England has extended its stress testing horizon to 30 years through the Biennial Exploratory Scenario (BES). The BES requires financial firms to run scenarios against their balance sheet exposure and set out management responses. In a second round, the BoE may ask firms for their responses in light of system-wide impacts. The BES is not strictly a stress test as it does not run high-impact scenarios.
- The Netherlands' Central Bank (Den Nederlandsche Bank, DNB) conducted an energy transition stress test in 2018, which has showed that Common Equity Tier 1 (CET1) ratio could drop by over 4 percentage points in a severe but plausible transition scenario.
- The French central bank's regulatory authority (*L'Autorité de contrôle prudentiel et de résolution*, ACPR) has developed stress testing based on the NGFS scenarios (see 3.1), and drilling down to explore national macroeconomic, sector and firm level risks using in-house models (ACPR, 2020b).
- These pilot stress tests by Eurozone national central banks have paved the way for the European Central Bank to integrate climate-related stress tests, integrating macroeconomic factors such as sudden transition risks (capital flight from certain sectors/regions).
- Outside of Europe, strengthening the finance sector's resilience to climate risk is one of the four pillars of the Monetary Authority of Singapore's (MAS) green finance action plan. Under these proposals, the MAS will include climate-related scenarios in its annual financial stress test by 2022.

2.2 Combining physical and transition risks

The physical impacts of climate change are already impacting on our economy and society, and further temperature rise is already baked in. Realistically, not even the most optimistic transition scenario can ignore the risks from the physical impacts of climate change. Therefore, scenario developers and methodology providers are increasingly working towards combined transition and physical risk methodologies to provide a complete picture of climate-related risk. Integration of these two approaches is not straightforward as physical and transition pathways are strongly dependent on different location- and sector-specific variables. Physical hazards are strongly location-specific and dependent on actual temperature rise, while adaptive capacity can vary between sectors. Transition risk is highly sector-specific and relates to politically determined mitigation targets.

The NGFS suite of scenarios aims to bridge the two risk frameworks, with methodologies being developed over 2020-21 to integrate the two aspects. Consolidation is also being delivered by commercial providers, while ratings agencies have moved to integrate climate risk specialists with both physical and transition risk expertise, for example Carbon Delta by MSCI and Moody's Analytics who have brought in physical risk expertise from Four Twenty Seven and transition risk specialists, Vigeo-Eiris (V.E), as part of the climate focus of the newly formed Moody's ESG Solutions Group.

While we focus in this report on scenario-based risk assessments, it must be remembered that the TCFD report also refers to other risks including litigation and reputation. UNEP FI's TCFD Pilot for insurers assesses the exposure of insurers to litigation risk in the face of climate change and UNEP FI are also aiming to publish a high-level briefing on litigation risk and climate change adaptation in March 2021.

2.3 Moving beyond the current risk disclosure framework

Mark Carney has suggested that current disclosure frameworks need to evolve in order to reflect financial institutions' climate-related risk, not only to their own portfolios, which are considered only through the very short-term lens of the investment horizon, but to take into account their contribution to systemic or global risks. In his 'Road to Glasgow' speech in 2020, he posited the need to expand the existing frameworks to adopt more active measures to address systemic risk, such as:

- i. the net zero alignment of portfolios,
- ii. reporting on transition progress, and
- iii. reporting portfolio warming potential.

These approaches could act as a stepping-stone from the current risk assessment paradigm of the TCFD framework to a more active alignment with the key objective of Article 2.1(a) of the Paris Agreement to "hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the increase to 1.5°C" (UNFCCC, 2015). The TCFD Secretariat are currently exploring how portfolio warming potential may be integrated into the TCFD framework to better measure the impact of business operations on systemic risk, while the Bank of England's BES adopts a temperature alignment score. For more details on the different types of alignment and impact models, and a discussion on how appropriate these metrics are for measuring portfolio alignment, see the recent study by the Institut Louis Bachelier (Reynaud et al, 2020).



3.1 Introduction

Developing a tool or methodology that can provide a robust assessment of climate-related risk, whether transition or physical, is a considerable undertaking. In terms of transition risk, it can require access to considerable data on future technology, access to a wide range of climate and macroeconomic models, and an understanding of forward-looking climate and economic assumptions. A number of proprietary tools and methodologies have been developed by commercial service providers.

This section provides an overview of eighteen transition risk tools and analytics. The set of service providers listed and reviewed in this section is certainly not exhaustive, but is an attempt to include the principal commercially available methodologies.

Almost all of the assessed methodologies' principal function is to analyse transition risk, using climate hazards and forward-looking carbon policy and technology variables as inputs in order to calculate the risk to clients, their operations and value chains, often in terms of financial metrics. A couple of exceptions to these risk assessment approaches have been included, as they may still be of use in assessing a portfolio's exposure to climate change transition. These are Carbone 4's Climate Impact Tool, which measures the impact of assessed portfolios on climate change, and 2DII's PACTA Stress Test Module, which assesses the level of exposure and potential losses of equity and bond portfolios to Paris-aligned transition pathways. Carbon Tracker's 2 Degrees of Separation tool is focused on one single sector (oil & gas), while the others cover all or most of the high emissions sectors.

This survey adopts the assessment framework developed in UNEP FI's Changing Course report last year, with some minor changes and including a number of supplementary criteria in order to complement the format of the overview of physical climate risk assessment tools in Chapter 4 of UNEP FI's Charting a New Climate report (pp. 42-53; UNEP FI, 2020). The information provided in this overview has been obtained firstly from publicly available sources and secondly from survey responses from most of the services providers covered below. Only Moody's Investor Services and PwC failed to respond to our survey.

The brevity of this overview does not allow for an in-depth review of each methodology. For more comprehensive research, the Swiss Federal Institute of Technology has published research on selected transition risk methodologies, including those developed by 2DII, Carbone 4, Climafin, ClimateWise, MSCI-Carbon Delta, Oliver Wyman, Ortec Finance, PwC/CO-Firm and Vivid Economics (now known as Planetrics) (Bingler & Colesanti Senni, 2020).

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Bottom-Up	Top-Down	Adaptive Capacity	Sensitivity	Exposure	Markets and clients	Operations and assets	Supply chain	Macroenvironment	Country	Sector	Firm	Asset)50)	2040)						Scenario Basis		
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Temperature Alignment	Financial metrics	Non-financial metrics	Semi-quantitative	Quantitative	Source references	Peer-reviewed	Open-source	Value of asset	Location	Counterparty name	Real Estate / Real Assets	Mortgages	Loans, Project	Loans, Corporate	Bonds, Government	Bonds, Corporate	Equity		
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User

inputs

Asset classes

Validity

Outputs

Table 3: Overview of transition risk assessment tools and analytics

Abbreviation	Abbreviation Service Provider	Tool
200	77	DAOTA 6
2DII (1)	Two Degrees Investing Initiative	PACTA for banks
2DII (2)	Two Degrees Investing Initiative	PACTA stress testing module
BAR	Baringa Partners	Climate Change Scenario Model
C4	Carbone 4	Carbon Impact Analytics
CFIN	Climate Finance Alpha	Transition risk toolbox
CT	Carbon Tracker	2 degrees of separation
CW	ClimateWise (CISL)	Transition risk framework
MA-VE	Moody's Analytics-V.E	On-demand transition climate risk scoring application
MIS	Moody's Investor Services	Carbon transition assessment
MSCI	MSCI-Carbon Delta	Climate Value-at-Risk (CVaR)
OF	Ortec Finance	ClimateMAPS
WO	Oliver Wyman	Transition Check
OW-S&P	Oliver Wyman & S&P Global Market Intelligence	Climate Credit Analytics
Pwc-cof	PwC (formerly CO-Firm)	Climate Excellence
SP(1)	South Pole	Risk screening tool
SP(2)	South Pole	Climate risk deep-dive assessment
TCS	The Climate Service	TCS Climanomics
VE-PL	Planetrics	PlanetView
₩	Verisk Analytics	Transition risk

Under development for 2021
Up to 2064
Up to 2080
At regional level
Operations only

<u>×</u>. ×

xv. Climate target alignmentxvi. Framework is open-sourcexvii. Reviewed and vetted by financial institution, not academic

- Not macroenvironment
- Macroenvironment only Infrastructure / real assets only Optional (but preferable)
- Top-down approach does not need company/asset information Outside of ~20,000 company database Methodology, not source code
- Open-source version will be available on
- OS-Climate platform
 Within Vivid Economics' academic

The Climate Risk Landscape
Overview of Transition Risk Approaches

3.2 Scenarios

The foundation of forward-looking climate risk assessment is the design of a scenario or set of scenarios that best shapes assumptions around the climate, society and the economy. Scenarios are built around the core assumption of a global temperature target or emissions pathway, with temperature pathways being preferred by the TCFD in line with the objectives of the Paris Agreement (TCFD, 2017). However, a number of secondary assumptions including carbon pricing, technological development, consumer behaviour, resource scarcity, energy demand, discount rates and how quickly those assumptions change have a considerable influence on how those pathways develop over time. The Changing Course report focused largely on temperature-based scenarios given the TCFD's recommendations. In terms of the highest transition risk, scenarios tended to focus on 2°C pathways. Furthermore, the most widely available and granular scenarios at the time assumed a considerable contribution from Carbon Dioxide Reduction (CDR), or 'negative emissions' technology.

The availability of scenarios for transition risk analysis has expanded since last year's Changing Course report, in particular because demand for more aggressive transition scenarios has built as firms respond to increasing pressure from clients, investors and governments to meet the objectives of the Paris Agreement. Only 6 countries have implemented net-zero legislation, but many others have committed to Net Zero emissions targets by 2050, and most significantly for global emissions, China committed at the 2020 United Nations General Assembly to 'net carbon neutrality' by 2060 (Economist, 2020). In the finance sector, a number of firms have committed to align their business with the Paris Agreement, for example the Principles for Responsible Banking's Collective Commitment to Climate Action, or to net zero emissions by 2050 in the case of the Net-Zero Asset Owner Alliance.

Policies aiming at a 1.5°C pathway are therefore starting to be shaped and financial institutions need to assess this pathway, which poses the greatest transition risk. Moving to 1.5°C scenarios implies important changes in the rate and timing of decarbonisation, as outlined by Bingler & Colesanti Senni (2020), which will necessarily imply a considerable step change in transition risk. It is therefore important that these scenarios are adopted by service providers and many have already done so.

The IPCC's Special Report on Global Warming of 1.5°C (2018) laid out a number of pathways (P1 to P4) for achieving net zero emissions by 2050, including a pathway which minimises the need for carbon dioxide removal (CDR) technologies, which are currently "unproven and reliance on such technology is a major risk in the ability to limit warming to 1.5°C" (IPCC, 2018). This Special Report also provides a preview into the Shared Socioeconomic Pathways (SSPs), which will be showcased in the IPCC's 6th Assessment Report (AR6), and will provide more nuanced socioeconomic pathways and therefore largely replace the Representative Concentration Pathways (RCPs) outlined in AR5.

Scaling up ambition to align with the Paris Agreement is also the aim of the One Earth Climate Model, which is aiming to set a new standard in identifying a feasible path to 1.5°C with little or no reliance on CDR technologies. The Principles for Responsible Investment (PRI) have also developed a Forecast Policy Scenario, which assumes an "inevitable policy response" (IPR) to net zero in the short term, without necessarily meeting the 1.5°C temperature target, unless a second, medium-term, policy ratchet is initiated. This attempts to respond to criticisms of other <2°C scenarios as 'tail scenarios' that set overambitious and unrealistic short-term policy ambitions and whose modelled transitions are optimal rather than disorderly (Energy Transition Advisors, 2020).

A further development in scenarios over the past year has been the release of the NGFS reference scenarios, which set a standard for climate scenarios for the finance sector (NGFS, 2020b). These integrate both emissions pathways and shared socioeconomic pathways (SSPs) and thus provide a common set of scenarios for assessing both transition and physical risks. The NGFS scenario set includes three principal scenarios:

- i. Orderly (1.5-2°C by 2100);
- ii. Disorderly (1.5-2°C by 2100, though with greater transition risks than for an orderly transition);
- **iii.** Hothouse world (3°C+ based on current policies, which do not meet even current Nationally Determined Contributions).

The NGFS scenarios have been based on integrated assessment models (IAMs) developed by PIK (REMIND-MagPIE), IIASA (MESSAGEix-GLOBIOM) and the University of Maryland (GCAM). It is likely that these scenarios will be adopted by central banks and regulators and will provide the basis for future climate stress tests for the finance sector. South Pole, Climate Credit Analytics and Oliver Wyman's Transition Check have already added the NGFS scenario set to their analytics.

A summary of available reference scenarios used for transition risk analysis is given in the below table:

Scenario Provider	Year	Name	Sector	Est. implied temp. rise	Basis
IEA World Energy Outlook (WEO)	2020	NZE2050 (Net zero emissions by 2050)	Energy	1.5°C	Outlines necessary technology, policies and behaviour change necessary to bring about net-zero emissions by 2050.
[updated annually]		SDS 2020 (Sustainable Development Scenario)	Energy	1.8°C (66%) 1.5°C (50%)	Takes in to account social (SDG) and climate goals
		STEPS (Stated Policies Scenario)	Energy	2.7-3.3°C	Takes in to account stated policies (replaces the New Policies Scenario, NPS)
		Delayed Recovery Scenario (DRS)	Energy	<2.7°C	STEPS with a delayed recovery from pandemic

IEA Energy Technology Perspec-	2017	B2DS (Below 2 Degrees Scenario)	Energy	1.75°C	
tives (ETP)		2DS (2 Degrees Scenario)	Energy	2°C	
release feeds into SDS scenario]		RTS (Reference Technology Scenario)	Energy	2.75°C	Takes into account existing energy- and climate-related pledges, including NDCs.
IPCC	2014	RCP (Representative Concentration Pathways)	All sectors	1.0°C (RCP 2.6) 1.8°C (RCP 4.5) 2.2°C (RCP 6.0) 3.7°C (RCP 8.5)	RCPs outline pathways according to different levels of radiative forcing in the CMIP5
IPCC	2018	SR15	All sectors	1.5°C	Set of P1-4 pathways to meet 1.5°C target, building on RCP 1.9
NGFS	2020	Orderly	All sectors	<2°C	Both orderly and disorderly have alternate scenarios with limited or full CDR
		Disorderly	All sectors	<2°C	Higher transition risk than for Orderly scenario
		Hot-house World	All sectors	3°C+	Only current policies implemented, not NDCs, i.e. equivalent to IEA STEPS
OECM	2020	One Climate Earth Model	All sectors	1.5°C	Minimal CDR. Released 2020.
PRI Inevita- ble Policy Response (IPR)	2020	Forecast Policy Scenario	All sectors	1.5°C	Based on the inevitable policy response to meeting the Paris Agreement.

Table 4: Overview of climate and transition scenarios

There are a number of other available scenarios, including IRENA's Remap, Greenpeace's Advanced Energy [Revolution] and IDDRI/SDSN's Deep Decarbonisation Pathways, which are less widely used in service providers' models.

In terms of the methodologies surveyed by UNEP FI, all now include a 1.5°C or below 2°C scenario, demonstrating the shift in transition risk analysis to scenarios which imply alignment with the objectives of the Paris Agreement, as well as the 2°C used as the basis for high transition risk scenarios in 2019. All methodologies supplement this with a 3°C or 4°C scenario to provide a comparison with the 'business-as-usual' or 'stated policies' approach, though Carbon Tracker focuses on oil & gas transition risks by using the IEA's STEPS scenario (~2.7°C) as a proxy for 'business-as-usual' by assessing the proportion of company expenditure that goes ahead under the STEPS scenario at the asset level but falls outside lower demand scenarios.

IEA scenarios are used by many methodologies, including 2DII, Carbone 4, Carbon Tracker, Planetrics, ClimateWise, Moody's Investor Services (MIS) and South Pole, as the IEA provides arguably the most granular scenarios for carbon intensive sectors, such as oil and gas, electricity, power generation, heavy manufacturing and automotive. Given the IEA's consistent under-estimation of renewable energy growth and high reliance on CDR, a number of providers use IEA scenarios as a basis for their own bespoke approaches – for example, Carbone 4 uses IEA SDS as a basis for modelling the electricity sector only.

NGFS scenarios will become increasingly important and Oliver Wyman's Transition Check Tool has integrated these scenarios in its initial release, building on Oliver Wyman's collaboration with PIK and IIASA in UNEP FI's first and second phase TCFD pilot. NGFS scenarios have also been integrated into Oliver Wyman and S&P Global Market Intelligence's Climate Credit Analytics.

Forecast Policy Scenario, based on PRI's Inevitable Policy Response (IPR) is adopted by Vivid Economics and Planetrics alongside IEA and IPCC scenarios to inform its 1.5°C transition risk tool.

Bespoke approaches are used in both of Oliver Wyman 's tools, by MSCI-Carbon Delta, in collaboration with PIK, IIASA and GCAM, by Carbone 4, and by Verisk, while Baringa Partners offers bespoke approaches in addition to standard scenario sets. Ortec Finance have developed 3 transition pathways similar to the NGFS scenario set including orderly and disorderly Paris aligned transitions and a business-as-usual, equivalent to a 'hothouse' world. The macroeconomic consequences, including GDP, inflation and sectoral GVA, of these scenarios are taken from Cambridge Econometrics' E3ME model, and cover countries, sectors and asset class risk return expectations, through a top-down approach.

It must be noted that many methodologies still employ scenarios, both sector specific such as the IEA scenarios or the IAMs, which continue to model relatively late emission peaks and CDR. This implies that many risk analyses are still building in a later transition, but with a much steeper decarbonisation and reliance on unproven decarbonisation technologies. Employing more ambitious 1.5°C aligned scenarios that do not rely on CDR, requires confronting technological and societal transformation in a more rapid and ordered manner. The continued use of 2°C scenarios or <2°C scenarios with a heavy reliance on CDR suggests a lack of confidence in the ability of economic governance institutions, businesses and society to confront the low-carbon transition in the medium to long term. Even the IEA's latest Net-Zero Emissions by 2050 scenario estimates that about 1,150 Mt of CO2 would have to be removed by 2030, using technology that does not yet exist.

Further information on scenario selection can be found in:

- Pathways to net zero: Scenario architecture for strategic resilience testing and planning (Energy Transition Advisors for PRI, 2020)
- Navigating Climate Scenario Analysis (IIGCC, 2019)

3.3 Hazards

As in the 2019 Changing Course report, the focus here is on two types of transition hazards:

- i. Policy changes in the counterparty's policy and legislatory environment, for example through direct costs such as carbon pricing, taxation or cap-and-trade, or indirect costs such as changes in subsidies, the introduction of renewables obligations, etc.
- **ii. Technology** changes in the availability and relative costs of technology, for example the lowering costs of renewable technologies and energy storage and the high costs of fossil fuel extraction from shale reservoirs, tar sands or deep offshore fields.

Market hazards are not included in this review, as it is assumed that the market is largely shaped by policy and technology, though recently markets have shifted independently of technology or policy due to the global pandemic, which impacted the demand for fossil fuels in certain sectors. Such changes in demand through changes in behaviour, lifestyle or economic model could be taken into account in these methodologies. Some methodology providers are accounting for pandemic or public health shocks in their risk assessment in response to the considerable demand shock in 2020.

All methodologies employ sector scenarios or integrated assessment models (IAMs) that automatically account for both policy (carbon prices) and shifts in technology, so almost all the methodologies take into account policy and technology hazards. The only exception to this is South Pole's Risk Screening Tool, which is a 'quick' assessment tool assessing only carbon price. South Pole do provide a more comprehensive assessment tool that also covers technological change, the Climate Risk Deep-Dive Assessment.

3.4 Assessment methodologies

Determining financial risk at the sector and firm level, from climate scenarios and associated socioeconomic pathways is dependent on the approach the methodology takes. The methodology has to assess a range of variables and assumptions that affect the economic impact at the macroeconomic or sectoral level and translate those impacts at the firm-level and subsequently estimate the financial impact to the financial institution.

This report bases its methodological assessment on the framework developed in the 2019 Changing Course report, which looks at each methodology's scope and breadth of assessment. The scope of an assessment is across four principal impact channels:

i. Macro-environment – economic trends at the macro-level tend to be the starting point for top-down analyses. Policy and technology changes at the country and sector level could impact macroeconomic indicators such as economic growth, the balance of trade and exchange rates, particularly in the case of disorderly transitions or price shocks.

- **ii. Supply chain** policy or technology shifts could see impacts on the upstream or downstream supply chain of counterparties, for example through changing costs of electricity generation or increased demand for certain products such as electric vehicles.
- **iii. Operations and assets** this impact channel directly affects the operations of counterparties, i.e. scope 1 emissions.
- **iv. Market** for emissions-intensive industries, most transition impact will be through the scope 3 emissions of consumers, so for coal mining or oil & gas production, policy or technology changes will lead to changes in market demand.

This overview also looks at three levels of assessment:

- **i. Exposure** determined by location and sector, and therefore exposure to climate policy or technology respectively.
- **ii. Sensitivity** determined by a counterparty's emissions intensity per unit of production and therefore how far it will be affected by a change in costs, or in supply chain terms, by a supplier's emissions intensity. This also affected by the counterparty's ability to absorb costs or to pass them on to consumers.
- **iii.** Adaptive capacity determined by a counterparty's ability to shift away from high emissions technology or suppliers (input substitution), or to develop new technologies or business models through R&D and strategy respectively.

Most of the described methodologies are based on deterministic modelling – where they differ is in how the economic modelling is approached: either bottom-up, which builds the economic impacts up from the firm level, or top-down, which directly models economic impacts at the macroeconomic or sector level. Bingler & Colesanti Senni give a good description of how these methodologies work (pp. 16-20; 2020). Stochastic modelling is integrated into some of the methodologies, such as Ortec Finance's ClimateMAPS, which takes deterministically modelled GDP, inflation and sector GCA shocks from its econometric model and feeds into their stochastically determined financial model.

Bottom-up methodologies provide a more granular assessment with arguably more accurate near-term results. They also tend to provide more detailed information at the firm level and through the supply chain. Such approaches include Baringa Partners' Climate Change Scenario Model, Carbone 4's Climate Impact, PwC/CO-Firm's Climate Excellence, Planetrics' Climate Risk Toolkit, Verisk's Transition Risk Tool and MIS' Carbon Transition Assessment and V.E's Carbon & Energy Transition metrics.

Top-down approaches measure emissions against the global carbon budget as country level emissions data is often more reliable and consistent than firm-level emissions data. Additionally, top-down approaches capture more readily the networked effects of interacting climate risk drivers, including policy, technology and physical risk. Ortec Finance's ClimateMAPS is an example of this approach.

Most of the covered assessment methodologies are able to provide macro-economic level analysis. The only tool not to cover this aspect at all is Carbon Tracker's 2 Degrees of Separation tool which is focused on granular firm-level transition risk analysis in the oil & gas sector. A majority of the methodologies are able to capture sensitivity and adaptive capacity at the macro-level, including Ortec Finance's top-down analysis and Vivid Economics and Planetrics who incorporate top-down macroeconomic assessment into their tool through the Vivid Economy-Wide (ViEW) model, while Baringa Partners' model allows for sector-level impact modelling in addition to their bottom-up analysis. Oliver Wyman and S&P Global Market Intelligence's Climate Credit Analytics also captures top-down macroeconomic impacts alongside its bottom-up analysis.

All methodologies are able to measure the transition risk to counterparty **operations** and to the **market**, while **supply chains** tend to be better modelled by those methodologies with a bottom-up approach that has been extended along upstream and downstream value chains. Top-down approaches can model supply-chain effects at a macro-level, through international trade impacts, for example. Often, however, **supply chain risk, otherwise known as second-order or indirect risk, is modelled using proxies such as vulnerability indicators**. It must be noted that this level of assessment is only as good as the visibility of a company along its upstream and downstream supply chains, while sector-level estimates of indirect risks are likely to increase the error of risk estimates.

In terms of methodologies' **depth of assessment**, exposure and sensitivity to transition risks are modelled across the board, though South Pole's 'light-touch' methodology only covers exposure and not sensitivity or adaptive capacity. Sensitivity tends to be modelled across the board by cost-pass through only. Only Oliver Wyman and the PwC/CO-Firm's models account for a counterparty's ability to absorb costs or to outperform peers (Bingler & Colesanti Senna, 2020).

Adaptive capacity is less well covered, though methodologies have improved over the past year on this score. Adaptive capacity in supply chains, operations and markets is necessarily modelled at the firm level through bottom-up approaches, as it is necessary to either understand the firm's technological and business strategies, or capacity to substitute away from high emissions inputs. Adaptive capacity in supply chains is perhaps the greatest challenge to methodologies given the need to model upstream and downstream. Currently six of the assessed methodologies are able to provide this level of analysis, though a number of other providers are developing this capacity over the coming year.

Transition opportunities are an important aspect of any transition assessment and a number of the methodologies covered here are able to model either patent data, including Carbon Delta's CVaR model, Planetrics' Climate Risk Toolkit and V.E's energy transition and governance data. Oliver Wyman's model is able to assess the capabilities of banks to respond to technological change through Transition Check, as well as in their collaboration with S&P Global Market Intelligence's Climate Credit Analytics. Top-down approaches can also identify sector-level opportunities, for example where, for example, transition technologies may drive sector GVA growth. This is perhaps the key element in a climate risk analysis enabling banks and investors to identify sectors likely to grow as a result of the economic transition, as compared to current focal sectors.

It is important to note that climate risk analysis must be distinguished from alignment, impact or target-setting tools, which have slightly different goals. We continue to include 2DII's PACTA, though in the framing of its recently released Stress Test Module, which was developed in partnership with the Bank of England and has been used to pilot a climate stress test methodology for UK-based insurers and was recently developed and further applied by EIOPA in their climate risk sensitivity analysis. Unlike a risk analysis tool, however, this impact approach focuses on a base case and high transition risk temperature scenarios – 3°C and disorderly <2°C. Other PACTA modules are focused on portfolio alignment for banks and investors and are not included in this overview, though measuring alignment of a portfolio can provide a useful proxy for transition risk.

3.5 Outputs

The majority of methodology providers are able to provide quantitative financial metrics and have expanded the range of outputs they are able to provide in order to meet the needs of different financial institutions – Baringa Partners, South Pole and Ortec Finance have indicated their flexibility in developing a range of financial output metrics. Moody's and Ortec Finance can also provide a range of climate-adjusted macroeconomic indicators using their top-down macroeconomic approach, including climate-adjusted GDP, interest & inflation rate expectations, risk-return/asset class, credit spreads, risk premia, etc. Value at Risk (VaR) from climate change is a widely used output metric used by MSCI-Carbon Delta, Ortec Finance, Planetrics and Verisk, which measure the financial impact of the climate transition against a baseline. South Pole's Risk Screening Tool provides a PRR metric, while Carbon Tracker's oil & gas sector focus provides an estimate of capital expenditure at risk outside the sector carbon budget. Verisk's Transition Risk analysis also provides metrics oriented towards the insurance industry: for example, the Risk Premium Rating.

Some methodologies provide semi-quantitative outputs such as Carbone 4's Carbon Impact Analysis, which provides an overall rating and alignment with 2°C trajectories risk rating (A to E), as well as an assessment of forward-looking company strategy (++ to –), based on quantified induced and avoided emissions, as well as forward-looking emissions. MIS' Carbon Transition Assessment Tool and Verisk provide semi-quantitative emissions intensity scores (0 to 10). 2DII's PACTA Stress Test Module estimates a Loss in Predicted Value, which assesses the level of exposure of equity and corporate bond portfolios to Paris-aligned transition pathways.

Increasingly, methodologies are adopting temperature alignment scores. These semi-quantitative outputs provide an indication of a portfolio's or loan book's implied impact on global warming. This metric is currently being explored by the TCFD Secretariat as an addition to the TCFD recommendations in order to gradually move financial institutions from risk assessment to active portfolio management to align portfolios with international climate objectives. Carbone 4's methodology implicitly assesses climate impact, while other service providers have added implied temperature scores to their services, including Baringa Partners, Moody's (V.E), MSCI-Carbon Delta, Planetrics, Ortec Finance through their ClimateALIGN tool. 2DII's PACTA methodology implicitly calculates the delta with a 2°C scenario, so can be said to calculate a metric alignment. One methodology that is not included in the current assessment as it is not a tool for calculating climate risk *per se*, is *Right.based on science*'s XDC tool, which directly calculates the temperate alignment score for a portfolio.

3.6 Resolution

This is where the difference of top-down vs bottom-up approaches can really come into focus. Bottom-up approaches are generally more granular, but as uncertainties around asset and firm level data increase over the medium to long term, top-down approaches, with their sector overview, may be more credible at these longer timescales. Furthermore, bottom-up approaches are likely to be more readily deployable by larger financial institutions with the reach and means to access more granular data or those institutions with an intimate knowledge of their investment portfolio. Top-down and bottom-up approaches can be complementary allowing for strategic asset allocation through top-down approaches and stock or investment level decision-making supported by bottom-up approaches.

High resolution, bottom-up approaches with facility and firm level analysis include Baringa Partners, Climate Credit Analytics, MSCI-Carbon Delta, Planetrics, Vigeo-Eiris, South Pole, Verisk and PwC/CO-Firm. Carbon Tracker's analysis assesses oil and gas production at the field level to estimate the extent of asset stranding. Carbone 4 assess impact at the firm level, rather than at the facility level. Top-down methodologies, such as Ortec Finance and PACTA can provide granularity at the company, sector and country levels.

3.7 Validity

Given the complexity of climate scenarios, socio-economic models and translating these model outputs into consequences for financial firms and their clients, each tool has its own set of assumptions and simplifications. This inevitably leads to variations in the calculation of financial risk metrics for a given input, so it is important for financial institutions to understand how the models work or at the very least to have confidence in the validity of the tools they are using.

In terms of full public access, only ClimateWise, 2DII and Climafin, as externally funded projects, have made their full source code publicly available. Ortec Finance is engaged in an initiative led by the Linux Foundation to make an open-source version of ClimateMAPS that will be made available on the OS-Climate platform, while their ClimateALIGN is based on the SBTi-FI developed open-source temperature scoring tool. In the majority of cases where access to the model is restricted, it is important to ensure validity through peer review or, at the very least, to understand the scientific basis of a methodology through its source references. Service providers may make elements of the methodologies available to clients under Non-Disclosure Agreements in order for users to have an understanding of key assumptions and parameters and how metrics are calculated.

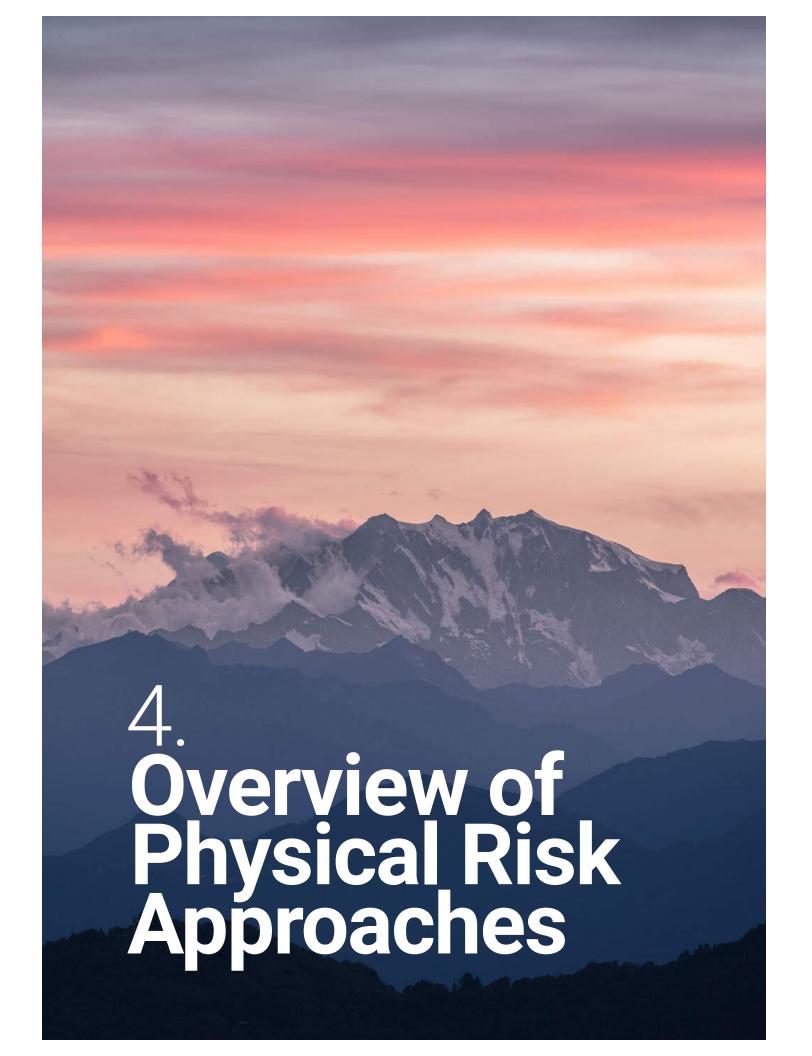
3.8 Usability

Further to the scope of last year's Changing Course report, we provide a brief overview of some additional criteria, including accessibility and coverage, and time horizon.

Accessibility: The majority of these methodologies are fee-based, except for 2DII's and CISL's tools. Oliver Wyman's Transition Check is free for UNEP FI members, while the results from Carbon Tracker's tool are free for all, though PRI members have access to greater functionality. PACTA's Stress Test Module is free to explore and use on transition-monitor.org, as well as access to PACTA's alignment tools for investors and banks. The Cambridge Institute of Sustainability Leadership's ClimateWise tool can provide a free, open-source introduction to scenario analysis. Finally, Carbon Tracker's oil & gas focused tool is free to use for PRI members at 2degreesseparation.unpri.org/.

Coverage: Almost all tools are described as 'global'. Ortec Finance's Climate MAPS, which nominally covers 29 countries worldwide, does integrate global interaction and impacts given its top-down approach, and other countries can be added into the model on a bespoke basis. ClimateWise, which currently only covers the EU, US and India, is looking to scale up its offering to China and Australia in 2021.

Horizon: The time horizon of the methodology varies between methodologies and care needs to be taken that the methodology chosen provides an adequate balance between short-term validity in terms of the estimated uptake of transition-aligned policies and technologies and the investment horizon required by the financial institution. The majority of methodologies provide horizons to 2030-40, with Planetrics and ClimateWise also providing nearer term outputs to 2025. Carbone 4 impact analysis has a near term horizon of 2025. Longer-term horizons are also provided by Oliver Wyman, Baringa Partners, PwC/Co-Firm and Planetrics (2050), Ortec Finance (2060, with narrative outlooks to 2100), Verisk (2064), Climafin (2080) and South Pole and The Climate Service (up to 2100).



4.1 Introduction

This section provides an overview of nineteen physical risk tools and analytics and reproduces the comprehensive overview in Acclimatise's <u>Charting a New Course</u> report (2020) developed for UNEP FI's TCFD Banking Pilot Project Phase II. The reproduction of this work in this report is firstly for completeness, as many financial institutions will want to assess both their transition and physical risk exposure. Furthermore, a number of providers offer both transition and physical risk methodologies and are aiming to provide combined risk assessments over the coming year. For a thorough and complete overview of physical risk tools and analytics, therefore, it is strongly recommended to also refer to <u>Charting a New Course</u>.

Secondly, in order to reflect the sector-wide scope of this report we have included a number of other service providers, including RMS and Verisk. These are firms who have traditionally provided historic risk assessments for (re-)insurance services and engineering projects and who are increasingly scaling their offerings to forward-looking climate change-related risk assessment for the wider finance sector. Their expertise lies largely on the analysis of acute physical risk, though they are developing expertise on chronic risks, such as RMS' collaboration with the Natural Capital Alliance on drought scenarios for Brazil, Mexico, the US and China. Given their recent entry into the sector of climate risk assessment for financial institutions (beyond underwriting), their offering is best suited to products directly associated with physical assets such as mortgages, real estate and project finance, where their analytic approach can provide highly granular analyses. Other service providers have been able to develop a framework to update these natural catastrophe models for climate change – ClimateWise, for example have demonstrated this approach for property portfolios.

Like the transition risk overview in chapter 3, the set of service providers listed and reviewed in this section is certainly not exhaustive, but we have attempted to include the principal commercially available methodologies.

For a detailed overview of the physical risk tools and analytics and a set of case studies by banks using a selection of the methodologies, it is strongly recommended to refer to *Charting a New Climate* (UNEP FI, 2020). Hereunder are a few additions to the commentary provided in the previous report.

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Table 5: Overview of physical risk assessment tools and analytics

Abbreviation	Service Provider	Tool
427 (1)	Four Twenty Seven	On-demand physical climate risk scoring application
427 (2)	Four Twenty Seven	Physical climate-risk scores for publicly listed companies
ACC	Acclimatise	Physical climate risk heatmapping tool
ACC-WTW	Acclimatise-Willis Towers Watson	Sector deep-dive assessments tool
C4 (1)	Carbone 4	Climate risk impact screening (CRIS)
C4 (2)	Carbone 4	Infrastructure and real estate portfolio assessment tools
CFIN	Climate Finance Alpha	Physical risk toolbox
CW	ClimateWise (CISL)	Physical risk framework
MSCI	MSCI-Carbon Delta	Climate Value-at-Risk (CVaR)
OF (1)	Ortec Finance	ClimateMAPS
OF (2)	Ortec Finance	ClimatePREDICT
RhG	Rhodium Group	Valued asset-level physical risk data
RMS	RMS	Climate risk models and consultancy service
SP (1)	South Pole	Risk screening tool
SP (2)	South Pole	Climate risk deep-dive assessment
TCS	The Climate Service	TCS Climanomics
VE-PL	Planetrics	PlanetView
VR	Verisk Analytics	AIR
XDI	XDI Systems (physical risk only or in p	XDI Systems (physical risk only or in partnership with Baringa for physical & transition)

- Under development for 2021
- $\overrightarrow{\times}$ \times $\overrightarrow{\times}$ $\overset{\triangle}{=}$ $\overset{\triangle}{=}$ $\overset{\triangle}{=}$ $\overset{\triangle}{=}$ $\overset{\triangle}{=}$ $\overset{\triangle}{=}$ $\overset{\triangle}{=}$ Up to 2080
 - Infrastructure / real assets only
 - Optional (but preferable)
 - Methodology available for users Top-down approach does not need company/asset information

 - Elements of the methodology are peer-reviewed Open-source version will be available on OS-Climate platform
 - Methodology, not source code
 - Within Vivid Economics' academic network
- such as probability of default term structures, expected loss estimates, credit spread effects, Leveraging Moody's Analytics' Public Expected Default Frequency structural credit risk model, offered in future as an on-demand analytics product. price effects, and value-at-risk. This is currently offered as consultancy services and will be 427's physical climate risk scores for listed companies can be translated into credit metrics

4.2 Scenarios

All methodologies surveyed adopt an RCP 8.5 (4°C by 2100) scenario to measure the maximum physical risk. There has been discussion as to whether RCP 8.5 can still be considered as a business-as-usual scenario, given the advances in scenario modelling and the trajectory of the energy transition since AR5 was published in 2014 (Hausfather & Peters, 2020; Shwalm, Glendon & Duffy, 2020). A recent study has marginally narrowed the range for global temperature rise by 2100 to a "likely" (66% confidence) range of 2.6-3.9°C, but this is not enough to shift the Business-as-usual case to RCP 6 (Sherwood et al, 2020).

Unusually, MSCI-Carbon Delta employs a stochastic approach to estimating physical risk, based on the 50th and 95th percentile expectancy of a business-as-usual risk distribution, rather than comparing a RCP8.5 scenario against a <2°C objective RCP 2.6 scenario. It is arguable as to whether this approach accounts for more extreme physical risks in the event of tipping points or climate shocks.

4.3 Acute and chronic risks

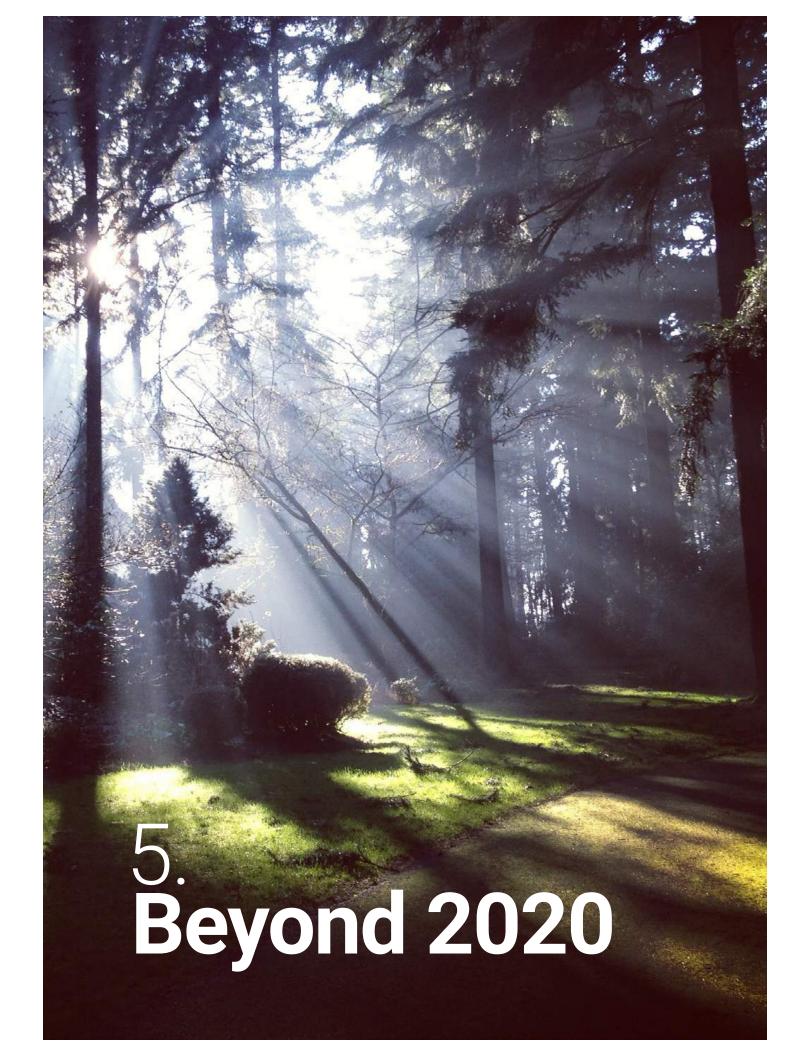
The inclusion of a number of risk assessment firms with experience working in the (re-)insurance industry, such as RMS and Verisk, opens up the risk assessment space to firms that have a history of developing highly granular physical risk models with a focus on acute hazards such as extreme weather, inland and coastal flooding, wild-fires, landslides, etc. With the rise in demand for climate risk assessment, these firms are rapidly developing forward-looking climate scenarios, which provides them with a distinct competitive advantage over other firms that have developed physical climate risk assessments for the financial sector, whose strengths lie more in modelling forward-looking chronic risks and in translating these models into output data of use to financial firms.

Chronic risks are a particular challenge. Approaches to chronic risk have focused either on quantitative analysis such as RMS' collaboration with the Natural Capital Alliance on drought and water scarcity, or on qualitative evaluation based on a comprehensive literature review, for example, by Ortec Finance to assess the impacts of precipitation changes and temperature rise, on industrial, labour and agricultural productivity. One area where chronic impacts are perhaps less of a challenge is in coastal flood risk due to sea level rise. However, sea-level rise has other effects including salination of agricultural land, which is less well modelled.

4.4 Secondary risks from climate change

One area for improvement in physical risk models is assessing the impacts from secondary climate-change driven effects, whether socio-economic, such as migration and conflict, or environmental, such as public health shocks. These secondary impacts are difficult to model given the human behaviour element of socio-economic shocks, and the unpredictable nature of public health impacts. However public research funding is being directed towards modelling limited climate change-induced impact scenarios, such as the CASCADES project. This EU-financed initiative will model trade and supply chains, analysing the impact of acute and physical climate change-related hazards on agricultural production, energy and commodity markets. Combined with "macro-economic modelling, qualitative political analysis and strategic policy simulations", this will enable an assessment of areas of critical concern and potential solutions for Europe and beyond.³

³ cascades.eu/



This review of the available methodologies for physical and transition risk assessment will hopefully be of benefit to financial firms embarking on climate-related risk assessment in order to meet the requirements of a TCFD-aligned climate risk disclosure. As highlighted previously, more in-depth information is available on physical risk methodologies and data sources from UNEP FI and on transition risk methodologies from ETHZ.

5.1 Developments in regulation

Policy makers and regulators are increasingly highlighting the threats from climate change and are pointing the way towards mandatory climate risk through the development of guidelines and standards. In section 2.1.1, a brief overview shows how central banks, regulators and policy makers are responding to climate risk, with New Zealand the first country to announce mandatory climate risk disclosure. Within the next year the European Union can be expected to release an update to the Non-Financial Reporting Directive (NFRD), which is likely to direct member states to implement climate-risk reporting regulation for financial institutions, and the UK's Joint Government Regulator TCFD Taskforce has released a strategy and roadmap to mandatory disclosure by 2025 at the latest, with many requirements in place by 2023 (HM Treasury, 2020).

Central banks and regulators will increasingly pilot and subsequently impose climate stress testing on banks. As described in section 2.1.2, a number of central banks in western Europe have already piloted climate stress tests and some service providers are moving to support the development of these stress tests, such as 2DII in Switzerland and Japan. As central banks move away from piloting individual scenarios, they will increasingly gauge sensitivity by stress testing against a bank of multiple climate scenarios. 2DII have also suggested that stress testing may move away from sector-level shocks to "technology-oriented" shocks, e.g. to renewable energies or to coal power.

Service providers are increasingly pooling resources or are being integrated into larger financial service providers. Trucost, an ESG risk consultancy not covered in this review, was acquired already in 2016 by S&P Global Indices. Over the last year, MSCI purchased Carbon Delta; Willis Towers Watson acquired Acclimatise; 427 and Vigeo-Eiris have come under the umbrella of Moody's Analytics; while 2DII and Carbon Tracker are increasingly collaborating. Firstly, this process of consolidation will allow climate risk specialists greater access to company data and resources to develop their risk tools. Secondly, greater integration will also improve access and usability: for example, Carbon Delta's data will be integrated into MSCI's ESG Manager platform before the end of 2020, while V.E and Four Twenty Seven data is made available on Moody's CreditView.

5.2 Developments in technology

Climate-related risk assessment is still only in its infancy and tools or methodologies are being constantly updated to allow for more granular analysis that takes into account a broader, more plausible set of scenarios, access to more granular datasets. Commercial providers that require a fee to access have a particular incentive to improve their risk forecasts. Below are some of the most important forecast developments:

Most of the service providers are moving away from the use of one scenario provider, if they have not already done so. Up to now, many models have relied on one scenario type, particularly IEA given its focus on high carbon emissions sectors. However, IEA scenarios have consistently had to be updated to account for low emissions technologies developing at a faster rate than predicted by the IEA and this is encouraging a move towards integrating either multiple or bespoke scenarios. For example, South Pole have indicated that they will broaden the scenarios available on their tool, while Moody's ESG Solutions (incorporating Four Twenty Seven and V.E) have indicated that they will expand their range of GCMs from 5 to 18, while also including additional scenarios. Oliver Wyman's online Transition Check tool launched with the three main NGFS scenarios, building on their previous use of PIK, IIASA, GCAM scenarios, but the online scenario module will, over time, integrate other scenarios including IEA, IRENA, OECM, etc. The increasing use of Shared Socioeconomic Pathways (SSPs) is allowing service providers to better model socio-economic inputs and impacts – The Climate Service is already using SSP3-60 and -45.

A number of scenario developers have already developed a bespoke range of transition scenarios, often at sector level, based on existing climate models to improve methodological accuracy or to model alternative transition or demand shocks, including Carbone 4, MSCI-Carbon Delta, Planetrics and Ortec Finance. Baringa Partners also offer bespoke options as well as industry standard scenarios. Bespoke approaches, as well as the use of opaque risk assessment methodologies may reduce the ability of financial institutions or financial regulators to understand the parameters or assumptions used in risk analysis.

Increasing demand for standardisation may move developers towards the use of reference scenarios. This would help to address growing concerns over the transparency and comparability of climate risk assessments (Bingler & Colesanti Senni, 2020). The NGFS reference scenarios, released earlier in 2020, are aiming at standardisation and have already been adopted by Oliver Wyman in their Transition Check tool, released September 2020. It must be noted, however, that the NGFS scenario sets need to be further developed to improve granularity at the sector and regional level, as well as integrating other market drivers such as technological change and alternative policy responses (Pierfederici, 2019).

Transition and physical risk methodologies are being increasingly combined in order to provide financial institutions with an overall picture of climate-related risks for each scenario. Some providers have already achieved this in-house, such as Ortec Finance. Others are pooling resources such as Baringa Partners, who have built on their experience in the energy sector to develop a transition risk tool, and are partnering with physical risk specialists, XDI, to provide a holistic climate risk analysis. Bottom-up assessment methodologies are perhaps more complex to integrate, but many of the service providers covered in this report are moving in this direction, including The Climate Service.

Physical risk models will be able to aggregate greater sources of data, with the use of geospatial and remote sensing data, Al and data mining. Artificial Intelligence will be of increasing importance in accessing data from various sources. For physical risks this could include 'vision learning' from geospatial data. This will also help to expand the range of physical hazards covered — Four Twenty Seven for example will expand their offering to include landslides and wildfire smoke. Jupiter Intel, not included in this current overview, has built a model for physical risk assessment up to 2100 that is constantly updated from real-time satellite and senor data. In terms of transition risk, data mining will enable banks to assess climate risks to a wider range of counterparties, including SMEs.

Increasing granularity of physical risk analysis. Given the increased access to data discussed above, it is likely that physical risk analyses will become far more granular, allowing more accurate risk analysis. Extreme weather and climate hazards are highly location dependent, especially acute risks such as coastal and fluvial flooding and wildfires. Several service providers are scaling up their resolution, including risk specialists such as RMS and Verisk, and XDI who can differentiate changes in impact at up to 1m scale.

Data is likely to become easier to access and in a format more easily usable by financial institutions, as corporates increasingly report on climate risk and respond to data requests, while a number of research projects, including ClimINVEST, are developing open source access to physical risk data, such as the EU's Copernicus Climate Change Service (E3CS). The OS-Climate platform (os-climate.org) initiated by the Linux Foundation, is also aiming to make relevant data publicly available, as well as providing some open-source analytical tools. Meanwhile increasing data availability and higher granularity will reduce errors in risk measurement, making it more likely that financial institutions are able to provide consistent and market-ready disclosures. This will allow analyses to move away from qualitative and exposure-based assessments to more quantitative vulnerability-focused assessments.

5.3 Challenges in 2021

Aside from the regulatory developments described above in 2021, we can expect financial institutions to be faced with the following challenges:

Increasing standardisation and mainstreaming: Industry reporting standards CDSB, CDP, SASB, GRI, and IIRC are moving to align over the coming year and integrate the recommendations of the TCFD, and there will almost certainly be wider uptake of NGFS reference scenarios. Standardisation may follow the guidelines in ISO 14097, the international framework for assessing standards assessing and reporting investments and financing activities related to climate change. Financial institutions will also increasingly want to integrate climate risk into their financial and economic decision-making tools, rather than relying on independent 'black-box' models from climate risk specialist firms.

Presidential transition in the United States: The election of Joe Biden in November will undoubtedly signal a dramatic change in climate policy with the President aiming to: (i) invest up to \$2tn on low-carbon energy, (ii) re-join the Paris Agreement, and (iii) achieve net-zero emissions by 2050. Regarding climate risk reporting, the Vice-President, Kamala Harris, is a supporter of climate risk disclosure, e.g. of Sen. Elisabeth Warren's Climate Risk Disclosure Act and Sen. Brian Schatz's Climate Change Financial Risk Act. The change in direction is reflected in the Federal Reserve Board's November 2020 report, which highlights, for the first time, the threat to financial stability posed by uncertain future climate change impacts, and the lack of knowledge on financial sector exposure. The report recommends that, "increased transparency through improved measurement and disclosure could improve the pricing of climate risks" (FRB, 2020).

Methodologies should all take into account carbon lock-in or 'expected greenhouse gas emissions', otherwise approaches that only look at present carbon emissions will ignore the risk of surpassing carbon budgets. This issue has been highlighted in research on climate risk assessment and alignment by financial institutions (Caldecott, 2020; Bingler & Colesanti Senni, 2020) and has been integrated by a number of the methodologies assessed here, including Baringa Partners, PwC, Planetrics, Ortec Finance and 2DII account for this among the models highlighted here.

Knock-on impacts of climate risk are also under-assessed by the existing set of tools and methodologies. Secondary effects of climate change including knock-on economic impacts, public health shocks or migration caused by the physical impacts of climate change have not been adequately modelled by existing methodologies, which may constitute a considerable blind spot in current climate risk methodologies. While there is no evidence for a link between the CoVID-19 pandemic and climate change, it is estimated that climate change will increase the range and survival of vectors that transmit disease and public health will be impacted by higher temperatures, water scarcity and extreme climatic events (Costello et al, 2009).

Integrating biodiversity risk is the next major environmental risk analytics challenge for financial institutions. With the 15th Conference of the Parties of the Convention on Biodiversity taking place this year (CBD, COP15) and the global extinction of flora and fauna worldwide accelerating, UNEP FI, UNDP, WWF and Global Canopy have launched the Taskforce on Nature-related Financial Disclosures (TNFD) together with a working group of around a dozen banks and investors. While this Taskforce was not initiated by the Financial Stability Board as was the case for the TCFD, it is hoped that the momentum of COP15 and widespread awareness of the links between climate change and biodiversity may help TNFD to develop into an industry standard for financial institutions to monitor their impact on biodiversity. Ideally, climate and biodiversity risks should be considered together in the same assessment framework, as climate change will have significant impacts on biodiversity, while biodiversity is a crucial factor in mitigating and adapting to climate change.

Abbreviations

2DII AR5 BCBS BES	2 Degrees Investing Initiative 5 th Assessment Report (IPCC) Basel Committee on Banking Supervision Biennial Exploratory Scenario (Bank of England)	IAM IDDRI	Integrated Assessment Model Institute for Sustainable Development & International Relations (Institut de Développement Durable et de Relations Internationales)
CBD	The United Nations Convention on Biological Diversity	IEA IIASA	International Energy Agency International Institute for Applied Systems Analysis
CDR CDSB	Carbon Dioxide Removal Carbon Disclosure Standards Board	IIGCC	The Institutional Investors Group on Climate Change
CET1	Common Equity Tier 1	IIRC	International Integrated Reporting Committee
CISL	Cambridge Institute for Sustainability Leadership	IPCC	Intergovernmental Panel on Climate Change
COP	Conference of the Parties (UNFCCC)	IPR	Inevitable Policy Response (PRI)
CVaR	Climate Value-at-Risk	IRENA	International Renewable Energy Agency
DNB E3CS	Den Nederlandsche Bank EU Copernicus Climate Change Service	MAS	Monetary Authority of Singapore
ESG	Environmental, Social and Governance	MIS NFRD	Moody's Investor Services Non-Financial Reporting Directive
ETHZ	Swiss Federal Institute of Technology, Zurich (Eidgenossische Technische	NGFS	The Network for Greening the Financial System
	Hochschule Zürich)	OECM	One Earth Climate Model
FSB	Financial Stability Board	PACTA	Paris Agreement Capital Transition Assessment
GCAM	Global Change Analysis Model (University of Maryland)	PIK	Potsdam Institute for
GCM	General Circulation Model		Climate Impact Research (Potsdam Institut für
GDP	Gross Domestic Product		Klimafolgenforschung)
GRI GVA	Global Reporting Initiative Gross Value Added	PRI	Principles for Responsible Investment

PwC	PricewaterhouseCoopers	TFCR	Task Force on Climate-related
RCP	Representative Concentration		Financial Risks (BCBS)
	Pathway	TNFD	Task Force on Nature-related
SASB	Sustainability Accounting		Financial Disclosures
	Standards Board	UNDP	United Nations Development
SDSN	Sustainable Development		Programme
	Solutions Network	UNEP FI	United Nations Environment
SME	Small and Medium Enterprises		Programme Finance Initiative
SSP	Shared Socioeconomic Pathways	UNFCCC	UN Framework Convention on Climate Change
TCFD	Task Force on Climate-related Financial Disclosures	VaR	Value-at-Risk

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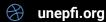
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finance initiative

United Nations Environment Programme Finance Initiative (UNEP FI) is a partnership between UNEP and the global financial sector to mobilize private sector finance for sustainable development. UNEP FI works with more than 350 members—banks, insurers, and investors—and over 100 supporting institutions— to help create a financial sector that serves people and planet while delivering positive impacts. We aim to inspire, inform and enable financial institutions to improve people's quality of life without compromising that of future generations. By leveraging the UN's role, UNEP FI accelerates sustainable finance.

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ATTACHMENT 3

David Carlin & Alexander Stopp, UNEP FI, The Climate Risk Landscape: 2022 Supplement (2022)



finance initiative

The Climate Risk Tool Landscape

2022 Supplement

Featuring an anthology of implementation case studies from financial institutions

Acknowledgments

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Project Management

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The pilot project was led by a Working Group of the following banks and investors convened by the UNEP Finance Initiative:

ABN-AMRO Rabobank CDL Intesa Sanpaolo Access Bank CIB **RBC** Investa AIB CIBC ltau Santander Bank of America Scotia Bank Citibanamex KB FG Bank of Ireland Credit Suisse **KBC** Standard Bank Banorte Danske Bank Linkreit Storebrand Desiardins Manulife TD Asset Manage-Barclays BBVA DNB Mizuho ment Bentall Green Oak **EBRD** MUFG **TSKB** BMO FirstRand NAB **UBS** Bradesco FTF NatWest Wells Fargo Caixa Bank ING NIB

Landscape Review Paper 2

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Introduction

The importance of climate risk assessments

Societies, governments, and companies have justifiably recognized the threats climate change poses to the global economy. Physical risks such as droughts, sea level rise, and flooding are likely to increase in the coming years, with consequences for real assets, supply chains, and business operations. While critical, mitigating global warming poses challenges as well. Businesses and countries will experience transition risks in the shift from a fossil fuel-driven economy to a low-carbon one.

The financial sector has a central role to play in managing climate-related risks and providing capital for climate resiliency and the low-carbon transition. As a result, a wide range of stakeholders have shown interest in how financial institutions are preparing to confront climate change.

- Activists and civil society have added public pressure for financial institutions to demonstrate that their activities are contributing to a sustainable future.
- National and local governments that have committed to reducing emissions are looking to the financial sector to catalyse the development and deployment of projects that will help them reach those goals.
- Financial supervisors and policy-makers around the world are aware of how climate change can threaten financial stability and have been increasingly setting climate risk management expectations and mandating climate disclosures, climate transition plans, and climate stress testing.
- Shareholders in financial institutions are eager to understand how firms are preparing to confront both physical and transition risks in their portfolios.
- Internal management within financial institutions want to identify the key risks and opportunities that a changing world presents and ensure that their firm is well-positioned.

In recent years, financial institutions have been exploring data, tools, and analytics that will enable them to meet the needs of these stakeholders. While many institutions are developing in-house climate capabilities, most are also working with outside vendors to obtain the skills, information, and outputs they require. As a result, there is a burgeoning market for climate solution providers for financial institutions to choose from. These providers can range from public data sources from organizations such as the United Nations and the World Bank to paid providers who can create bespoke tools for an institution.

Program and module overview

TCFD program retrospective

The work in this report was carried out as part of UNEP FI's TCFD programme. Since the publication of the FSB's TCFD recommendations in 2017, UNEP FI has run a series of pilot programs to assist members in exploring physical and transition risks and developing practical approaches for evaluating these risks using climate scenario analyses. Over 100 financial institutions (banks, investors, and insurers) from all around the world have participated in these pilots. Participating institutions have been supported by over a dozen technical partners including climate modelers and climate risk experts.

The latest TCFD programme (beginning in March 2021) involved forty-eight global banks and investors. The program contained two parallel components. The first was a climate risk roadmap to empower participants at all stages of their climate disclosure journey. The roadmap featured dozens of interactive discussions with regulators, climate modelers, climate scientists, as well as peer presentations. The second component was a series of "modules" where participants could dive deeply into specific aspects of climate risk. These modules explored topics from the economic impacts of climate change to conducting a climate stress test.

Detail on the Landscape Review Module

The case studies and recommendations for tool providers that comprise this paper were completed as the primary output of the module titled: "Landscape Review of Climate Risk Assessment Methodologies" or the "Landscape Assessment" module. The Landscape Assessment module offered participants hands-on opportunities to learn about and demo the latest physical and transition risk assessment tools. The module allowed participants to explore the range of climate risk tools and determine their strengths, limitations, and areas for potential enhancement. Over a dozen tool and data providers gave presentations to the group about their methodologies and analytics. The module was also supported by expert guidance and insights from the Centre for Economic Research at ETH Zurich.

The module contained three phases:

First phase—background and context

In the first phase of the module the lead authors of UNEP FI's Climate Risk Landscape report (UNEP FI 2021) discussed the report's key messages and conclusions with participants. The participants then compared methodologies for transition risk assessment based on ETH Zurich's paper: Taming the Green Swan (ETH, 2020). The ETH sessions allowed participants to consider multiple dimensions of existing tools as shown below.

Figure 1: Areas of assessment in ETH tool analysis

l.	Accountability
1	Public transparency
а	Model modules, code public
b	Study questionnaire completed*
2	Emission data strategy
а	Data sources reported
b	Third party verified
С	Missing data strategy explained
3	Science-based approach
а	Scientific references
b	Peer-reviewed
II.	Donth of rick analysis
	Depth of risk analysis
4	Hazard (shock/smooth trnsition)
4	Hazard (shock/smooth trnsition)
4	Hazard (shock/smooth trnsition) 1.5/<2°C scenario
4 a b	Hazard (shock/smooth trnsition) 1.5/<2°C scenario Country=differentited
4 a b c	Hazard (shock/smooth trnsition) 1.5/<2°C scenario Country=differentited Sector-differentiated
4 a b c	Hazard (shock/smooth trnsition) 1.5/<2°C scenario Country=differentited Sector-differentiated Exposure
4 a b c 5 a	Hazard (shock/smooth trnsition) 1.5/<2°C scenario Country=differentited Sector-differentiated Exposure Current GHG emissions
4 a b c 5 a b	Hazard (shock/smooth trnsition) 1.5/<2°C scenario Country=differentited Sector-differentiated Exposure Current GHG emissions Expected GHG emissions
4 a b c 5 a b	Hazard (shock/smooth trnsition) 1.5/<2°C scenario Country=differentited Sector-differentiated Exposure Current GHG emissions Expected GHG emissions Vulnerability & resilince

7	Adaptability
а	Input substitution
b	Climate strategy, climatee-ligned R&D or future CAPEX plans
8	Economic Impact
а	Economic losse and gains
b	Macroeconomic development
9	Risk amplification
а	Mutual risj amplification
b	Financial market amplification
	'
III.	Usability
III. 10	·
	Usability
10	Usability Output interpretability Model structure, scanarios and assump-
10	Usability Output interpretability Model structure, scanarios and assumptions reported Assumptions-based output communica-
10 a b	Usability Output interpretability Model structure, scanarios and assumptions reported Assumptions-based output communication
10 a b	Usability Output interpretability Model structure, scanarios and assumptions reported Assumptions-based output communication Uncertainty
10 a b	Usability Output interpretability Model structure, scanarios and assumptions reported Assumptions-based output communication Uncertainty Baseline adaptable

Following these background sessions, participants worked with UNEP FI to define a set of criteria for producing a structured case study on the tools they would pilot in the second phase. The agreed-upon structure is referenced in the case study section of this report.

Second phase—tool presentations and demos

Figure 2: Tool and data providers which feature in the case studies in this paper



In the second phase of module UNEP FI invited around fifteen tool providers to provide a demonstration of their latest climate risk assessment tools to the participants. In these interactive sessions, participants were able to ask providers about tool methodologies, coverage, and functionality. At the end of these demonstrations tool providers gave details on the potential piloting of their tool (e.g., how many participants could pilot, how many assets would be assessed, what outputs may look like).

Following these demonstrations, module participants decided which tools would be most appropriate for their institution to pilot. UNEP FI then matched up participants with tool providers and held an introductory session to provide the parameters of the pilot and to kick off the collaboration between providers and participants. During the course of the pilot, providers and participants met bilaterally to discuss topics such as data required and interpretation of outputs.

Third phase—review and case studies

The third phase of the module allowed participants the opportunity to discuss the piloted tools with the wider group. These post-pilot discussion sessions enabled participants to compare their experiences in the pilot and discuss the strengths and limitations of the tools they had seen. These feedback sessions facilitated the drafting of the case studies found within the report.

Objectives of this report

Given the expanding use cases for climate risk analyses in the financial sector and the growing number of tool providers, over the past few years, UNEP FI has worked to inform financial institutions about the structure, coverage, and methodologies of commonly used tools. This research has encouraged firms to integrate climate risk analyses into their operations and ensure they are informed consumers of climate tools and data.

In 2019, UNEP FI published Changing Course, as an output of the TCFD pilot for investors (UNEP FI, 2019). This report covered the climate risk assessment methodology developed as part of the pilot (in coordination with Carbon Delta), but also explored a selection of other methodologies that analytical tools have deployed to assess climate risks.

Since the release of Changing Course, climate risk analysis has gone mainstream. Demands of regulators and other stakeholders has driven financial institutions to improve their capabilities for conducting physical and transition risk analyses. Financial institutions have also identified new needs such as improved geographic coverage for physical hazards and 1.5°C-aligned scenarios for assessing transition risk. Tool providers have responded by increasing their offerings and developing new approaches to generate decision-useful and actionable outputs for their clients. A number of new providers have entered the market while others have partnered or been acquired in order to enhance their capabilities.

Due to the rapidity of change around climate risk tools, in early 2021, UNEP FI released The Climate Risk Landscape, a report that mapped climate-related financial risk assessment methodologies. The landscape review summarized key developments across third party climate risk assessment providers since the publication of Changing Course, including new and updated scenarios, methodological tools, as well as an overview of the changing regulatory landscape and potential future developments. The report explored almost 40 providers, split between physical and transition risks. These providers completed a detailed survey to inform key conclusions about the state of third party tools. A summary of the assessments is shown below. For physical risk tools, the report built on work within UNEP FI and Acclimatise's 2020 paper, Charting a New Climate (UNEP FI and Acclimatise, 2020). For transition risk tools, the report benefitted from the analyses included in ETH's 2020, Taming the Green Swan, which provided deep methodological assessment of existing transition risk tool providers (ETH, 2020).

Landscape Review Paper Introduction

Figure 3: Summary table of physical risk tools from The Climate Risk Landscape, 2021

Physical Hazard Type					Risk analysis							Phy Haz	sical ards			me zon	s	S	cen	ario	os												
Wildfire	Water scarcity	Drought	Landslide	Extreme precipitation	Extreme heat	Extreme weather	Flood, inland	Flood, coast		Meniod	Method			IIIpact Cilailiei	Impact Channel				Level of analysis			Acute	Chronic	Long-term (2100)	Medium term (2050)	Near term (2025-2040)	Baseline/historical	>4.0°C (RCP 8.5)	3.0°C (RCP 6.0)	2.0°C (RCP 4.5)	<2.0°C (RCP 2.6)		
									Financial modeling	Physical impact modeling	Vulnerability indicators	Physical Exposure	Markets and customers	Operations and assets	Supply chain	Macroenvironment	Portfolio	Country	Sector	Firm	Asset												
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This current report aims to extend the work of The Climate Risk Landscape in a new way. Rather than expanding the number of providers explored (a topic for the next edition of the landscape paper), this report seeks to catalogue the actual experiences that financial users had while piloting different tools. The detailed case studies include insights into the process, challenges, outputs, and learnings related to using selected climate risk tools. These case studies should be seen as a companion to the categorizations provided within The Climate Risk Landscape. Together, the two reports begin the process of providing financial users with a resource for understanding both the theoretical attributes of different tools as well as how they function in practice.

In addition, the case studies were designed to inform tool providers on specific topics and aspects where their tools and services could benefit from additional components, and where they could be enhanced or complemented with further information and features. Finally, the case studies were designed to inform supervisory authorities and regulators about the status quo of tool applicability, possible existing gaps and ways forward in the near future.

Through this piloting process, participants gained deep familiarity with the tools they used and provided feedback and reflections on their experiences. The following section discusses some of the major trends related to climate risk tools observed by UNEP FI and participants as well as areas for further tool development. Given the emerging trends towards better comparability and baseline climate risk metrics in climate risk disclosures, this report could also inform about the status quo of tools coverage and performance, and possible issues to be solved by regulatory guidance in the near term.

Key takeaways on climate risk tools

Major trends to note

 Tool creators are partnering and larger players are bolstering their capabilities through acquisitions

With growing demand for climate risk tools and data, mergers & acquisitions are becoming ever more common. These partnerships can be between tool developers and data providers, such as between Oliver Wyman and S&P Global Market Intelligence to launch their Climate Credit Analytics platform. They can also include acquisition of climate expertise into a larger professional services firm. Examples of this include Willis Towers Watson's acquisition of Acclimatise, Moody's Analytics acquisition of Vigeo-Eiris, and McKinsey's acquisition of Vivid Economics. Whether through partnership, joint venture, or acquisition, the moves towards collaboration and consolidation may expand the resources in standard financial service providers capabilities devoted to climate risk tool development. This trend is a signal of growing investment in provider capabilities.

Transition and physical risk methodologies are being combined

In the past, many tools focused exclusively on physical risks or transition risks. However, as financial institutions and supervisors look to assess overall climate strategies and exposure to climate-related risks, a more integrated approach has been required. This has been very much driven by the physical-transition risk-combined reference scenarios of the NGFS. Rather than assessing physical risks and transition risks under different scenarios, some tool providers have sought to provide a holistic view of a firm's climate-related risks under different scenarios. Providers such as ISS-ESG and Moody's Analytics offer combined assessments for both risk types, while other providers calculate risks separately and then aggregate them. While the consideration of interaction effects between transition policies and physical risks is complex, the first steps are being taken in this direction. For example, in the NGFS's latest climate scenarios, the trade-off of impacts between transition and physical risks were incorporated into the reference scenarios.

Development of tools to meet regulatory expectations

In 2021, a handful of jurisdictions announced mandatory climate risk disclosures (often based on the TCFD framework), climate risk management expectations, and climate stress tests. These increased demands represent a growing appreciation of the risks that climate changes poses to the financial system and a desire to understand the nature and magnitude of those risks. Two of the most comprehensive stress tests have

been developed by the Bank of England/Prudential Regulatory Authority and the European Central Bank. Their exams require financial institutions to modify existing stress testing models and create new ones. Third party tool providers have closely observed the expectations of these leading central banks in developing offerings to meet the needs of financial users. Data providers have also been focusing on providing detailed information on counterparties, regions, and industries necessary to generate stress testing outputs.

New physical risk data sources and improved granularity

One of the major challenges tool providers seek to address is converting physical and transition risk data into financial impacts. Doing this effectively demands reasonably granular data that captures elements of financial relevance. Given that many of the original forecasts of climate-related physical risks were developed for scientific purposes, a recent focus of data providers has been on the needs of corporate and financial users. Initiatives such as ClimINVEST are developing open source access to physical risk data as is the EU's Copernicus Climate Change Service (E3CS). Alongside E3CS, through the Linux Foundation, Open Source Climate (OS-Climate) aims to be a clearinghouse for climate data needed by financial actors. In addition to these initiatives, there are also emerging collaborations between tool and data providers to enhance the resolution and coverage of physical hazard data.

Improved physical risk data allows financial institutions to assess their exposures against physical risks in various regions. The proliferation of data also means that tool providers and financial institutions have shown a greater interest in understanding asset-level physical risks, which are highly location dependent. The ability to evaluate asset-level risks is also enhanced by the increasing frequency and detail of corporate climate-related risk disclosures.

Growing interest in machine learning, Al, and remote sensing data sources

Big data has been key to improved climate model projections for many years. Typical simulations of climatological phenomena are highly computationally intensive. As computing power has grown and new statistical techniques have developed, climate risk tools providers are also looking to leverage advanced data collection and analysis techniques. For physical risks, remote sensing technologies can provide early warnings of a hazard or can offer a more detailed picture in previously data-scarce regions. For transition risks, new technologies can detect methane leaks and other sources of emissions to refine estimates of financed emissions.

Machine learning and artificial intelligence have been increasingly used to pour through climate-related datasets and derive new insights. For physical hazards, advanced data analyses have led to the identification of drivers of extreme event severity and the potential for business and supply-chain disruptions. New data sources and AI have also helped tool providers to refine forecasts in real time. An example is Jupiter Intelligence, which has developed a physical risk model up to 2100 that is constantly updated through satellite and sensor data. Also, AI could help to extract firm-level communications of their own climate targets and strategies, which are by some tool providers included in their risk analyses.

New transition risk scenarios and a focus on net zero

Earlier transition risk assessments focused on comparisons between current policy scenarios and Paris-aligned transition scenarios (below 2°C). However, in the past few years there has been a growing focus on 1.5°C scenarios and increased nuance in the design of transition pathways.

First, there has been a widespread recognition of the need to incorporate 1.5°C scenarios into tools. The global focus on 1.5°C followed the publication of the IPCC's Special Report on 1.5°C in 2018 that showed significantly greater harms experienced by a 2°C warmer world than a 1.5°C one (IPCC, 2018). That report spurred financial actors to call for the development of 1.5°C scenarios from leading modelers such as the IEA, which obliged with its net-zero 2050 scenario (IEA, 2021). Climate science indicates that the 1.5°C threshold requires reaching net-zero $\rm CO_2$ emissions by 2050, which has become a central goal of policymakers and financial institutions alike. Following COP 26, over 90% of the world's governments had made preliminary net-zero commitments, and they were joined by over 450 financial institutions (GFANZ, 2021). The global consensus on the need for net-zero 2050 and the goal of 1.5°C have made it imperative that tools enable financial institutions to assess their performance under these objectives.

In addition, there has been a growing appreciation that while more ambitious temperature targets can increase transition risks, the nature of the transition itself (orderly vs. disorderly) can have a major impact on the level of transition risk experienced. In UNEP FI's paper Decarbonisation and Disruption, the effects of a disorderly transition were explored for various economic sectors (UNEP FI, 2021). Likewise, the latest NGFS scenarios have developed scenario narratives that explore both orderly and disorderly transitions as well as the implications of delayed action and regional policy differences (NGFS, 2021). These NGFS scenarios provide a more detailed picture of the risks that may result from different transition pathways, and tool providers and financial institutions have been eager to determine the impacts of these new scenarios on financial portfolios.

Rising expectations of tool capabilities from FIs

As more financial institutions use climate risk assessment tools and are faced with growing pressure to disclose and act on their climate risks, tool providers have sought to improve their offerings. Broadly, financial institutions look for tools to be: decision-useful, disclosure-useful, and commitment-useful.

Decision-useful tools enable senior leadership and those in the business to act on the outputs produced by the tool. Such outputs can inform overall climate strategy, improve client engagement, and spur the development of new policies. Decision-useful outputs should be clear and able to answer the questions posed by users.

Disclosure-useful tools are developed to meet regulatory or other external disclosure requirements. They can be used for climate stress testing, TCFD reporting, or other sustainability disclosures. Multiple tool providers have worked to develop approaches that allow a financial user to easily translate the outputs of the tool into commonly used reporting frameworks. In a sense, these tools work backward from the reporting expectations in order to produce outputs that are likely to align to reporting standards.

Commitment-useful tools recognize the large number of financial institutions that have made commitments to green-financing and net zero in recent months. These tools enable appropriate target-setting and can also help financial institutions to monitor progress against specific targets. For commitment-useful tools, the methodology used in the assessment is particularly important as it may need to align with the methodology permitted under specific target-setting protocols.

Tools can serve more than one of these functions and often do.

Recommendations for future tool enhancement

As the trends above suggest, tools are constantly improving as providers look to meet the needs of their financial services clients. However, through the piloting exercise and group discussions, UNEP FI and the participating financial institutions identified several areas for future tool enhancement. These recommendations are geared towards tool providers (both third party and within institutions) in hopes of spurring the further development of approaches and methodologies required by financial institutions. They are grouped into specific areas for ease of reference.

Input data coverage

Although new data sources continue to be developed and many tool providers are working with more data than ever before, financial institutions still identify room for improvement. A common concern for financial users is how appropriate a tool's data is for their portfolio. This can include coverage of different asset classes, economic sectors, and geographic areas. While proxies and extrapolations may be required, there is a strong desire to ensure that their application is both intuitive and transparent. Through the piloting exercise, feedback regarding input data coverage pertained to three areas: physical risk data, transition risk data, and emissions data.

Physical risk data

Regional data coverage

While new sources of data are helping to address gaps in certain regions, much work remains to be done. Pilot participants with holdings in Africa, Southeast Asia, and South America all raised concerns about the degree of granularity offered by climate risk tools. Where data is unavailable, proxies and regional averages are sometimes used. However, there is no replacement for good data, and emerging economies continue to experience data gaps for physical hazards, transition risks, and emissions data.

Physical asset level data

A number of climate stress tests have required financial institutions to conduct counterparty level analyses on potential climate risks. Effective counterparty assessment requires data on the exposures of major assets to physical risks. That in turn demands highly granular data. As noted above, this data is most often lacking in emerging economies, but in some instances even when available only certain hazards are covered.

With a growing interest in asset-level assessments, many tool providers are working to improve their level of coverage and granularity.

Additional physical hazard scenarios

Pilot participants noted that physical risk scenarios typically considered representative concentration pathways (RCPs) associated with IPCC reports. Participants considered the strong mitigation (RCP 2.6) and the no action (RCP 8.5) scenarios to be most relevant in assessing the range of physical risk outcomes. However, within each of the RCPs are a variety of different potential pathways for the development of hazards. These pathways vary based on the underlying climate model used but can demonstrate that even for a given RCP the speed and severity of certain hazards can vary significantly. Participating financial institutions expressed interest in seeing a greater diversity of physical hazard scenarios for given RCPs, something that can be integrated into future tool design.

Transition risk data

Private company transition plans

In late 2021, the TCFD provided new guidance about the importance of disclosing climate transition plans as part of its recommended disclosures (TCFD, 2021). Additionally, certain jurisdictions (such as the UK), have mandated the disclosure of climate transition plans. These plans can provide a wealth of information about a company's preparedness and resiliency during a low-carbon transition. Financial institutions are looking at ways to integrate insights from corporate transition plans into their company-level assessments. Third party tool providers should also consider how this new information can be effectively incorporated into company assessments.

Sectoral assumptions

The transition to a low-carbon economy will affect nearly every sector in unprecedented ways. Assumptions around how different sectors will respond and which industries will be winners and losers of the transition have major implications for tool outputs. When exploring transition risk tools, pilot participants were eager to understand the key sectoral assumptions made by the tools. Participating financial institutions wanted more guidance around sectoral assumptions both to understand their effect on outputs and also to compare them to their own analyses of sector and industry outlooks. Tool providers can offer greater detail on the narratives in their scenarios and the implications of those scenarios for major emitting sectors such as energy, transportation, buildings, and industrials. They can also continue to add nuance to how carbon budgets for these sectors and their associated decarbonisation pathways vary across countries.

Additional transition scenarios

As noted in the trends section, many tool providers have increased the number of transition scenarios available to financial users. The added focus on net-zero pathways and scenarios reflecting current and potential climate policies has been a positive development. However, tool providers can go further in adding nuance to different scenarios, especially for disorderly transition scenarios. While the comparison of an orderly and disorderly transition is useful, a disorderly transition can proceed in many ways. Tool providers can work with economic modelers to consider the implications of different transition pathways on specific sectors and the global economy overall.

Emissions data

Emissions data has become increasingly important for financial institutions to define and track their decarbonisation commitments and to assess the transition risk of their exposures. While initiatives like CDP have done valuable work in collecting and providing self-disclosed data on corporate emissions, coverage is largely limited to public companies. For financial institutions that lend to or invest in small and medium enterprises, a number of assumptions are needed to address reporting gaps. These extrapolation methodologies may have major impacts on a portfolio's financed emissions or its transition risk, and so should be clear, transparent, and aligned with commonly accepted approaches for calculating emissions. Third-party verification of data is also important to validate and improve the quality of self-reported information. Tool providers will need to continue developing methodologies that cover these data gaps in greater detail in order to ensure that outputs generated for alignment and risk assessments are considered credible.

Risk types included

As financial actors and supervisors acknowledge the systemic risk of climate-related developments for financial stability, it has become imperative to gain a comprehensive view of a firm's climate risks. Such a holistic view demands tools that capture potential impacts from a wide range of climate-related phenomena. Pilot participants desired tools to capture the broad set of physical hazards they might be exposed to, common policy-driven transition risks, and emergent literation risks, interactions between risks, and financial system contagion.

Physical risks

Additional hazards

The physical risk tools profiled in the case studies of this report contain a variety of different physical hazards. However, as pilot participants noted, the most prominent hazards may vary significantly by region, and these prominent hazards may require additional detail. An example can be the hazard of flooding, which depending on location may be predominantly driven by coastal inundation (coastal), river overflow (riverine), or rainfall (pluvial) or some combination of these. Some tools already separate hazards into different types, but for those that do not, this additional nuance is welcomed.

Another area of interest involves indirect hazards of climate change. Pilot participants noted that few tools explored topics such as disease burden, water desalinization costs, and biodiversity loss. A full picture of climate risks requires consideration of the range of negative outcomes associated with a warming world. Additional work is needed to determine the financial and economic consequences of some of these more indirect effects of climate change.

Extreme event severities

For physical risks, many tools provide estimates that include both changes in incremental risks and changes in the frequency and severity of extreme events. While the likelihood and nature of extreme events may be moderated by changing baseline conditions (incremental risks), risk managers within financial institutions are highly concerned with the effects of extreme events. However, given different forecasting models there is a large degree of variation in the frequency and severity of these extreme events. Pilot participants sought to consider a larger set of extreme event frequencies and severities in assessing the performance of their portfolios. One way for tool providers to offer this is to show losses under different tail risk events and their associated probabilities (a topic discussed in the methodology points raised below).

Transition risks

Policy risks

During discussions with UNEP FI, pilot participants spoke about their interest in better understanding the implications of various policies on their portfolios. While net-zero commitments have been made by nations around the world, the implementation of this major economic change often remains vague. Different transition scenarios within climate risk tools offer financial institutions the opportunity to consider the effects of various policies and decarbonization strategies. However, among pilot participants, there was a strong recommendation that tool providers include more policy-driven scenarios in their tools and provide clear narratives for how the policies are likely to influence different sectors.

Carbon pricing

While carbon pricing can be considered a policy decision, it also reflects the development of global carbon markets and the use of internal carbon prices by different firms. Pilot participants considered the carbon price one of the clearest ways to evaluate the performance of portfolios and particular counterparties across a transition scenario. Tools that allow users to change the carbon price or compare different carbon prices and their effects were particularly desirable to participants.

Litigation risks

One area of risk rarely, or only indirectly captured by most tools is climate litigation risk. 'Climate litigation risk' in this context refers to the financial risks from any cause of action, regulatory investigation, or any dispute, that has a physical or transition risk catalyst. Customer and counterparty actions that could, for example, give rise to climate litigation include: failures to: mitigate emissions, consider climate change impacts, manage or disclose material climate risks, make accurate representations about climate risks/ green credentials, or to comply with regulatory adjacencies.

Climate litigation risks function like other traditional risks in that they can reduce asset values or pose credit risks by creating additional costs that corporates must pay. And whilst it may be challenging to incorporate such risks into tools, the recent growth in litigation in this area means that their consideration is necessary to both fully and adequately assess climate risks.

Additional time horizons

After data granularity and risk coverage, time horizons were frequently brought up by pilot participants as an area for future tool enhancement. Some tools designed for regulatory purposes adhere to the time horizons requested by the supervisory exams, while others align to the time horizons of the publicly available scenarios they take as inputs. These decisions are sensible, but as pilot participants noted in their discussions, financial institutions need to assess climate risks over a variety of time horizons. This can prove challenging given the progressive emergence of physical risks or the time needed to adapt the global economy to a low-carbon operating model. However, greater consideration of short-term shocks can allow financial decision-makers to understand the low-probability high-severity consequences of climate change or the low-carbon transition on today's portfolios. In addition, shorter term risk assessments can be more easily integrated into strategic planning and turned into actionable policies by business lines.

Output application/interpretation

While many providers consider their products as multi-solution tools, pilot participants were eager to better understand the implications and applicability of tool outputs. In order to effectively use the results, participants put a premium on transparency and clarity of assumptions. Relatedly, there was a strong desire to understand the range of uncertainty around different results. Many tools produce a single answer for a portfolio, but according to participants, a range of output values might be as useful if not more so in interpreting the results. Participants also requested additional guidance on how to use tool outputs in reporting and a desire to see illustrative examples to confirm the sensibility of the outputs generated.

Greater transparency

Participants within the UNEP FI pilot program often serve as critical communicators of climate risk insights to the rest of their organization. As a result, these individuals need to understand the outputs and the key assumptions of the tools they are using particularly well. The pilot exercise with tool providers received positive feedback from participants in terms of the transparency and openness shown by the tool providers about their methodologies and outputs. However, that transparency was made possible by direct meetings between the participants and tool providers. It would be valuable for all tool providers to provide accessible documentation that supports a greater understanding of their tools and the associated output among financial users. While this information should not compromise intellectual property, it should enable financial institutions to act as informed consumers of the various tools they may consider using.

Uncertainty around results

All tools based on future projections are subject to uncertainty, a fact widely acknowledged by the pilot participants. More details on the range of that uncertainty in outputs was considered a high priority by program participants. The IPCC itself uses various certainty measures (e.g., highly likely, likely) to connote probabilities of different outcomes in the climate projections it uses. Tool providers could also add more clarity around which results are more likely and which are more highly uncertain. Uncertainty may depend on data considerations, time horizons, and the measures being forecast. However, the inclusion of a form of "error bars" would aid in the communication of tool results and greater confidence in how to act on the information they provide. In addition, users should understand the probabilities associated with different outcomes and where those outcomes fall in a distribution, for example, does an output represent a mean estimate of losses or a 95th percentile? The topic of probabilistic estimates is explored further below.

Clarity in how outputs can be used to meet needs

During the individual tool piloting phase, participants were asked to consider how the tool outputs could be used throughout their organization. Many participants requested that tool providers offered additional guidance for how to interpret results and where the outputs might be most relevant. In the case of regulatory tools, use cases may be clear, but for many outputs, there are a range of potential applications. Tool providers can consider how their outputs might be used and also structure those outputs to fit the needs of these use cases. An example provided by a participant was the challenge in transforming the outputs from the tool into a format that could be incorporated in a TCFD report. Another question regarding tools involves how to effectively use outputs for internal decision-making.

Methodological assumptions

As outputs of climate risk tools are reported in public disclosures, regulatory exams, and internal analyses, methodological considerations around these tools are critical. Through discussions with UNEP FI, the pilot participants identified multiple areas where enhancements in tool methodologies could increase the realism of results. In most of these instances, participants expressed a concern that existing tools and analyses resulted in an underestimate of potential climate risks. The fuller incorporation of different hazards, tipping points, and tail risk events might present an opportunity to capture the potential consequences of climate-related financial impacts more fully.

Additional complexity/realism

Integration of physical and transition risks

As noted previously, some tool providers have begun integrating physical and transition risks into their models. However, even for tools that consider both physical and transition risks, internal consistency may be limited. Rather than applying a single scenario that covers both physical and transition risks, a tool may consider the risks separately and link them based on RCPs or temperatures, meaning that the underlying assumptions between the physical hazards and the transition pathway can come from different models. Beyond just using the same underlying models, tool providers should consider the interaction effects of both risk types on individual assets and portfolios overall. Examples include how coastal real estate may be hit by tropical storms due to climate change and also face higher electricity and rebuilding costs due to the low-carbon transition. On the other hand, a positive synergy might be resiliency measures that also increase energy-efficiency.

Interaction effects between hazards

For physical hazards, interaction effects are critical to understanding the full extent of the climate-related risks. A storm that strikes in a location that has suffered from coastal erosion and sea level rise will be more damaging than its windspeed and flood heights would indicate. There are often correlations between different hazards that also amplify potential damages, such as warmer and drier conditions that make wildfires more likely and severe. While these interaction effects may not be directly modelled by a climate risk tool, tool providers should move away from considering individual hazards in isolation where possible and look for underlying models that consider the relationships between hazards.

Incorporation of tipping points

Climate tipping points have become an area of growing concern due to scientific research indicating that many of them may be activated at even modest levels of warming. Fundamentally, tipping points are non-linearities in a system, which when exceeded change that system from one state to another. They can be physical in nature, such as melting ice sheets, or economic, such as the collapse of confidence in global credit markets in 2008, but regardless of where they manifest, they are critical to gaining an accurate view of climate risks. Few tools explicitly capture tipping points as they relate to physical risks, such as marine ecosystem collapses, or as they relate to transition risks, such as the collapse of coal power in OECD economies. Given that these non-linearities are where outsized climate risks may be experienced, it is imperative that tool providers consider how they can be both integrated into their models and used to inform the outputs generated. These tipping points also demand a paradigm shift for financial institutions from risk-return management to resilience management.

Inclusion of second and third order effects

Climate risk tools often focus on a set of hazards when assessing their financial impact on a portfolio or individual counterparty. These hazards (both physical and transition) are often the direct effects of climate change or of the transition. Examples for physical hazards include damages from flooding or wildfire, examples for transition risks include carbon taxes or rising energy costs. However, many climate-related impacts are not the direct result of the initial event, but rather the secondary and tertiary effects. The case of

Hurricane Katrina is illustrative on this point. While the damage from the storm itself and the attendant flooding were estimated at over \$100 BN, the New Orleans economy felt additional shocks. Businesses that remained closed for months or longer lost revenues and customers, the city lost tax revenues, and investments in new projects were repurposed to rebuild the damage. Furthermore, over 100,000 residents who left New Orleans did not return, leading to a smaller city with lower output than before the storm. Assessing the true costs of climate change requires evaluating the long term consequences of different events and policies.

Probabilistic estimates of losses

Many climate risk tools provide specific output values for a given portfolio and time-frame. However, the uncertainties inherent within climate modelling mean that climate risk is a fundamentally probabilistic challenge. Unfortunately, in some cases, users and providers may confuse a scenario with a severity. For physical risks, this may mean considering RCP 8.5 to be the "severe" scenario or for transition risk, it might be considering 1.5°C to indicate "severe" transition risks. However, each scenario is merely a single potential pathway and the results of a tool are a point estimate of losses or impacts on that pathway.

However, RCP 8.5 may have widely varying implications for different physical hazards. This is easier to see given the proliferation of climate models that are run for RCP 8.5 that may show different levels of flooding, storms, wildfires and other hazards. To look at the most severe outcomes, a probabilistic method should be considered which looks at these different underlying models and considers hazard severity. As such, the 95th percentile of flooding for an RCP 8.5 scenario should be in the top 5% of the worst flooding as indicated by different models. For transition risk, this approach is slightly different, but relies on macroeconomic probabilities of key variables like growth rates and trade balances. It may be more challenging to assign numerical probabilities to different transition scenarios, but certainly for a given 1.5°C scenario, optimistic, base, and pessimistic cases of economic performance can be considered. The modelling community has explored some of these different futures through the creation of shared-socioeconomic pathways (SSPs).

While these challenges may require the involvement of climate modelers and scenario developers, their implications should be contemplated by thoughtful tool providers. Looking at the tail risks of different scenarios can provide a better view of downside risks that financial institutions must prepare for, and avoid the mistaken assumption that if a portfolio performs well in a certain RCP 8.5 or 1.5°C scenario than it faces limited climate risk.

Strategic guidance

According to the pilot participants, climate risk tools are already being used to guide decisions. However, in addition to the enhancements noted above regarding coverage, hazards, outputs, and methodologies, participants want tools to provide guidance as well. Specifically, participants are looking for tools that can identify potential climate-related opportunities, improve client engagement, and develop new climate strategies. These desires represent a step forward for many climate risk tools that have been developed to produce a loss estimate or meet a reporting need. The application of forward-looking analytics to opportunities and strategies can allow firms not only to manage their risks but to take advantage and thrive in a changing world.

Opportunity identification

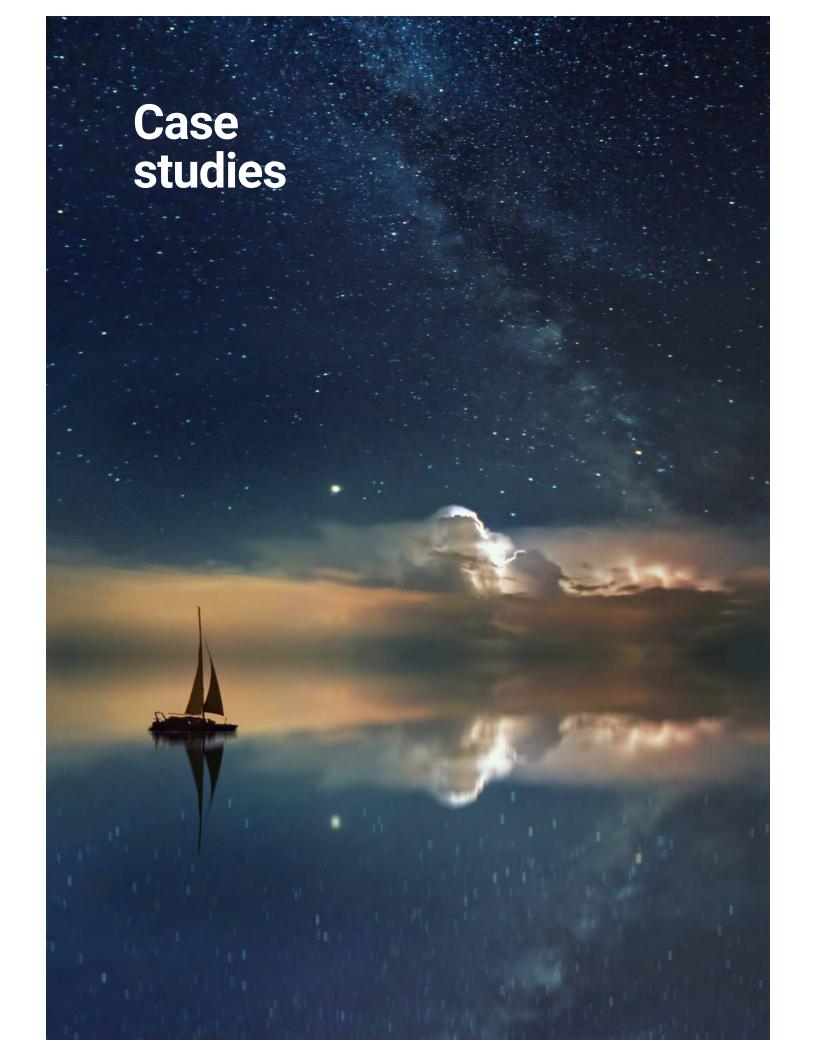
While recent years have seen a large number of tools marketed to help manage climate risk or report on climate alignment, fewer tools appear to focus on the tremendous opportunities presented by climate change through mitigation and adaptation solutions. In the UNEP FI pilot program, many participants indicated awareness of potential climate-related opportunities, but few mentioned that they were using tools to evaluate them. Given the widespread economic shifts that climate change and net zero will bring globally, financial institutions have the opportunity to support the creation of a resilient, just, and sustainable future and profit while doing so. Forecasts from the IEA and NGFS for reaching net zero require trillions in annual funding for the development and deployment of clean technologies. Pilot participants expressed an eagerness to see tools that helped them identify opportunities most suitable to them and determine how best to capitalize on them.

Client engagement

When asked about how they planned to use the outputs of the pilot analyses, participants frequently mentioned client engagement. Information about climate risks and individual counterparties can help financial institutions decide on the relationship the firm would like to have with those counterparties in the future. However, there was a desire for tools to be developed that even more explicitly focused on client engagement, and specifically in helping clients to transition to net zero. A number of participants have made public commitments about supporting client transitions and would welcome the creation of tools that allow them to assess transition plans and more effectively communicate with clients on how they can advance their progress towards net zero.

Strategy-setting

In addition to client engagement, participants also mentioned that pilot outputs could be used in determining climate strategy. Many tools provide outputs that are helpful in developing high-level climate strategies. Yet, for specific businesses, the desire for actionable guidance on climate policies demands more granular outputs. Part of the challenge involves getting the business line familiar with the outputs of climate tools and confident in their usefulness for developing a forward-looking strategy. Beyond that, tools geared towards specific businesses, sectors, or asset classes can provide information that can be integrated into processes such as underwriting and origination.



Case study structure

The case study structure was developed in consultation with experts at ETH Zurich and covers the major areas noted below to promote comparability of the tools and the usability of the case studies as a resource for the financial sector. In the case studies that follow, the detail and nature of the criteria below may vary at the discretion of the pilot participant.

Figure 2: Criteria included within case study assessments

Introduction

Overview of the piloting exercise Key findings or conclusions

Process

The process followed in using the tool, step-by-step Main challenges encountered

Data and coverage

Data needed to conduct the analysis

Internal External

Portfolio coverage

What geographies and sectors can the tool assess? What was actually assessed in the demo? Percentage of portfolio, geography, sector, total exposure? Number of counterparties?

Risk factors and scenarios

Key risk factors explored during the demo (e.g., hazard types)

Temperature pathway(s) analyzed

Scenarios used (NGFS, IEA, etc.)

Outputs and insights

What outputs were generated?

What learnings came from using the tool?

What are use cases for this type of analysis or for the full tool?

Any future plans to extend the analysis or conduct similar analysis internally?

Suggested enhancements for providers

How easy was the tool to use?

Are there any modifications or suggestions you have that would enhance your analysis?

What are areas that you'd like to see the providers explore in the future?

Detail on tool providers and tools

As mentioned in the acknowledgements, UNEP FI and the pilot participants would like to thank the providers for allowing the piloting of their tools. The table below provides a high-level overview of the participating providers and the tools that were piloted.

Provider	Description	Featured tool overview	Risk types covered by tool
Entelligent	Entelligent is a climate risk analytics platform that measures and manages investment exposure to climate risk.	Entelligent has built technology — the first to be patented — that leverages macroeconomic and forward-looking climate-scenario models. This allows Entelligent's platforms to help institutional investors managing equity and corporate bond portfolios to maximize both financial performance and carbon-emissions reductions, while minimizing climate change transition risk.	Transition Risk
ISS-ESG	ISS ESG solutions enable investors to develop and integrate responsible investing policies and practices, engage on responsible investment issues, and monitor portfolio company practices through screening solutions.	ISS ESG provides climate data, analytics, and advisory services to help financial market participants understand, measure, and act on climate-related risks across all asset classes. In addition, ESG solutions cover corporate and country ESG research and ratings enabling its clients to identify material social and environmental risks and opportunities.	Physical & Transition Risk
Moody's Analytics	Moody's Analytics provides financial risk intelligence and analytical tools supporting our clients' growth, efficiency, and risk management objectives. The combination of our unparalleled expertise in risk, expansive information resources, and innovative application of technology helps today's business leaders confidently navigate an evolving marketplace.	Moody's Climate Solution suite offers a complete framework that spans across the overall risk management framework covering climate change analytics across both physical and transition risks, a comprehensive climate scenario analysis framework and stress testing, integration to credit risk modelling and financial metrics and tools to support Climate-related financial disclosures. Note that these studies were conducted pre-acquisition of RMS by Moody's, therefore, can be enriched to bring the breadth and depth of climate-related financial risk analysis that joint firms can today bring.	Physical & Transition Risk

Physical & Transition Risk	Subscription to the Climanomics® platform enables climate risk reporting and disclosure aligned with the Task Force on Climate-Related Financial Disclosures (TCFD) framework. Subscribers use the outputs to measure and report their transition and physical risks and opportunities in financial terms under different climate scenarios.	The Climate Service is backed by an Advisory Board including 4 IPCC Nobel Prize winning scientists, and strategic partners including Aon, IBM, the AICPA, and LMI Consulting. Their goal is to help investors, companies and communities to understand their risks from the changing climate, and the opportunities from the transition to a low-carbon economy. Their mission is to embed climate risk data into every decision on the planet, and facilitate the world's transition to a lower carbon economy.	TCS
Transition Risk	Climate Credit Analytics—S&P Global Market Intelligence and Oliver Wyman developed Climate Credit Analytics, a climate scenario analysis and credit analytics model suite. These tools combine S&P Global Market Intelligence's proprietary data resources and credit analytics capabilities with Oliver Wyman's industry-leading climate scenario and stress-testing expertise. This solution provides a comprehensive, tailored approach to assess credit risk on counterparties, investments, and portfolios under multiple climate scenarios, including those published by the NGFS Phase II framework. Coverage includes more than 1.6 million public and private companies globally.	Oliver Wyman is a global leader in management consulting. With offices in 60 cities across 29 countries, Oliver Wyman combines deep industry knowledge with specialized expertise in strategy, operations, risk management, and organization transformation. Oliver Wyman is a business of Marsh McLennan [NYSE: MMC]. S&P Global Market Intelligence is a division of S&P Global (NYSE: SPGI), the world's foremost provider of credit ratings, benchmarks and analytics in the global capital and commodity markets, offering ESG solutions, deep data and insights on critical business factors.	Oliver Wyman and S&P Global Market Intelligence
Physical Risk	RMS has over 200 peril models in nearly 100 countries enabling insurers, reinsurers and other organizations to quantify the potential magnitude and probability of economic loss from catastrophe events.	RMS, a Risk Management Company at the Forefront of Risk Intelligence At RMS, Risk Management Solutions is their name and what they've been building over 30 years: industry-leading risk management solutions for insurers, reinsurers, financial services organizations, and the public sector. Their science, technology, and 300+ catastrophe risk models help (re)insurers and other organizations evaluate and manage the risks of natural and man-made disasters.	RMS, A Moody's Analytics Company

right. based on science of economic a climate-related science. Specialized an ers: Their softy economy, final	JBA Risk Management They are JBA F Flood People. They are the or helping the ins and financial ir flood risk.	Willis Towers Watson At WTW, they provide areas of people, rise and local expertise and markets, we had organizational resilemize performance.
The pioneering °C data provider: right. based on science GmbH (right.) provides transparency on the climate impact of economic activities—plain & simple in °C. Their aim is that climate-related decisions are guided by the best available science. Specialized and high-quality data for various key stakeholders: Their software and metrics enable actors from the real economy, finance, and real estate to plot pathways to 1.5°C alignment	They are JBA Risk Management, otherwise known as The Flood People. They are the one of the global leaders in flood risk science, helping the insurance and property industries, governments and financial institutions to understand and manage global flood risk.	At WTW, they provide data-driven, insight-led solutions in the areas of people, risk and capital. Leveraging the global view and local expertise of our colleagues serving 140 countries and markets, we help you sharpen your strategy, enhance organizational resilience, motivate your workforce and maximize performance.
X-Degree Compatibility (XDC) Model—We developed the X-Degree Compatibility (XDC) Model to calculate the climate impact of e.g. companies, buildings, and financial portfolios (private & listed equity, bonds, sovereign bonds). The central question: How much global warming would occur by 2050 if the whole world performed as the entity in question? Results are expressed as tangible degree Celsius values, allowing a direct benchmarking against the Paris Agreement goal of keeping global warming to 1.5°C or, at least, well below 2°C.	They help the insurance and property industries, governments, and financial institutions understand and manage global flood risk across a wide range of flood sources, including river, surface water and coastal. Our probabilistic (CAT) models and flood maps cover 190+ countries in the World.	Climate Diagnostic—It can be difficult to conceptualize climate change as a specific risk to your organization—2100 or even 2050 can feel far off, talk of sea levels rising by inches can sound insignificant, and the global effects are broad and complex. This tool shows changes in acute hazards such as extreme wind and flood as well as chronic stress factors like sea level rise and heat stress under multiple combinations of climate scenarios and timelines. It shows how those changes could affect your specific properties. Climate Diagnostic can advance your journey to effective climate risk management. Climate Quantified (CQ) is WTW's suite of models, tools, datasets and services to support organizations to identify, assess, and respond to physical and transition risk—for example through climate stress testing of investment portfolios, assessing compliance with legislative requirements or identifying opportunities to invest in the transition. Combined with learning and knowledge-sharing opportunities, CQ supports implementation of strategic responses to climate change.
Transition Risk	Physical Risk	Physical Risk

Baringa	Baringa have set out to build the most trusted consulting	Climate advisory	Physical and
(firm in the world. They team up with their clients to tackle their toughest business challenges. Their work spans the big picture—vision, strategy, future direction—and the nuts and bolts of the delivery. They work on challenges like helping clients define their net strategy, deliver complex change, spot the right commercial opportunities, make the move to digital, manage Climate risk, or bring their purpose and sustainability goals to life. They work with everyone from FTSE 100 names to bright new start-ups, in every sector. They have hubs in Europe, the US, Asia and Australia, and they can work all around the	We advise clients across financial services, government, regulatory bodies and wider sectors on climate risk and net-zero strategy through; Leading climate scenario and transition modelling capabilities Deep sectoral expertise in transition to net zero	Transition Risk
BlackRock	BlackRock's purpose is to help more and more people experience financial well-being. As a fiduciary to investors and a leading provider of financial technology, they help millions of people build savings that serve them throughout their lives by making investing easier and more affordable.	Aladdin Climate: Central to understanding—and ultimately acting upon—the effects of climate change on investments is a need to quantify the financial impact of climate-related risks. Aladdin Climate was built to quantify climate risks and opportunities in financial terms—bridging climate science, policy scenarios, asset data, and financial models to arrive at climate-adjusted valuations and risk metrics.	Physical and Transition Risk
Pricewater- houseCoopers	PwC's Sustainability practice helps organisations plan, source, deliver, finance and measure the wider impact of products and services. They help to future-proof businesses by making them more resilient, agile and sustainable. They provide guidance on a wide variety of issues, working with clients from the corporate, private equity and public sector. They are specialists in how organisations can spot the risks and harness the opportunities.	PwC's "Climate Excellence" tool for climate scenario analyses supports investors and companies in making their portfolios fit for the risks and opportunities of climate change. This enables them to realize increases in value, adequately manage risks, and set up a long-term sustainability strategy and compliant reporting.	Physical and Transition Risk

Participant:

Sustainable Leaders Capital

Provider:

Entelligent

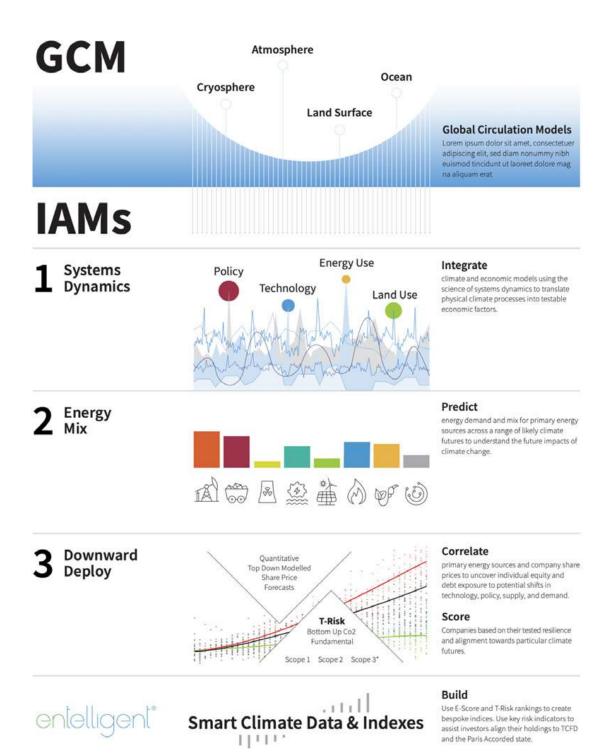
Risk types covered by tool:

Transition risk

Introduction

Sustainable Leaders is a private, employee-owned institutional investment boutique offering actively managed thematic and rules-based ESG investment strategies addressing environmental and social themes. We aim to deliver sustainable, first-class investment performance, and to make a material and positive difference for our clients and society.

Entelligent is a data analytics platform that leverages the capital markets to make a positive impact on climate change mitigation and adaptation. Entelligent's climate scenario analysis and climate risk approach—which are patented—use sophisticated climate models and systems dynamics approaches to project scenarios for the future energy mix as the world aligns with the Paris Accord and net-zero commitments. Entelligent's SmartClimate technology scores companies based on climate resiliency, providing data that can underpin stock selection for funds and indexes.



Bringing together the experienced investment team at Sustainable Leaders and the climate science and machine-learning teams at Entelligent, we have built two Paris-Aligned net-zero strategies (U.S. and Global) that are optimized to maximize financial returns and environmental out performance. These case studies demonstrate a break-through in terms of enabling investors to better track investments alongside the transition to a low-carbon economy and lower the carbon in their portfolios, therefore reducing climate-related transition risks.

Process

Promethos Capital (now branded Sustainable Leaders for the Entelligent Index and other passive index-tracking, rule-based smart beta strategies) and Entelligent partnered to build two climate change-focused investment strategies: 1) Paris Aligned Net-zero US Large Cap and 2) Paris Aligned Net-zero Global Large Cap. The strategies are designed to build investment portfolios that feature inclusive climate transitions toward Paris goals. The portfolios are optimized to be climate resilient, have neutral representation across sectors and regions relative to the benchmark, and are focused on reducing carbon exposure.

SmartClimate is used by asset and fund managers in a joint product development effort. Sustainable Leaders selects the global index benchmarks, and Sustainable Leaders integrates ESG and mission-oriented strategies with Entelligent's climate science-based transition risk scores¹ to build portfolios that seek to create superior financial performance and environmental outcomes based on TCFD recommended metrics. The steps in the process are summarized below:

- Select global benchmark (Sustainable Leaders)
- Design ESG and mission-based strategies (Sustainable Leaders)
- Select climate scenarios (Sustainable Leaders & Entelligent)
- Project share price returns on the benchmark constituents for the selected scenarios (Entelligent)
- Compute climate risk exposures by estimating share price sensitivity to the range of energy transitions, including energy price and demand (Entelligent)
- Set screening and optimization thresholds for climate resiliency and ESG criteria (Sustainable Leaders & Entelligent)
- Run portfolio strategies and climate optimization (Entelligent)
- Deliver weights/allocations to Sustainable Leaders (Entelligent)
- Build financial products/set trades and provide investable universe to financial leaders (Sustainable Leaders)

Data

For climate modeling and inputs, we use data from MIT's En-ROADS climate and energy simulator. En-ROADs, which incorporates systems dynamics, was first used by Donella Meadows in her Limits to Growth report, published by the Club of Rome.² The model uses data from the Internal Energy Agency (IEA), NASA's Goddard Institute for Space Studies (GISS), the Carbon Dioxide Information Analysis Center (CDIAC), the National Climatic Data Center (NCDC), the National Ocean Atmospheric Administration (NOAA), the multisector, multiregional, computable general equilibrium model of the world economy (MIT EPPA). The financial data is from MSCI, S&P and FactSet. The carbon data on Scope-1 and 2 emissions, used to validate findings, is provided by ISS. The model is validated by a third party WSP. The model inputs and outputs are in the confidence

¹ More information on Entelligent methodology and score computation is provided here: A demo version of the model is available here: https://en-roads.climateinteractive.org/scenario.html?v=2.7.29

² A demo version of the model is available here: https://en-roads.climateinteractive.org/scenario.html?v=2.7.29

interval of forecasts from EMF 27 suite, WEO, BP and EIA. The ESG data and company-level exclusions were provided by Sustainable Leaders.

Coverage

The selection universe for the Paris Aligned Net-zero US Large Cap strategy is a U.S. large cap index tracking 500 major companies. The Paris Aligned Net-zero Global Large Cap selects from MSCI world large-cap and mid-cap equity universe.

The data produced (E-scores) is forward-looking, action based and does not hedge on a particular scenario. The model estimates the deviation of share price forecasts two years into the future to estimate climate transition risk. The difference in return forecasts under different climate scenarios is taken as a measure of transition risk. The focus of the methodology is entirely on the climate scenario resilience of share price estimates. Securities with higher area dispersion are more exposed to future policy, technology and energy shocks related to climate change mitigation and adaptation.

There are no bottom-up sustainability factors in our computation. But ISS Scope I and Scope 2 data are used to validate the efficacy of resultant risk-adjusted portfolios. Carbon reductions are an outcome (value-add) of E-score application to portfolio construction for climate-risk minimization, and not inputs to the model. The companies that show more resiliency toward climate and energy shocks tend to be more sustainable compared to their peers in the same sector and region. The process of score computation is fully standardized. It is same for BP, Walmart or Tesla.

The database is updated every quarter to make sure the latest data, price movements and corporate actions are captured. The unit of output is area estimates of dispersion. More specifically, the raw units are a two-year summation of absolute deviation over expected returns under a max and min carbon scenario.

Risk Sources & Scenarios

The sources of risks are climate transitions such as carbon tax, electrification, changes in energy efficiency, technical breakthroughs and other socio economic and energy factors. Each of these factors contributes to a shift in the supply, demand and price of energy. This approach considers climate transition risk and chronic physical risk factors such as temperature rise, atmospheric concentrations and sea-level rise. The visuals and scenario outputs are provided in more detail below.

Entelligent Climate Scenarios

We use four different scenarios to answer a pressing question: What will the world look like in the year 2100?

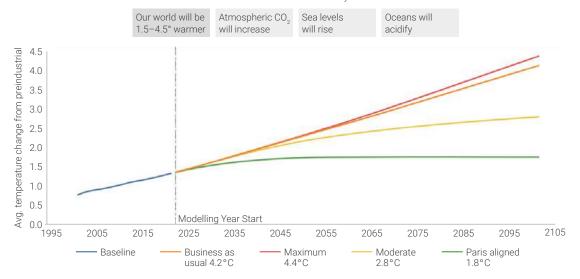


Table 1: E-Score Dataset: Default Min & Max Scenario Settings- Environmental & Energy Impact (2100)

Time of Departure 2018											
BAU		Min Scenario	Max Scenario								
Global population in billions	11.18	11.18	11.18								
Global GDP per capita	59,473.60	59,473.60	66,671.30								
Average total final energy intensity of GDP	1.52	0.62	1.41								
Carbon intensity of final energy	105.01	34.82	103.94								
CO ₂ emissions from energy	106.03	14.48	109.25								
Total Final Energy Demand	1009.65	415.86	1051.06								
Atmospheric concentration CO ₂	893.84	536.62	948.51								
Equivalent CO ₂	904.404	627.95	957.69								
Temperature change from preindustrial	4.24586	2.86	4.45								
Fuel price of oil per barrel	181.77	233.89	201.02								
Market price of electricity in KWh	0.11	0.16	0.15								
Sea level rise (from 2000)	1282.81	1054.27	1305.48								
Delta pH levels (from 2000)	-0.32	-0.12	-0.25								

Output

Entelligent's SmartClimate platform minimizes portfolio exposure to climate transition risk subject to diversification principles such as min/max holding size, regional exposure, sector allocation and constituent turnover.

This strategy yields U.S. and global equity portfolios with decreased exposure to climate change risk and greater opportunity for resilient business activities. Hypothetical financial and environmental performance over a four-year backtest for the global portfolio is presented below.



The chart above shows the performance of the Global Paris Aligned Net-zero index versus an all-cap world index. The goal of the index, comprised of about 300 companies in 23 developed markets and 27 emerging markets, is to reallocate capital toward a low-carbon and climate-resilient economy. Index components are developed by screening out certain weapons, tobacco, coal and fossil fuel companies. Additionally, companies that are non-compliant with international ESG standards such as the United Nations Global Compact Principles are removed. The companies included are projected to have the greatest potential for both environmental and valuation impact.

The tables below show comparative environmental out-performance of the index based on TCFD-recommended metrics. Entelligent projects the Sustainability Leaders can achieve an 80% improvement on carbon intensity, a 400% increase in revenues per tons of carbon invested and a 257% improvement in carbon footprint.

Carbon Impact Results	Portfolio	Benchmark	% Better
Carbon intensity	119	597	80%
Carbon revenue/ton	8,373	1,675	400%
Carbon growth percentage	-3.4%	-3.1%	10%
Average carbon footprint	13.6	35.0	257%
Total carbon emissions/MM	15.5	26.7	172%
Exposure carbon related assets/MM	1.7	13.6	800%
Exposure carbon related assets/%	1%	6%	600%

Annualized return	1 Yr	3 Yr	Inception
Global Paris Aligned Net Zero	54.7%	18.7%	19.4%
ACWI	50.9%	13.4%	13.7%
+/- Benchmark	3.8%	5.3%	5.7%

Global Paris Aligned Net-Zero Characteristics					
Benchmark	MSCI ACWI				
Position Size	5% Maximum				
Holdings	200				
Sector	+/-3%				
Region	+/-3%				
Top 10 Holdings	43%				
Market Cap	Large				
Tracking Error	4.63%				
Beta	0.96				
Style	Core				
E-Score	4.95 5.0				

Insights gained

It is possible to maximize financial returns and environmental performance via a climate transition strategy. Science-based strategies (such as this) are both effective and scalable. The strategies outlined above demonstrate that, when science meets business, we can find opportunities that are win-win for both investors and the environment.

Working with Entelligent, Sustainable Leaders streamlines the TCFD six-step process for applying scenario analysis to climate-related risks and opportunities and into investment decision-making processes:

- i. Sustainable Leaders' board and management have been directly involved in the definition and adoption of climate-related risks and opportunity KPIs for investment decision and monitoring. This aligns with the Step 1 governance of TCFD recommendations.
- **ii.** Entelligent's approach helped Sustainable Leaders' board and management learn how to determine the present-value of the medium- to long-term material impacts of climate change—technology, policy and market shocks—to near-term outlooks. This involves setting up processes and functions for risk management, per TCFD Step 2.
- **iii.** Through a series of climate scenarios (from Paris alignment to 4+ hot world) relevant to Sustainable Leaders investment strategies, selecting climate scenarios and investment benchmarks are very close to TCFD's Step 3 recommendation.
- **iv.** The computed climate risk exposure (Step 4) establishes the important of setting up screening and optimization thresholds to ensure long-term financial and environmental performance in line with Sustainable Leaders' fiduciary duty.

This case study helped us identify key processes and KPIs that should be communicated to relevant parties to ensure full transparency and accountability. Establishing climate targets, metrics and quarterly measuring standards ensure portfolios remain aligned with Paris goals. This aligns with the final TCFD recommended metrics and targets.

TCFD states that this exercise can be a useful additional factor in determining how to prioritize risk management activities and where to consider making additional allocations.³

Usability

Sustainable Leaders and Entelligent Paris Aligned Indices are available to asset managers and asset owners to capitalize their financial and sustainability goals. These applications are highly customizable and can be integrated to multiple investment visions, missions, themes and philosophies. We understand the diversity in investment practices, and we want to use the power of diversity and inclusion to build Paris and net-zero aligned climate solutions.

Suggested enhancements for the tool providers

Sustainable Leaders suggests Entelligent include bottom-up data such as carbon emissions, biodiversity, water and physical risk packaged with the existing top-down transition risk approach. That way, the analysis will be more complete and persuasive. The development of a 360-degree view on climate risk and opportunity, which may require collaborating across multiple climate scoring systems, would be beneficial. Entelligent uses Scope 1 and Scope 2 emissions data in the validation of its E-Scores. The next iteration of its scoring methodology, known as T-risk, will add Scope 1 and Scope 2 emissions as inputs into the ranking.

³ https://www.tcfdhub.org/scenario-analysis/

Participant:

TD Asset Management

Provider: Risk types covered by tool: ISS ESG Physical and transition risk

Introduction

TD Asset Management Inc. (TDAM, a wholly-owned subsidiary of The Toronto-Dominion Bank) considers climate change a systemic risk affecting economies, companies, and investors. Our approach to climate change is aligned with our overall philosophy of integrating all sources of risk and return in our investment processes.

As an investment manager of diversified asset classes, we consider climate change as an important area of research to fulfill our fiduciary responsibility on behalf of our clients. We actively engage with companies as well as our partners, and leverage our asset ownership positions to encourage improvements in company disclosures on climate-related risks and opportunities facing their businesses. In addition, we participate in numerous industry collaborations including Climate Action 100+, Carbon Disclosure Project, and the United Nations Environment Programme Finance Initiative (UNEP FI) TCFD investor pilots, with the first two furthering our company engagement efforts, and the latter developing a better understanding of climate-related investment risks. Our approach continues to evolve to help position our portfolios to capitalize on investment opportunities arising from an accelerated transition to a low carbon economy and manage undue climate-related physical and transition risks.

As part of the UNEP FI landscape review module, TD Asset Management Inc. was tasked to evaluate a third-party tool used to measure the climate risks of an investment portfolio. We were matched with Institutional Shareholder Services (ISS) ESG (Climate Solutions), a source of corporate governance and responsible investment solutions. We were provided with login credentials (usernames and passwords) to access ISS' proprietary DataDesk platform (the "platform") as well as a brief tour and walk through of the platform to ensure that we would be able to maximize our 4-week trial period.

For our analysis, we turned our attention to the portfolio analysis section of the platform which let us generate a PDF report emphasising the key climate risk exposures of the portfolio. Notably, all data used to create the report could be conveniently downloaded as a CSV file for added flexibility and further examination.

Data and Coverage

For this exercise, we uploaded the holdings (as of December 31, 2020) of a long-only global equity portfolio benchmarked to the MSCI All Country World Index. The portfolio held 195 securities from over 30 countries across both developed and emerging markets, and leaned toward mid-sized, dividend-paying and low volatility securities from defensive sectors such as Utilities and Consumer Staples.

Uploading the portfolio to the platform was straightforward. We simply had to provide the platform with a CSV file comprising the following information: portfolio name, client identifier type (e.g., ISIN), client identifier (i.e., the ISIN values), modeling currency (in our case, CAD) and weight in percentage. Every security of the portfolio was successfully mapped onto the platform. Moreover, all dual-class shares and ADRs were correctly mapped to their underlying issuers.

The platform contained data for 99.83% of the portfolio (by weight), or 194 out of the 195 securities. It is worth noting that all missing data, as with that of the non-covered security, was suitably labelled as either "not applicable", "not collected" or "not disclosed", to avoid confusion with available but zero or null-valued data points.

Risk Sources and Scenarios

ISS ESG's offering can be split into four categories: emission analysis, climate scenario alignment analysis, transition risk analysis and physical risk analysis.

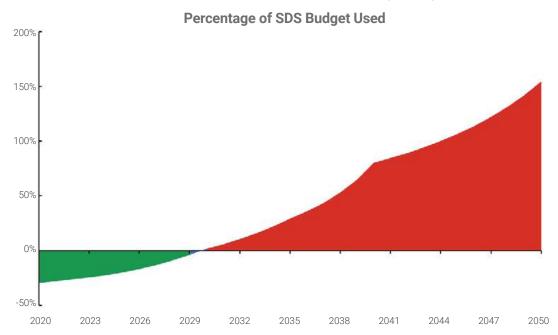
The first category, emission analysis, comprises common carbon metrics, where applicable aligned with the TCFD Recommendations and the PCAF Global Standard, such as the share of disclosing holdings, carbon emissions (including scope 3 emissions) and carbon intensity. An interesting feature of the platform is the emissions "trust" rating. This metric estimates the extent to which we can trust a company's reported carbon emissions numbers. For instance, emissions that have been externally audited would be rated higher than emissions that have only been estimated. The second category, climate scenario alignment analysis, compares current and future portfolio greenhouse gas emissions with the carbon budgets from the International Energy Agency (IEA) Sustainable Development Scenario (SDS), Stated Policies Scenario (STEPS) and Announced Pledges Scenario (APS). The third category, transition risk analysis, focuses on green energy generation and fossil fuel reserves (i.e., oil, gas and coal). The fourth and last category, physical risk analysis, gauges the impact of the six most costly physical climate change risks such as floods, droughts or storms on the current and future overall value of the portfolio.

Outputs and Insights

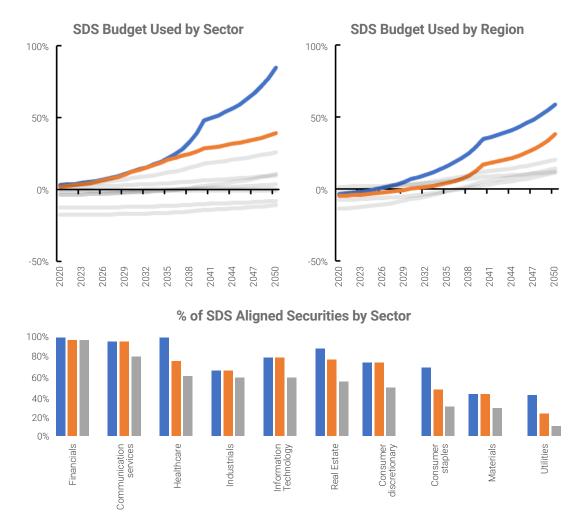
For the sake of brevity, we chose to focus solely on the last three categories, namely climate scenario alignment analysis, transition risk analysis and physical risk analysis, and only on the data that we deemed most interesting to us, as specified below.

Climate Scenario Alignment Analysis

For the climate scenario alignment analysis, we concentrated on the IEA's Sustainable Development Scenario (SDS) pathway as it boasted the most comprehensive and intuitive data. The SDS charts a GHG emission pathway in line with the Paris Agreement of holding warming to well below 2°C by the end of the century. The following chart plots the portfolio's emission pathway as a percentage of its SDS budget. As it stands, the portfolio is misaligned with the SDS scenario by 2050 and is on course to exceed its SDS budget by 2030. By 2050, it is expected to overshoot its SDS budget by nearly 150%, corresponding with a potential temperature increase of nearly 2°C by 2050.



The PDF report generated by the platform highlights the key sectors contributing to the misalignment of the portfolio. Having the data readily available outside of the platform allowed us to perform additional analysis on the portfolio. For example, we could easily single out the sectors, regions or even securities which used most of the SDS budget of the portfolio. Namely, we found that most of the SDS budget is used by securities in the utilities sector. In particular, we found that a small portion of the portfolio, representing roughly half a dozen securities, was responsible for using most of allocated SDS portfolio budget.

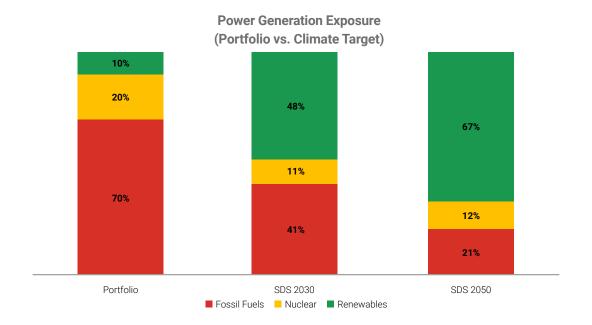


This information is important because it alerts us to the fact that the portfolio could be more closely aligned with the SDS pathway with only minimal changes to the portfolio's holdings. This information also reveals which sectors and/or securities we should target our carbon risk reduction efforts on.

Transition Risk Analysis

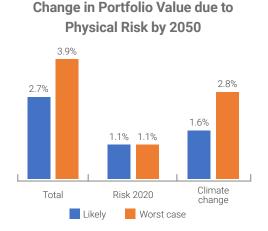
The transition risk analysis module of the platform emphasizes both power generation (demand side) and fossil fuel reserves (supply side) as key to transitioning to a greener, decarbonized economy. The rationale is that exposure to "brown" (i.e., non-renewable) electricity generation or fossil fuel reserves may eventually lead to higher reputational risks, policy and/or regulatory risks as well as stranded asset risks.

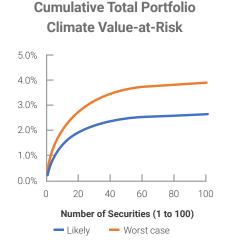
The portfolio used in this exercise holds no energy companies and therefore has minimal exposure to fossil fuel reserves. However, it is strongly exposed to traditional utilities companies, and consequently, to "brown" electricity generation. The graph below compares the energy generation mix of the portfolio against the SDS target mix for 2030 and 2050.



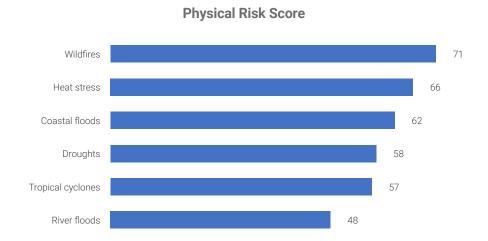
Physical Risk Analysis

The platform's physical risk analysis measures the potential financial impact of the six most costly natural climate hazards such as floods, droughts or wildfires on the value of the portfolio. The first metric used to assess physical risk is a portfolio-level climate value-at-risk. The chart below on the left highlights the potential impact on overall portfolio value in 2050 based on 2020 risk levels (Risk 2020) and hazards due to climate change (Climate Change) for two climate warming scenarios of the Intergovernmental Panel on Climate Change (IPCC) (most likely and worst-case scenarios), while the chart below on the right highlights the cumulative portfolio value-at-risk for the first 100 risk-iest securities (based on climate value-at-risk). A striking observation from these two charts is that nearly 80% of the climate value-at-risk of the portfolio can be attributed to just 30 securities.





The other metric used to quantify physical risk is a physical risk score. This physical risk score is impacted by the projected change in financial risk due to individual hazards in a likely warming scenario. A low (high) score implies a large (small) projected increase in physical risks. The figure below charts the weighted-average physical risk score for the six main natural hazards.



It should be noted that physical risk scores were unavailable for close to a quarter of the securities in the portfolio, most of which were in the utilities sector, since the underlying asset-level data base is still being scaled up.

Uses Cases

The platform offers a broad and deep look into potential climate risks, encompassing emissions analysis, alignment analysis, transition risk analysis and physical risk analysis. This information can be used in security selection, to get a better understanding of the climate risks faced by companies under consideration, as well as for portfolio construction, to lower or cap the portfolio's overall exposure to climate related risks. It can also be a useful tool for reporting purposes.

Conclusion and Suggestions

The platform was approachable, and the web interface was intuitive which made navigation straightforward. The platform included a data dictionary carefully describing the various data series which helped along with our exploration of the data at hand. Having the ability to download the data in spreadsheet-form was also extremely useful to further our understanding of the data and expand our analysis beyond the bounds of the platform. We did encounter minor online formatting issues and glitches that may have been due to browser compatibility. For example, highlighting a data column would occasionally display the wrong data definition. However, none of these issues prevented us from successfully using the platform.

In a future iteration of the platform, it would be interesting to see more ambitious climate alignment scenarios, such as such as net-zero emissions by 2050 (NZE2050). According to ISS ESG, this scenario is already on their product roadmap and should be available on the platform by the end of 2021. Lastly, many well-know indices and benchmarks are available in the screener portfolio of the platform, but without weights. Therefore, they cannot be use for portfolio benchmarking in the portfolio analysis section of the platform. ISS ESG acknowledged this limitation and advised that it will be discussed internally as to whether weighted indices will be included on the platform going forward.

Author:

Jean-Francois Fortin, Vice-President, TD Asset Management Inc.

Participant:

DNB Asset Management

Provider: Risk types covered by tool: ISS ESG Physical and transition risk

Introduction

As part of this UNEP FI-TCFD pilot project, DNB Asset Management (DNB AM) selected ISS ESG to conduct a trial of the ESG Carbon and Climate Impact solutions tool. The tool is intended to help investors to understand, measure, and act on climate-related risks across all asset classes by providing detailed analyses of Scope 1, 2 and 3 emissions, transition and physical risks, and climate scenario analysis. The trial was conducted on 10 of DNB AM's equity portfolios, all of which implement the DNB Standard for Responsible Investments. This is our investment policy which is intended to ensure that DNB does not contribute to the infringement of human or labour rights, corruption, serious environmental harm or other actions that could be regarded as unethical. It shall also ensure that assessments of risks and opportunities related to ESG (Environment, Social and Governance) factors are integrated in the investment management process. Several of the funds implement additional exclusion criteria, others have an additional sectoral focus, including those which focus on selecting companies providing solutions to climate and environmental issues faced throughout the world.

The tool contains the following components:

Data	Portfolio Analytics	Ratings
Carbon and Climate DataPotential Avoided Emissions Data	Carbon Footprint ReportClimate Impact Report	Carbon Risk RatingFund Rating

While the trial provided access to all components of the ISS' solution, we chose to focus on the Portfolio Climate Impact Report and the accompanying dataset to explore physical and transition risks, as well as the Climate Scenario Alignment across the selected DNB equity portfolios used in the trial.

Sectoral and geographical coverage

The tool allows for the assessment of both transitional risk and physical risk for the uploaded portfolios—with the production of a range of outputs in a single report. As part of the transitional risk assessment, the tool considers fossil fuel reserves and renewable energy assets contained within the portfolio. As part of the physical risk assessment, the tool provides an assessment of the potential financial implications of a range of climate hazards on the portfolio value. The analysis uses the median impact of the ensemble of models forced with the RCP 4.5 and RCP 8.5 scenarios. The RCP 4.5 is a "middle of the road" emission scenario (likely) while the RCP 8.5 is a high emission scenario (worst-case). The analysis is done for baseline year 2050 (median of 2025 through 2075). Several metrics are provided to offer insights on the physical risk exposure of individual issuers and the portfolio, namely Financial Risk metrics, Value at Risk, a Physical Risk Score and a Physical Risk Management Score.

Given we are based in Norway, as are many of our customers, we chose to analyze a number of our Norwegian and Nordic funds, to understand the potential transitional and physical risks faced. We also chose to assess several our fund products which focus on selecting companies providing solutions to climate and environmental issues faced throughout the world. These funds assessed include both actively and passively managed funds. Coverage of data for the funds assessed ranged between 76–100% of constituents.

Assessment process

The tool was straightforward to use, and available through the ISS DataDesk platform. After logging in, the following steps were undertaken to conduct the assessment:

- 1. Upload fund holdings into platform. For each of the holdings, the tool required information regarding the holding identifier, weight, and values of the holding.
- **2.** Ran 'Climate impact assessment' for the funds in question.
- **3.** Reviewed PDF report and the excel file of data factors produced by the tool.
- **4.** Also possible to assess the results in the online tool using the DataDesk screening function to deep dive into issuer level analysis of companies. This provided greater detail regarding the companies' commitments and performance relative to targets under different scenarios.

It was possible to undertake analysis using equity, fixed income or mixed portfolios, however for the purpose of the case study we only assessed equity portfolios.

Outputs and potential use case

As part of the Portfolio Climate Impact report, two outputs of the data are produced:

Climate Impact Assessment Report

This is intended to provide users with a straightforward overview of the information produced by the tool. The report includes a range of analyses and metrics across carbon emissions, transition risk, and physical risk (by risk type, sector, and company)—a few

select elements of the report are outlined below. Broadly the report provides an overall assessment of the potential performance of the fund with regards to climate, while also highlighting companies most at risk—this information could be fed into a company engagement process, and feature as part of investment decision making.

Alignment analysis

The report includes an analysis of the funds' alignment with the IEA Sustainable Development Scenario (SDS), Stated Policies Scenario (STEPS) and the Announced Pledges Scenario (APS), based on current and projected future emissions. Comparison is indicated as the percentage of assigned budget used by the portfolio and benchmark, as well as an indication in which year the fund will, based on the modelling, exceed the SDS budget along with the corresponding potential temperature increase associated with the fund (see table in graphic below). The results from this analysis across the funds assessed were within our expectations. For the example in the graphic below, given the focus of that fund on climate and environmental solutions, we would expect to see the fund not exceeding the SDS budget in 2040 or 2050. We anticipate that as more companies within the fund begin to set science-based emission reduction targets and begin to reduce emissions in line with these targets, that the budget overshoot will be lessened. At the same time, our experience with other approaches is that for companies providing products and services which lead to emission reductions, these reductions can be difficult to quantify and as a result are not sufficiently captured. This could also be a consideration here.

Portfolio and Benchmark Comparison to SDS Budget (Red=Overshoot)						
2021 2030 2040 2050						
Portfolio	-57.45%	-31.36%	-45.70%	+213.91%		
Benchmark	-14.41%	+15.05%	+92.74%	+166.23%		

2036

2.7°C

The portfolio exceeds its SDS budget in 2036

The portfolio is associated with a potential temperature increase of 2.7°C by 2050.

As part of this assessment, there is also a visualization of the Portfolio emissions pathway compared with the carbon budgets of the selected climate scenarios, this could be utilized as part of regular assessment of funds' holdings and climate related risks (both physical and transitional). This visual (and the underlying data) may prove useful with fund clients interested in the understanding the alignment/misalignment of their funds with different climate scenarios—and may be particularly relevant for fund managers with public commitments for net-zero or other science-based emission reduction targets. The assessment of the alignment could also be a KPI of interest to management/board, as it may provide an indication regarding the potential direction of travel for specific funds, different classes of funds, or all holdings. For the example below, the assessed fund in its current state is misaligned with the SDS scenario in 2050, while the fund's benchmark is also misaligned.

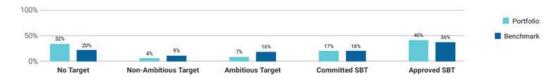
Portfolio Emission Pathway vs. Climate Scenarios Budget



Climate Targets Assessment

To reach the global climate goal set out by the Paris Agreement—to limit global warming to well below 2, preferably to 1.5 degrees Celsius—companies are widely being called upon to set public GHG emission reduction targets to ensure they are part of the solution. These targets should be public to ensure transparency and accountability of the companies' actions. A challenge faced as an investor when assessing companies' emission reduction targets relates to the comparability of and quality of the targets set. As we continue to focus on how companies position themselves and manage climate related risks, having insight into the targets being set is important.

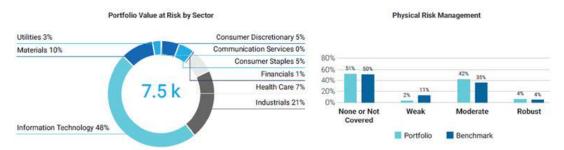
The Climate Targets Assessment provides a fund level overview on the targets companies within the fund are setting. The targets are placed in 5 categories: Approved SBT (Science-based target), Committed SBT, Ambitious Target, Non-Ambitious Target, and No Target—the chart below is then produced based on the weights of companies in the fund and can be compared with the benchmark (see below). This information is also available on the company level as part of the data file. As with the above analysis, the assessment of the targets could be a KPI of interest to management/board and may be particularly relevant for fund managers monitoring emission reduction targets of companies within their funds. This will likely be of increasing importance with increasing commitments to net zero, as well as from increasing disclosure requirements in the European Union including the Sustainable Finance Disclosure Regulation (SFDR).



Physical Climate Risk Analysis

The assessment of the physical climate risk is comprised of four elements, providing insight into the physical risks the fund is potentially exposed to, as well as an assessment into how the company is managing these risks. One output is included below, with the left chart providing a quantification of the value at risk by sector (under the RCP4.5 scenario), with Information Technology contributing 48% of the risk. The chart on the right provides a breakdown of the strength of the physical risk management approaches of companies

within the fund. We found these charts used together provides a clear overview of where the potential risks exist within the selected fund from a sectoral perspective, while also indicating the portion of companies in the fund managing these risks.



Underlying data via excel, API, FTP or data desk.

The underlying data for the companies included in the analysis is provided for the companies in the portfolio. The company specific data can be analyzed in the excel spreadsheet or on ISS' Data Desk, and it is also possible for the data to be delivered by API or FTP.

The data output allows direct integration into internal databases for further internal integration into the active ownership and investment processes, particularly when comparing companies to peers and the fund relative to the benchmark. Access to granular data provides the opportunity to deep dive into the potential performance of the companies under different scenarios. The metrics indicating a company's percentage of the carbon budget utilized under three climate scenarios presents an opportunity to assess a company's emissions trajectory and assess scenario alignment at a given point in time. The scenarios included are the Sustainable Development Scenario (SDS), the Stated Policy Scenario (STEPS), and the Announced Pledges Scenario (APS). When combined with other data points regarding targets provides a picture of a company's commitment to decarbonization, and the likelihood of achieving this. This could also be utilized as part of TCFD reporting regarding climate scenario analysis.

Overview and Future plans for tool

The opportunity to demo the tool provided some new and useful insights into the potential climate risk and impact of the selected funds. The tool was straightforward to use and produced the desired reports and data files without issue. The results from the analysis were broadly in line with our expectations. We observed for the funds where we place a greater emphasis on climate and the environment, were associated with temperature increases closer to 1.5 degrees and also lower potential exposure to physical risks, while funds with greater exposure to sectors or geographies with high emitting companies or sectors, were associated with higher temperatures.

The assessment of the carbon reduction targets for the companies in the fund and categorization of targets into SBT-committed/approved, and ambitious and non-ambitious targets, is greatly welcomed. This aspect of the analysis presented some unexpected results particularly when compared to benchmarks, namely that some funds were without. With the increasing focus on net zero both for companies and for investors, insights like this can help to provide focus for engagement and impact the selection decisions.

We provided feedback on suggested enhancements to the company directly, and ISS flagged several future developments expected in late 2021/early 2022. Including:

- Introduction of metrics related to the IEA's NZE2050 scenario as part of the development of their net-zero product. This will utilise the ISS climate data, as well as ISS' voting and engagement services.
- A transition Value at Risk will be launched which will reflect carbon pricing and sector growth risks.
- Update its current estimation approach on Scope 3 data and add reported and quality checked Scope 3 data to the existing dataset.
- Provide derived data in excel file for further use by asset managers in integration of the data in internal systems.
- Continued expansion of physical risk assessment, increasing the number of risks covered.

Participant:

TD Bank

Provider:

Moody's Analytics

Risk types covered by tool:

Physical and transition risk

Introduction

TD Bank Group (the "Bank") and Moody's Analytics worked together in a pilot project in March 2021 to explore an approach to quantifying climate change impacts on actual Bank borrowers and exposures held by the Bank. Moody's Analytics used its internally developed tools to evaluate the climate-related risks for a sample of the Bank's publicly traded Commercial & Industrial (C&I) and U.S. Commercial Real Estate (CRE) obligors under three representative Network for Greening the Financial System⁴ (NGFS) scenarios.

Overall, the Moody's Analytics models provided meaningful insights into how the Bank could approach incorporating climate risk into its credit assessments. It also highlighted the significant challenges associated with trying to quantify the impacts of a multi-dimensional scenario over a long-time horizon, including sensitivity to assumptions and model validation challenges. TD feels confident it can use the information from the pilot project to help the Bank move forward on its climate risk quantification and management journey.

Process and Data

The initial base for all scenario analysis for both the C&I and CRE models was a set of Moody's Analytics' proprietary macroeconomic scenarios that align with the NGFS scenarios. These scenarios reflect many of the chronic physical and transition risk impacts with variables including productivity metrics, energy demand, commodity, and carbon prices, as well as classic macroeconomic measures like government spending, employment by industry, incomes, and output.

C&I Credit Analysis

The C&I analysis estimated the individual and combined impacts of physical and transition risk on each individual borrower's propensity to default. Both physical and transition risks were estimated using Integrated Assessment Models (IAMs), which predict economic and climate outcomes for the underlying scenarios. For transition risk, the IAM was augmented to incorporate an oligopoly-based model of firm competition

⁴ A global group of 90 (as of April 2021) central banks and supervisors helping the financial sector address the risks of climate change and support the transition to a resilient economy: https://www.ngfs.net/en/page-som-maire/governance.

and price setting. These were then extrapolated into equity, asset volatility and liability impacts, customized by individual firm's carbon emission intensity and energy emission intensity to determine a Climate-adjusted Expected Default Frequency (EDF) and associated change to Borrower Risk Ratings (compared to the non-climate-adjusted model).

The model automatically sources the required data from either public source (i.e., corporate financials) or proprietary databases (i.e., firm-level physical climate risk scores⁵ and total carbon emissions). Where the required degree of granularity is not available, including for private entities⁶, proxies can be used. For TD's sample of 13 firms, one firm lacked a firm-specific physical climate risk score and a sovereign average was automatically used as a proxy. Similarly, two firms lacked carbon emissions data and industry averages were used.

CRE Credit Analysis

The CRE Climate-adjusted EDF model also sources proprietary physical climate risk data automatically, at very precise spatial granularity, focusing only on wildfire and flooding impacts for the TD CRE footprint. Those physical risk impacts are calibrated to historical losses for similar building types and locations. The remaining inputs are typical of any CRE credit model, principally including loan origination and maturity dates, loan rate and outstanding balance, property type, address, value, and net operating income.

Coverage

The intent of the pilot was to improve TD's understanding of the capabilities of Moody's Analytics climate risk models, as opposed to a sampling analysis of TD's entire credit portfolio.

The 13 public firm C&I borrowers evaluated in this pilot represented a very small fraction of TD's customers, but the sampled firms did span eight industries with headquarters in two countries (U.S. and Australia). The CRE sample of 55 properties represented less than 10% of the value of TD's global CRE portfolio, although they spanned 12 metropolitan areas in the U.S., five property types⁷, and had varying loan maturities, including some exceeding 10 years.

At the time of the pilot, the C&I Climate-adjusted EDF model accommodated only public firms, which could be located anywhere in the world, subject to the availability of appropriate macroeconomic scenarios. Climate-adjusted scenarios were then available only for the U.S., Canada, UK, and Western Europe.

⁵ These scores include acute and chronic physicals risks (wildfire, cyclone, inland flooding, heat stress, water stress, sea level rise) to all corporate facilities and operations, as well as to the firm's supply chain and markets.

⁶ Functionality also supports the inclusion user-supplied firm characteristics in order to enhance the analytical output for non-public entities.

⁷ Multifamily, Office, Retail, Industrial and Hotel.

The climate risk impact data used by the CRE Climate-adjusted EDF model are translations of specific physical risk (e.g., inland flooding) scores for each Metropolitan Statistical Area, and climate transition risk macroeconomic scenarios. When the pilot project was undertaken, coverage was limited to the U.S. data coverage for both the CRE and C&I EDF modeling approaches has since expanded significantly.⁸

Risk sources and scenarios

This pilot project examined the impact of climate risk on the EDFs of a sample of C&I borrowers and CRE loans. The key sources of risk included acute physical climate risks (wildfire, cyclone, flooding), chronic climate risks (sea level rise, heat stress and water stress), and transition risks stemming from political, economic, and technological drivers, with firm sensitivities driven by industrial subsector and current carbon emissions. For TD's specific CRE portfolio, only wildfire and inland flooding were considered since none of the properties were subject to cyclone risk.

The physical risk quantifications were provided by Moody's ESG Solutions, and reflect future potential temperatures based on Representative Concentration Pathway (RCP) 8.5. Transition risks were introduced through a consistent set of local macroeconomic scenarios that were fully aligned with the NGFS definitions of Orderly, Disorderly, and Hot House World scenarios.

While a great many parameters in these models can be specified or manipulated, this pilot project focused more on the differences within the loans and borrowers, and across the three primary NGFS scenarios.

Output

Both models produce term structures of EDFs, with annual granularity extending forward 10 years for the CRE loans and 30 years for the C&I borrowers. One such EDF term structure is produced for every loan or borrower, for each of the three NGFS scenarios. In addition, EDF term structures are also provided showing the pre-climate adjustment EDFs, and a "worst case" EDF (based on the 95th percentile highest temperature pathway). Expected loss figures are also produced for the CRE loans, where outstanding balances are available.

One summary view of the climate risk impacts is the overall change in implied ratings at a future point in time, and an example of this is shown in Exhibit 1 for TD's C&I portfolio. The physical climate risks to all these obligors produced implied rating deteriorations, while the transition impacts produced both risks and opportunities for various obligors. In only one case was the upside (transition) risks greater than the physical risk impacts, resulting in an overall projected implied rating improvement.

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Case studies

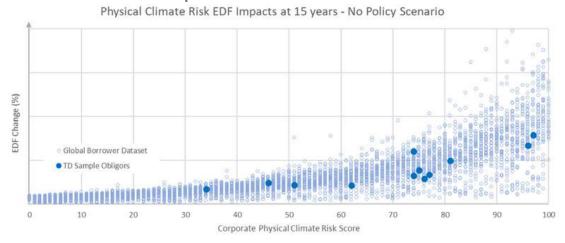
As of September 2021, physical climate risks scores and macroeconomic scenarios were available globally, and CRE translations were available for US, Canada, the UK and Western Europe. The C&I model coverage had also expanded to include private firms, globally.

Exhibit 1: Change in 10 Year Annualized EDF-Implied Rating for C&I Sample Set

Risk	Scenario	2 Notch Improve- ment	1 Notch Improve- ment	No Change	1 Notch Deterio- ration	2 Notch Deterio- ration	3+ Notch Deterio- ration
Combined	Early Policy		8%	23%	38%	15%	15%
	Late Policy			8%	54%	31%	8%
	No Policy			23%	46%	15%	15%
Physical	Early Policy				85%	15%	
	Late Policy				69%	31%	
	No Policy				77%	23%	
Transition	Early Policy		8%	54%	23%	8%	8%
	Late Policy		8%	77%	8%		8%
	No Policy	8%	15%	54%	8%		15%

While all the output is provided as digital flat files, a variety of automated sorting, filtering, aggregating and mapping functions were also used to better understand the C&I exposures. In addition, physical risk output can be compared to a much larger universe of borrowers to provide some perspective and relative sense of impact, as shown below in Exhibit 2.

Exhibit 2: TD Borrower Sample vs Global Dataset9



Landscape Review PaperCase studies

The graph plots TD's sample of 13 public firm C&I borrowers against the global dataset; only 12 points are shown in the graph due to an overlap of two of the TD Sample Obligors.

Insights gained

The relatively small fraction of TD's total portfolio that was analysed precludes drawing any conclusions about aggregate impacts to the Bank, but it did highlight the range of scenarios and parameters available, and the outputs and metrics that might be useful in the future. TD has made several observations about its exposure to various borrowers and loans during this pilot project, including:

- Many of the credit risk impacts, under all scenarios, were relatively small for both the CRE and C&I books, but some EDFs were projected to increase dramatically even looking forward only 7–10 years. This may indicate both the difficulty of using a top-down evaluation approach, and the opportunity to pinpoint individual loans and borrowers that have much higher exposures to climate risk.
- Where credit deterioration was projected for CRE loans, it was almost exclusively due to acute physical risks. In contrast, the impacts to the C&I portfolio being more mixed, with physical risk deteriorating credit quality somewhat broadly but transition risk causing significant EDF erosion for a subset of borrowers.
- In some cases, borrowers were projected to benefit from the anticipated economic transition, driving credit quality improvement. While this was broadly a function of the industry sector, it was also observed for firms whose earnings were derived from several industrial sub-sectors, highlighting the value of detailed earnings attributions. The clear articulation of winners and losers within industries and regions show the potential advantages of a more fulsome credit analysis, incorporating climate risk.
- The transition risk impacts become evident at the date of a policy announcement, driven by the resolution of the uncertainty in investor expectations. For some borrowers those dates markedly increased or decreased creditworthiness which pointed to the potential value of exploring alternative policy development timelines or expectations.
- More broadly, these insights may be useful in the future for portfolio risk analysis and stress testing, as well as individual borrower credit underwriting and loan structuring.

Usability

As TD continues to strategically build capabilities in climate risk analysis, understanding the nature, content and detail of the analytical results will be critical in developing that roadmap. This pilot provided good transparency into the current methodology and process and was a foundational step in the Bank's journey.

This pilot revealed that the differences across loans could be sufficiently large, at some date in the future, to warrant further attention, review or action. Quantification of such risks is growing increasingly important for several use cases, including pricing reviews, portfolio allocation, the potential for stress tests and disclosure requirements at some point. The Moody's Analytics models sourced the required data automatically, and were thus straightforward in terms of execution, though a more fulsome integration into existing credit applications has not yet been explored. Model outputs provided the detail necessary to "drill-down" and explore the drivers of individual results.

Ultimately TD's climate risk management process could provide key metrics for the executive team, and further enable the Bank to examine and guide the loan portfolios relative to the Bank's risk appetite. A key function of usability will be considerations regarding how to establish validation techniques beyond traditional credit risk models, noting TD has historically validated credit risk models against past performance metrics that may not be appropriate given the forward-looking nature of the analysis.

Suggested enhancements

Given the nascent nature of the industry, both Moody's Analytics and TD have identified areas to continue to enhance both the capabilities and the usability of the models.

Capability Considerations

- Expansion of CRE Physical Risk Model and translation data to global geographies, to fully cover the Bank's CRE portfolio.
- Inclusion of forecasted forward-looking physical frequency and damage assessments. The CRE model uses hypothetical scenarios at the user's discretion, however including expected changes would provide a meaningful baseline scenario.
- More granularity in key industries or data availability for private firms. Lending to publicly traded entities is a small subset of TD's overall commercial lending exposures; additional granularity is required (e.g., sub-industry emissions averages) to more meaningfully differentiate across borrowers within a given industry.
- Better flexibility regarding input scenarios. The fundamental basis of the Moody's Analytics' models is the NGSF scenarios and IAMs; the ability to alter assumptions would be useful, primarily to better isolate the impacts of individual assumptions.

Usability Considerations

- Model "validation" guidance—recognizing that traditional approaches to validating this credit model may not be effective, additional detail regarding how we can assess the appropriateness of the model is necessary to be comfortable the Bank is not introducing significant model risk.
- Integration with other internal or third-party platforms to minimize duplication of work efforts by credit analysts.
- TD worked directly with Moody's Analytics to generate the outputs, therefore there
 was limited ability to assess the user interface. However, further data exploration
 tools would be useful, including the ability to view portfolio wide metrics and impacts.
- Further documentation and training materials, recognizing that this would need to be used by individuals at the Bank that are not heavily involved in ESG or climate risk matters.

Participant:

A European Bank

Provider:

Moody's Analytics

Risk types covered by tool:

Physical and transition risk

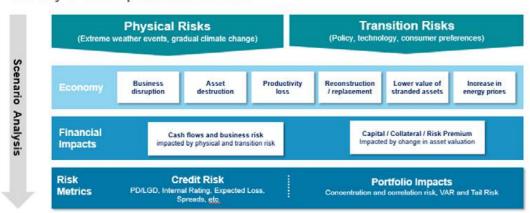
Introduction

Banks can be impacted by climate change in different business lines, overlapping opportunities and risks. Our Group is a global commercial financial institution with positions in Europe and South America. Our engagement in this pilot aimed at investigating leading practices on tools covering the physical and transition impacts of climate risk applied to some of our portfolios. This pilot provided us with a comprehensive view into how Moody's tool could be used to assess physical and transition risks and opportunities.

Process

Moody's tool offers a complete framework that spans across the overall risk management framework covering climate data analytics across both physical and transition risks, climate scenario analysis and stress testing, integration to credit risk modelling, and financial metrics and tools to support Climate-related financial disclosures.

Moody's conceptual framework



Moody's structural approach combined with ESG, transition risk, physical risk and macroeconomic analysis allows to:

- 1. define appropriate climate scenarios
- 2. link the climate scenarios to the climate risk impact channels
- 3. translate risk into financial and economic scenarios
- 4. estimate the climate adjusted risk metrics.

It can also leverage reference climate scenarios (such as the NGFS) as well as support the bank's vision based on the level of desired complexity, granularity in scenario analysis through its tailored approach.

Data inputs/Coverage

Moody's pilot analysis started with the assessment of a representative portfolio of our Group:

- **1.** Retail & Wholesale Real estate Collaterals in several geographies in Europe and South American countries: location specification
- 2. Corporate (listed) in Spain and Mexico: ISINs were sufficient to perform the complete climate credit risk analysis on the entities.
- **3.** Fixed Income & Equities Global (listed): ISINs were sufficient to perform the complete climate credit risk analysis on the entities.
- **4.** SME (Spain) and Corporate (private firms): Moody's assessed physical risk exposure based on location-specific inputs through its Climate on Demand real asset application. Bank also provided sector-level (granular NACE classification), baseline rating (PD) to analyse the climate adjusted credit risk metrics and financial analysis.

In summary, 6.870 ISINs of more than 3,000 listed entities were analysed in the sample. Moody's also conducted a full analysis on climate physical risks across 1 million collaterals in Spain, and in two South American geographies.

Risk factors and scenarios

The methodology assesses policy, market upstream, market downstream and technology risks associated with climate transition scenarios and includes physical risk exposure scores for listed entities with detailed analytics for six climate hazards (extreme rainfall and inland flooding, heat stress, water stress, hurricanes & typhoons, sea-level rise and wildfires) as well as an overall score and benchmark measures of supply chain risk and market risk.

The physical risk methodology leverages highly granular raw climate data from global climate models and applies them to a broad range of asset classes for listed companies, private equity, real estate, sovereigns, and sub-sovereigns.

On transition risk, Moody's provides emission profiles and energy transition risk scores for counterparties. The score provides an opinion on the quality of the company's management of risks and opportunities related to the transition to a low carbon economy and its capacity to reduce its future carbon footprint. These risks and opportunities are specific to each sector and the company's operations.

Moody's collects issuer's emissions data following the GHG protocol for all scopes. When emissions data is not publicly disclosed, Moody's estimates Scope 1 and Scope 2 emissions using its own proprietary models.

At the firm level, physical and transition risks are modelled by linking the climate scenarios to the key drivers of a Merton style structural model framework. Thus, each firm's

Earnings and Asset Values are considered to be affected by each scenario through information obtained by carbon footprint and transition risk assessment, as well as by the physical risk exposure scores.

Scenarios

Moody's tool can support Climate Change Scenario Analysis in line with reference practices, including and not limited to:

- Orderly/Immediate 2C with CDR (Carbon Dioxide Removal), Emission peak year as 2025, net-zero-year 2050 CO₂ only
- Disorderly/Delayed 2°C with limited CDR, Emission peak year as 2030, net-zero year 2060 CO₂ only
- Hot House/No additional policy, Emissions continue to rise till 2100
- **Alternative scenarios** on physical risk via 1.5°C (with 66% probability)—NGFS Immediate 1.5 with CDR, IPCC RCP2.6, 4.5, 6 and 8.5.

In addition, physical risk scenarios can be provided by either **directly specifying a path** of global expected economic damage from physical risk or specifying an emissions path from an IAM or other assumptions.

Moody's is committed to updating reference scenarios (like NGFS) in its solutions as they become available.

Time horizons: 30-year time horizon considered whilst there is full flexibility to change it, such as nearer-term or longer-term to 2100.

Outputs and Insights

The analysis results were provided at firm/asset level (output for the retail portfolio is based on mortgage collateral location and SME production site location) and the bottom-up methodology captures firm/asset specific factors to differentiate across sectors, countries, specific location of facilities/supply chains/market context and emission profiles (Scope 1+2 and forward-looking) of counterparties. The same methodology is applied for the SME and private firm universe, depending on the data inputs provided.

A short summary of outputs that were provided for the bank Fixed Income, Corporate & Private Firm portfolios, where possible:

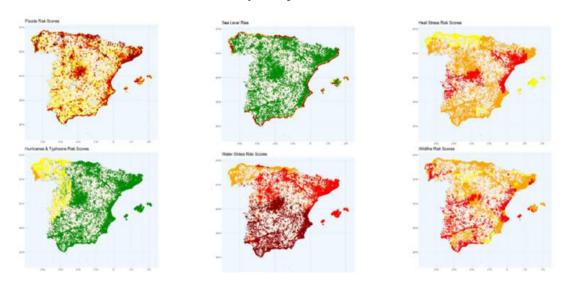
- Probability of Default (EDFTM)—Expected Default Frequency- change (due to climate risk), Probability of Default (climate risk-adjusted)
- Credit Rating change (due to climate risk), Credit Rating (climate risk-adjusted)
- EBITDA change (due to climate risk) where Moody's use Free Cash Flow to the Firm as a measure of earnings, EBITDA (climate risk-adjusted)
- Expected value (e.g. mean estimate—high probability, estimated impact)
- Extreme value (e.g. tail estimates—low probability, high impact)

Moody's provided a set of climate risk assessments for physical risk and transition risk and trial access to its Climate on Demand application for real assets where our Group was able to analyse at granularity the physical risk exposure against key hazards. In

addition, Moody's also conducted a full analysis on climate physical risks across more than 1 million collaterals in Spain, and some thousands in South American geographies during the pilot and provided results.

Insights:

Collaterals (retail & wholesale): 2040 physical risks results based on the RCP 8.5 scenario for 1 million collaterals in Spain by climate hazard:



A similar analysis was conducted in some South American countries (where the largest mortgage exposure is concentrated). The climate hazards exposure differs in each region. For example, hurricane and typhoon risk is not relevant in Spain, but it is significant in some countries of South America.

Suggested enhancements for the provider

Overall, our Group was satisfied with Moody's tool and Moody's team. The demo was effective at demonstrating the climate risk analysis capabilities of Moody's tool for several asset types. The tool is easy to understand, and the methodology document and overview provided were very helpful.

We have developed a wish list of enhancements related to data, scenarios and methodology that could be advisable:

- The physical risk scoring model is limited to the 2040 time-period and the RCP8.5 scenario. It would be useful to be able to compare results with the baseline and other time periods, as well as other IPCC warming scenarios in the long term.
- While there are some sensitivity/mitigating factors implemented for some types of assets, there is room for improvements to be able to customize other adjustment factors in the physical risk scoring.
 - The methodology used for the assessment of wildfire risk by Moody's tool is very much designed for large rural areas (low resolution 25x25 km), extrapolating the

- most common type of vegetation to all the area, and does not take into account other factors such as urban infrastructure and vulnerability by sector. These limitations should be taken into account when assessing the results (which could be overestimated in some cases).
- Sensitivity factors based on the asset types or industry activity of the asset (such as collaterals) or clients (such as corporates or SMEs) are not taken into account, aside from some sensitivity adjustments based on activity for real assets. It does not consider the resilience/sensitivity of clients based on their production activity (not only sector), supply chain characteristics, and initiatives aimed at mitigating physical risks.
- Regarding how transition and physical risk impact the risk parameters such as PD and LGD for the mortgage portfolio, there was a limitation of local historical data in certain geographies. In addition to the NGFS scenarios and existing methodologies, extensive preparation is needed to develop tailored models for each geography (such as the ones created for the USA and UK). This effort was left out of the scope of this pilot.

In general, we also believe transparency when accessing internal parameterisation and scoring rules should be a priority for future developments, for Moody's tool and for any other platform.

Due to time constraints, our Group did not access the broader suite of Moody's solutions, and there are some aspects of the tool that couldn't be tested, such as the Moody's ESG Score predictor which expands climate profiling coverage to the uncovered universe, e.g. SME credit, on-demand scoring to address further any geocoding issues (transforming postal addresses to coordinates), the outcome visualization within the tool (heatmaps, geographical distributions, PD impacts, etc), or the potential data connection required to connect internal financial data with the results.

Note that these studies were conducted pre-acquisition of RMS by Moody's Analytics, which expands the depth and breadth of physical risk capabilities (direct/indirect risk (cost) factors, scenario sets and time spans and impact analysis across broader asset classes) that joint firms can today provide.

Participant:

Intesa Sanpaolo

Provider:

Risk Management Solutions, Inc. (RMS)

Risk types covered by tool: Physical risk

Introduction

As part of the UNEP-FI TCFD pilot program, Intesa Sanpaolo selected Risk Management Solutions, Inc. (RMS®) as the supplier to participate in the case study.

The RMS climate conditioned catastrophe risk models were used in order to quantify the flood risk related to a small sample of the Intesa Sanpaolo Italian mortgage portfolio. ¹⁰ In particular, the RMS climate change Europe Inland Flood HD Models were used in this case study considering the Region interested and the type of risk.

The results of the analysis show losses at sample portfolio level comparing today's risk to 2040 using RCP 6.0 and RCP 8.5 scenarios and related province level estimates.¹¹

Differences in the "climate-adjusted" Probability of Default (PD) and Loss Given Default (LGD) are also provided with different return period losses.

Flood risk methodological framework

The RMS modelling framework consists of five key modules, which are detailed below:

■ **Stochastic:** the stochastic module contains thousands of simulated events for a given peril. For example, the Europe Inland Flood HD Models' stochastic event set stem from a continuous simulation of precipitation and all subsequent hydrological processes over a period of 50,000 years. These events have been created to represent the full range of possible flood extents and severities, both from pluvial and fluvial flooding, that can impact Europe;

The RMS methodology is commonly used by governments, financial institutions and their corporate clients to manage their exposure to extreme events and has over 200 peril models in nearly 100 countries enabling organizations to quantify the potential magnitude and probability of economic loss from catastrophe events (from earthquakes and hurricanes to flood and wildfire). A combination of science, technology, engineering knowledge, and statistical data is used to simulate the impacts of natural and man-made perils in terms of damage and loss.

¹¹ Province level coincides with the NUTS 3 classification (Nomenclature of statistical territorial units of the EU).

- **Hazard:** the hazard module determines the flood extent and severity for each event in the stochastic set. It simulates each precipitation event and determines how these are translated into flooding in space and time considering all relevant processes, such as topography, hydrology, built-up areas, antecedent conditions, to just name a few. Flood hazard is expressed by the extent and flood depths of each flood event;
- **Exposure:** exposure is information about the assets at risk in a given study area. This information is captured in an exposure database. The exposure database contains information on the type, location, value and additional characteristics of each property asset. During the modeling process, the locations of exposed assets are overlaid with the hazard footprint of each stochastic event to determine the severity of the hazard each asset is subjected to;
- Vulnerability: vulnerability is the relationship between hazard (e.g. flood height) and damage (e.g. 30% of a building structure damaged). The vulnerability of an asset is dependent on its physical attributes, and can vary by peril (e.g., flood, extreme winds). The models store vulnerability information for thousands of asset types in the form of vulnerability curves, which link hazard values to damages;
- Financial: the hazard experienced at an asset location is linked to damage to that asset in the vulnerability module. The financial loss from this damage is then calculated (for each stochastic event and for each asset) using the financial module. Losses are then aggregated across all assets included in the analysis, taking into account any applicable protections (physical or financial) which may be in place or under consideration.

It follows that catastrophe models can be used to deliver insights into how frequently a location is to be impacted by different hazard levels. For example, they can be used to determine how frequently a given location can be expected to be impacted by flooding in excess of 6ft, or other thresholds of interest. These insights can then be used to inform decisions such as top elevations for new seawalls, or road elevation standards for new infrastructure developments.

When used in combination with the exposure, vulnerability and financial module, the model can additionally assess the frequency and severity of the economic impact caused by a specific peril, such as flooding.

This impact is quantified by subjecting the location, its associated vulnerability and financial value of exposed assets to the corresponding hazard severity for each simulated event. This economic impact analysis is particularly useful to objectively compare levels of potential loss to financial assets at different levels of likelihood.¹²

¹² As mentioned, the RMS Europe Inland Flood HD Climate Change Models were utilized to quantify the impacts of climate change under different potential future states. This climate change model framework allows a selection between four different Representative Concentration Pathways (RCPs), as defined by the IPCC (https://www.ipcc.ch/), at five-year intervals until the year 2100 to understand the physical risk of climate change in the portfolio.

Data and coverage

The case study was made on a limited sample of the Intesa Sanpaolo mortgage portfolio in Italian locations with the aim to estimate the related flood risk.

A sample consisting of 1,200 positions within the Intesa Sanpaolo mortgage portfolio (0.27% of the mortgage portfolio) was selected for this case study. The total value of the collateral to which these positions refer, is equal to a total of \leqslant 680 Mn (0.15% of the collateralized portfolio) and 85 out of 110 Italian provinces (NUTS 3 level classification) are represented. The key information of the sample is represented below.

Risk drivers' composition of the selected sample (sorted by Probability of Defaults)

Positions sorted by PDs	Average PD	Average LGD
PD <= 0.1%	0.04%	4.98%
0.1% < PD <= 0.5%	0.24%	10.50%
0.5% < PD <= 1%	0.68%	10.56%
1% < PD <= 3%	1.75%	10.67%
PD > 3%	6.25%	12.86%

Italian provinces included in the sample (in red)

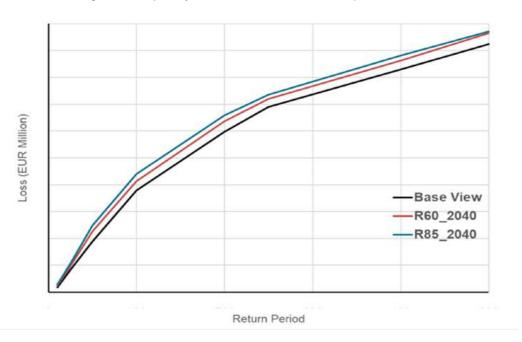


Risk factors, scenarios and outputs

The RMS model was applied to both the RCP 6.0 and the RCP 8.5 scenarios, considering 2040 as the reference year for the projections. The application of the model resulted in the definition of a haircut on the value of the collateral with a proportional increase in the expected LGD. The graphs and tables below show the effect of the model assumptions in relation to an inertial baseline view and two commonly used climate projections (RCP 6.0 and RCP 8.5) considered in terms of impact on:

- 1. the probability curves related to the gross value loss caused by the event damages and in relation to different return periods;
- **2.** the average return period annual losses, reported in percentage changes with respect to the baseline view, in the most important Italian provinces.

Portfolio Probability Curves (Sample Portfolio Gross Losses)



Average Return Period Annual Losses (most populated Provinces)

Province	Average Annual Loss (% vs Baseline) Change R85_2040
Rome	Over 50%
Milan	Under 20%
Naples	Over 50%
Turin	Under 20%

Based on the analysis, Intesa Sanpaolo calculated the impact on Loss Given Default (LGD) and the effect on the Probability of Default (PD) was deduced by exploiting the relationship between PDs and LGDs (following the approach proposed by J. Frye and M. Jacobs Jr., 2012 [1]).

The underlying general premise behind the Frye-Jacobs model is that LGD is an increasing function of default rate, and consequently of the PD, which essentially means that if the default rate increases, the LGD also increases approximately in a similar proportion and vice versa.

Once all steps were performed, the LGDs and PDs implied in the different stress scenarios were estimated for all counterparties of the given sample. The following table summarizes the results taking into account the initial risk drivers' composition of the borrowers, in terms of PDs, and a return period equals to 1 on 500 years losses (for 2040 under RCP 8.5) as a worst scenario. The impacts on PDs and LGDs are substantial and vary from 4% to 39% with respect to the initial values.

Main impacts of scenarios analysis on the mortgage sample selected (sorted by Probability of Defaults)

Positions sorted by PDs	Initial Average PD	Stressed PD	Initial Average LGD	Stressed LGD	Stressed PD (x-times)	Stressed LGD (x-times)
PD <= 0.1%	0.04%	0.05%	4.98%	5.63%	1.19x	1.13x
0.1% < PD <= 0.5%	0.24%	0.30%	10.50%	14.64%	1.23x	1.39x
0.5% < PD <= 1%	0.68%	0.85%	10.56%	12.22%	1.25x	1.16x
1% < PD <= 3%	1.75%	1.92%	10.67%	11.54%	1.09x	1.08x
PD > 3%	6.25%	6.53%	12.86%	14.09%	1.04x	1.10x

Final considerations and suggested enhancements

Regarding the relationship between climate scenarios and credit methodologies, it is certainly true that this tool represents a useful opportunity for understanding the impact of flood risk (especially after the recent ECB Guide on climate and environmental risks, 2020 [2]).

Nevertheless, there is a potential for further enhancements for assessing the risks related to the mortgage portfolio.¹³ Below some key points and general considerations:

1. a sample of the mortgage portfolio deemed sufficiently significant in terms of territorial diffusion, collateral values, duration of the loan to provide an acceptable output for the application of the model was chosen. The results appear to be quite satisfactory, despite the need to verify their consistency by expanding the scope of application;

¹³ RMS is working on methodologies to integrate damage and loss output from RMS cat models with Moody's credit models

- **2.** although collateral properties are identified by the physical address of the building, it has not always been easy to bring them back to NUT 3 level;
- **3.** the choice of the correct time horizon for the risk models used should be consistent with the long term strategies of the institution and in line with the reallocation portfolio decisions;
- 4. in this preliminary phase, the most direct way to define a correlation between the results of the model and the credit parameters was to evaluate the impact in terms of LGD and, through the relationship between PD and LGD (Frye-Jacobs approach), obtain an impact also in terms of PD. Although the results showed a good level of rationality, further refinements should be developed;
- this case study primarily focused on acute physical risk from climate change. The analysis should be enhanced by considering other issues such as the energy efficiency certificates (EPC) that characterize every single collateral and the related impact on PD, the possible macroeconomic effects deriving from an indirect effect of a natural catastrophe (e.g., the unemployment rate) and the possible mitigation effects deriving from the presence of specific insurance policies at each counterparty level.

The proposed approach should therefore be considered as an attempt to assess the potential impact on the mortgage portfolios of the flood risk in Italy from the point of view of the financial system, to be refined time by time with the new methodologies and enrichment of data that will gradually become available.

References

[1] J. Frye, M. Jacobs Jr., Credit loss and systematic loss given default, The Journal of Credit Risk Vol 8, 1–32, Spring 2012

[2] European Central Bank, Guide on climate-related and environmental risks—Supervisory expectations relating to risk management and disclosure, November 2020

RMS is a trademark of Risk Management Solutions, Inc.

Participant:

Banorte Financial Group

Provider:

Risk Management Solutions (RMS)

Risk types covered by tool: Physical Risk

Introduction

Banorte is participating in the third phase of the TCFD-UNEP FI 2021 program for banks, in which we involved various business areas (including risk, credit, specialized areas, sustainability, insurance, and innovation) in developing capabilities to identify, manage, and disclose climate-related risks and opportunities. To better understand and assess climate and physical risks to our portfolios, Banorte began by focusing on our loan portfolio. This was an introductory study to establish a baseline view of risk. The intent of the study was to explore using RMS models to better understand Banorte's exposure to climate and environmental risks. RMS models have the ability to show the baseline risk and climate change risk from hurricane, and as a next step, we will explore opportunities to examine future climate change risk against our baseline. We chose RMS™ from amongst several suppliers to participate in a demo that focused on the physical risk of real assets from our clients across all territories in which Banorte has provided a credit.

RMS is a very well-known provider of physical risk evaluation solutions. The company has performed several assessments for the insurance and reinsurance industry in Mexico. In fact, one of the reasons we chose RMS is because the company has been evaluating our region for more than 20 years. The RMS demo focused on sectors such as metal and mineral processing, business services, agriculture, and manufacturing of cement, lime, and plaster. The demo covered our Commercial Bank Loan book, which represents 10% of our portfolio.

Because we did not have the exact location and detailed characteristics of the facilities and assets included in the exercise, we gave RMS only the ZIP code, city, and state as an approximation to the location, the asset amount, and the sector. RMS performed its analysis based on this data.

Process

RMS consulting ran all of the model and communicated to us how their model would work. Once we had agreed on the data that RMS required to run the Banorte portfolio, we worked internally to team up with different areas of our loan department.

Our loan department and our insurance subsidiary helped us find the information we needed. We realized that our insurance subsidiary had the exact location of the clients we chose for the analysis, because all loans must be protected by an insurance policy. This significantly expedited data collection. The greatest challenge we had been facing was related to overcoming internal legal requirements so that we could share information with providers' and customers' exact geolocation.

Data and coverage

During the analysis, RMS requested data from our clients to load into their platform. Our clients provided this data via a spreadsheet that shared their sector, location, and total assets. To increase the granularity of the analysis, our clients also provided their ZIP codes.

Table 1: Data showed by RMS using their platform.

Top 10 locations by Asset Value					
Loc num	State	City	Postode	Occupancy	TIV
57842	Guanajuato	El Liano	36390	Metal & Minerals processing	2,587,000,000
57853	Jalisco	Marina Vallarta	48335	Business Services	2,504,000,000
57844	Distrito Federal	Polanco II Sección	11530	Metal & Minerals processing	2,177,000,000
57846	Distrito Federal	Moctezuma Segunda Sección	15530	Business Services	1,697,000,000
57835	Tamaulipas	Roma	89350	Metal & Minerals processing	1,371,000,000
57856	Quintana Roo	Tulum	77760	Agriculture	1,230,000,000
57840	Sinaloa	Bachigualato	80130	Agriculture	1,060,000,000
57855	Nuevo León	Pedregal de Escobedo	66061	Agriculture	700,000,000
57847	Distrito Federal	Sector Naval	2080	Business Services	631,000,000
57839	Puebla	Guadalupe	74126	Metal & Minerals processing	509,000,000

Table 2: Example of information provided on Banorte's behalf.

State & Sector	Zip Code	Total Assets USD*
Baja California Sur		
Hotels and similar accommodation	23403	140
Nuevo Laredo		
Hospital activities	87120	302
Manufacture of cement, lime and plaster	89350	1371
Mining and quarrying n.e.c.	89606	12
Rental and operating of own or leased real estate	89000	64
Waste collection	87080	303

	RMS
Internal	 Sector Location Total assets

Because Banorte only has operations in Mexico, our assessment focused on specific locations within the country. We shared data of 25 clients representing 10 percent of our portfolio and have commercial activities in the following sectors:

- 1. Hotels and similar accommodation
- 2. Hospital activities
- 3. Cement manufacturing
- 4. Lime and plaster
- **5.** Mining and quarrying.
- **6.** Rental and operation of own or leased real estate
- **7.** Waste collection
- **8.** Growing of perennial crops
- 9. Structural metal manufacturing
- 10. Motor vehicle manufacturing
- 11. Electric motor manufacturing
- **12.** Generators
- **13.** Electricity distribution and control
- **14.** Monetary intermediation
- **15.** Office administrative and support
- **16.** Real estate activities on a fee or contract basis
- **17.** Architecture and engineering
- **18.** Office administrative and support
- **19.** Meat processing and preserving.

Number of companies: 25

Total: \$1.6 billions

GEOGRAPHY



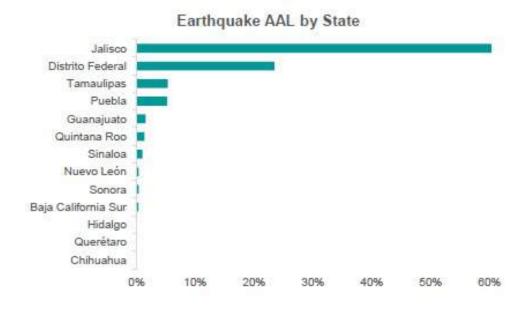
Risk factors and scenarios

RMS provided us with an analysis that focused on physical hazards such as windstorms and earthquakes. This analysis used the following assumptions:

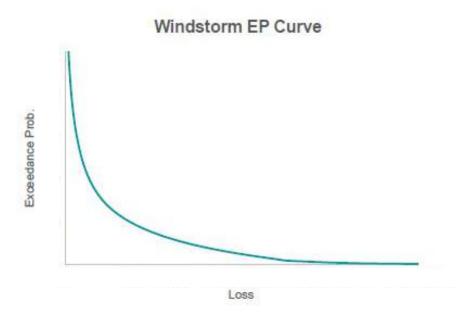
- Asset value is building only.
- Construction class, year built, and number of stories: unknown (based on inventory database in the model).
- RMS has construction assumptions included in their model data.
- Temperature pathway(s) analyzed: none. It was an exercise with current climate conditions.
- Scenarios used (NGFS, IEA, etc.)
 Because this was an exercise with current climate conditions, the scenarios were based on three situations:
 - **1.** Baseline current physical building risks (what is used today for insurance)
 - Earthquake and windstorm
 - 25 locations

Earthquake results:

Loss By Geography



Windstorm

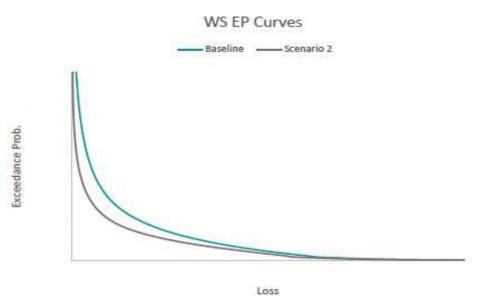


- 2. Borrow equity captures exposed risk to bank
 - Made assumption to show how one could model LTV
 - Used a 10% LTV assumption
 - Shows loss amounts after 10% borrower equity is considered

Results:



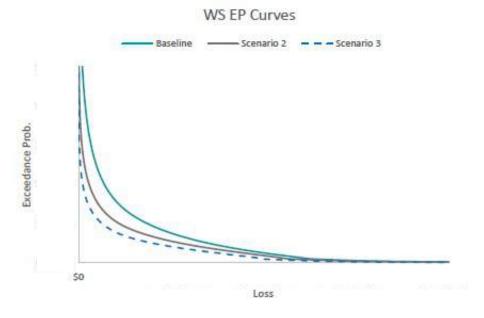
Windstorm



- 3. Insurance modeling projects losses after insurance is applied
 - Assumed that insurance limit is 10% of each property value
 - Modeled net losses to bank after borrower equity and insurance is considered

Results:





Summary of Windstorm Exceedance Probability Loss Results with % Scenario Change

Exceedance Probability	Return Period	Baseline	Scenario 2	Scenario 3
0.00%	50,000	\$2bn+	-6.70%	-14.59%
0.01%	10,000	\$2bn+	-6.12%	-14.60%
0.02%	5,000	\$1.5bn-\$1,99bn	-6.75%	-16.07%
0.10%	1,000	\$1,000-\$1.49bn	-9.90%	-20.39%
0.20%	500	\$1bn-\$1.49bn	-10.26%	-22.55%
0.40%	250	\$500M-\$999M	-17.22%	-35.85%
0.50%	200	\$500M-\$999M	-21.64%	-42.98%
1%	100	\$200M-\$499M	-41.35%	-65.88%
2%	50	\$0-\$199M	-59.59%	-84.25%
4%	25	\$0-\$199M	-84.89%	-98.13%

The outputs generated form RMS included Loss Outputs on each scenario they provided and the following metrics:

EP (Exceedance Probability): Probability that the single largest event loss in a year will exceed a loss threshold.

Return Period: Refers to a point on a loss curve (for example, an occurrence exceedance probability or aggregate exceedance probability curve) that describes the likelihood of exceeding a loss threshold from the single largest event (OEP) or the aggregation of one or more events (AEP). It is defined as the inverse of the annual exceedance probability. For example, a return period of 100 years corresponds to an annual exceedance probability of 1.

AAL (Average Annual Loss): Sometimes called Pure Premium or Burn Cost, AAL is the expected value of the modeled loss distribution. It is the average loss one would expect to see in a year. The actual annual losses will fluctuate around the AAL in any given year. AAL does not include expenses, non-modeled loss, profit, or risk load.

RMS can assess physical risk under actual conditions. They are working on a model to incorporate climate change to simulate future possible conditions. It would be possible to run climate change views for hurricane risk using any of the above scenario perspectives (specifically Hurricane).

- We believe that using this type of analysis helps us to assess physical risk under actual conditions.
- RMS displays clients graphically, exposing the distribution of assets by geolocation, exposure, and sector.
- Within the results of the model, RMS shows which states of our republic have the greatest risk of loss for hurricane and earthquake.
- Results could be displayed per client to see how different scenarios affect them individually.

Suggested enhancements for providers

How easy was the tool to use?

It was easy to gather the information for the exercise because RMS told us we could use an approximation of the geolocation. They only needed three indicators: sector, location (ZIP code), and total assets.

Do you have any modifications or suggestions that would enhance your analysis?

Because we did not provide details of the assets evaluated by RMS, they used some assumptions to perform the analysis:

Asset value is building only construction class, year built, and number of stories: unknown (based on inventory database in the model)

RMS includes construction assumptions in their model data.

For the reasons already explained, having more details of the assets we gave RMS would have resulted in a more refined analysis.

What are the areas you would like to see the providers explore in the future?

This study did not include running RMS climate change catastrophe models. In the next phase, RMS will have the opportunity to demonstrate the capabilities of their climate change catastrophe models with detailed exposure data as part of the analysis. It would be important to see the recent capabilities they have developed around climate change. This new feature was just being finished at the time we needed to get the results to comply with the TCFD deadlines. We would like to explore it and we agreed on a demo because the new feature assesses:

- Mexico Windstorm baseline vs. RMS climate change views.
- RMS climate change views based on four RCP scenarios (2.6, 4.5, 6.0, 8.5) and/or a 2o C increase.
- Loss estimates from 5 to 80 years forward (in 5-year increments). Example output shows 2030 and 2050.

RMS is a trademarks of Risk Management Solutions, Inc.

Participant:

BMO Financial Group

Provider:

Oliver Wyman/S&P Global Market Intellgence

Risk types covered by tool: Transition Risk

Introduction

As part of the Landscape Review exercise, BMO Financial Group worked with Oliver Wyman and S&P Global Market Intelligence to demo Climate Credit Analytics, a climate scenario analysis and credit analytics model suite. Climate Credit Analytics is a turnkey solution that enables bottom-up analysis of five high carbon-emitting sectors (oil and gas, metals and mining, power generation, airlines and automotive) as well as a generalized approach for all other sectors. For the purposes of the demo, the Bank focused on the metals and mining sector.

The scenario analysis tool is used to assess the credit risks associated with the transition to a low carbon economy. Climate Credit Analytics assesses the credit rating impact of climate scenarios on a counterparty or portfolio level by calculating climate adjusted financial statements. The tool leverages S&P Global Market Intelligence's data resources, including financial and industry-specific data, credit scoring methodologies and Trucost environmental data. This is combined with Oliver Wyman's climate scenario and stress-testing expertise.

Process

Climate Credit Analytics can be accessed through two interfaces: an Excel version or an Application Programming Interface (API) version.

To generate results through Climate Credit Analytics, the user follows a few simple steps:

- Search or upload portfolio companies in Climate Credit Analytics
 - Tool automatically populates required financial and environmental data
- Select scenarios to run and interval period of results (either at 5-year intervals or annually)
- Select the S&P Global rating model that will be used to re-rate the companies
 - Internal rating model can also be used
- Adjust or override model parameters, if desired
 - The parameters available to adjust range from financial parameters (e.g. level of dividends paid, leverage ratio) to sector-specific parameters and scenario variables

- Run the model
 - Results presented in two ways:
 - Single entity view: focuses on a single company, showing the evolution of the financial statements and the rating and probability of default changes
 - Batch view: gives the full financial statement and rating results for all counterparties selected to run in the model to allow for further portfolio analysis internally by the user

The model translates climate scenario and sector-specific supply and demand elasticities and market dynamics into drivers of financial performance to provide financial statement forecast, impact on credit score and probability of default. Core metals and mining assumptions include:

- **Price:** as demand for coal decreases prices will likely fall, while other minerals see an increase in price as the scenario emissions costs are passed through to consumers
- **Volume:** demand for coal falls in the transition while demand for energy transition minerals increases with electrification/ EV adoption. Other minerals grow with the economy
- **Unit cost**: mining production costs increase due to the carbon price and emissions intensity of production for each mineral
- Capital expenditure: coal capex is expected to decrease along with demand as high cost mines close, while increasing for other minerals to meet rising production levels

Based on this information, the model calculates scenario adjusted financial statements (e.g., income statement, balance sheet and cash flow statement). It then links the scenario-adjusted financial statements to S&P's credit rating model to calculate scenario-adjusted credit scores, or ratings. The user can also link the scenario-adjusted financials to internal risk rating models.

Data

A sample of North American and European publicly traded metals and mining counterparties was assessed. The data required for the analysis is included in the Climate Credit Analytics tool. Climate Credit Analytics covers 1.6 million public and private companies across all geographies. If a company is not included in the S&P Global dataset, the user can upload the required data via the API.

Climate Credit Analytics segments metals and mining production into three categories: fossil fuel minerals, energy transition minerals and other minerals and models the impact related to demand and emissions. Fossil fuel minerals include thermal/steam coals used for electricity generation and metallurgical coal used in steel making. Energy transition minerals are critical to electrical vehicle battery production and include lithium, cobalt, nickel, manganese and copper. Other minerals include iron, silver, uranium, aluminium, zinc, gold, molybdenum, diamonds, lead, platinum/PGM and titanium.

Risk factors and scenarios

Climate Credit Analytics enables analysis of climate transition reference scenarios published by the Network for Greening the Financial System (NGFS). NGFS scenarios extend to 2050 and are loaded in the model. These scenarios cover temperature pathways ranging from 1.5°C to 3°C+ and have over 1700 sector specific and macro variables, e.g., GDP. Credit risk can also be analysed under a global carbon tax scheme that is enacted over a three-year period (e.g., 2020–2022). Users also have the option to run customized scenarios.

The key transition risk factors explored in the demo were technology and carbon pricing. The following NGFS transition scenarios were assessed:

- Immediate 2°C with carbon dioxide removal (CDR) technologies
- Immediate 1.5°C with limited CDR. Limited CDR scenarios require larger reductions in fossil fuel use as CDR technology cannot be relied on

Outputs and insights

Climate Credit Analytics generates full scenario-adjusted financial statements (Income Statement, Balance Sheet, Cash Flow Statement) at a counterparty level on an annual basis. The model also generates climate adjusted credit ratings and probabilities of default using an embedded rating model from S&P Global. Counterparty level outputs can then be aggregated at a portfolio level.

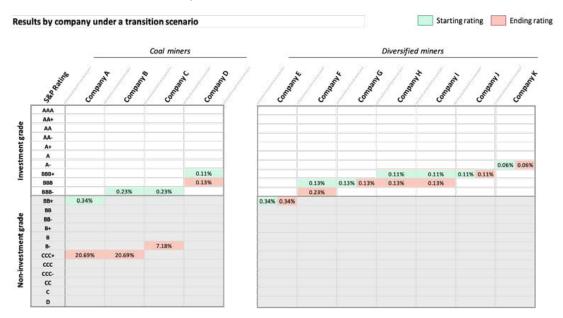
Immediate 2°C, with CDR

- Diversified miners are expected to maintain profitability as losses in coal are offset by growth in other minerals, e.g., energy transition and other minerals
- As the demand for transition minerals increases, profitability should grow for companies with no coal production
- The average rating impact for the sample of counterparties was limited. This is attributed to nature of the companies included in the sample

Immediate 1.5°C, limited CDR

- Diversified miners are expected to maintain profitability due to growth of non-coal minerals provided they have sufficient profit margins
- Margins expected to shrink for companies with no coal production as growth in volume of transition and other minerals is counteracted by increased unit costs of emissions for mining these minerals, however they should remain profitable provided they have sufficient starting margins
- The average rating impact for the sample of counterparties was limited. This is attributed to nature of the companies included in the sample

The following illustrates how counterparty ratings can change under a transition scenario. Note the results depicted do not reflect demo results.



Demo results are consistent with what we would expect, namely that diversified companies are better positioned to navigate transition risk. The ratings impact is aligned with exploratory analysis that we have conducted internally on the same sample of counterparties. Climate Credit Analytics outputs can inform discussions on transition risk implications.

Climate Credit Analytics is user friendly and easy to navigate and results are generated quickly. It automatically populates the necessary input data for analysis which saves significant time and effort in sourcing data. The integration of NGFS and carbon scenarios in the model and the ability to customize scenario parameters further contributes to the ease of use.

Participant:

Desjardins Group

Provider:

The Climate Service (TCS)

Risk types covered by tool:

Physical and transition risk

Introduction

As part of the UNEP FI TCFD pilot programme, Desjardins selected The Climate Service (TCS) as one of its preferred potential suppliers to participate in a demo. The Climanomics® platform of TCS provides screening-level climate risk analysis and enables users to identify physical and transition risks across their portfolio of real assets. Desjardins provided a sample of 50 real assets from different sectors (residential, industrial, and corporate) to upload into the platform and interpret results. The platform models absolute climate risk (\$M) and relative climate risk (%), reported as percent of asset value. Overall, the sample provided by Desjardins faces the highest physical risk from fluvial flooding and the highest transition risk from carbon pricing in the 2030s, in both RCP 4.5 and 8.5 scenarios. This fact remains true to 2100 with most physical risks and transition risks increasing over time. At the asset level, most impacted assets are those with high emissions, as a result of carbon pricing over time in both scenarios. Renewable energy assets have the lowest total risk in both scenarios. The platform also offers a high-level analysis of the opportunities related to climate change; however, our focus for this first assessment was on climate risks.

Process

The Climanomics® platform is accessible by creating a user profile in <u>climanomics.com</u>. Once the user has logged into the platform, the user will be given an option to access the Real Assets or the Listed Equities platform. Our demo was focused on the Real Assets platform, with data provided in an Excel file (see Data and coverage section) and TCS conducting the upload. Note that regular users can directly upload data through files or an Application Programming Interface (API).

Once the user has entered the platform, a view of the aggregated portfolio risk is seen with the option to drill down to the asset level. All assets have been geolocated and are visible on a map. Risk factors analyzed are listed to the left of the screen with the calculated absolute risk and relative risk, with toggles to provide values for both RCP 4.5 and 8.5 at decadal intervals (from 2020s to 2090s). The relative risk is shown in green if it is below 10% risk, yellow if it is between 11% and 15% and in red if it is above 16% to facilitate materiality analysis. The ranges for this colour coding can be modified upon request to the TCS team.

For a given asset, a deeper analysis is provided for each risk, with a chart showing the evolution of the hazard (e.g. temperature increase per decade compared to baseline) and the associated impact function (e.g. production loss per additional degree of daily max temp). The user has the option to navigate from the risk tab to the opportunities tab which has a very similar format. The platform also has a quick access to the methodology document.

Our main challenge with the platform during this demo is external to TCS and completely related to our institution's strict IT security processes. While we were able to create a profile in the Climanomics® platform website, we were not able to access the real assets platform for several weeks. This issue is completely external to TCS but other financial institutions with strict security processes may face similar issues when engaging potential suppliers of climate risk tools. Even though the data provided for this demo had already been assessed as nonconfidential, accessing the platform from Desjardins's environment required a thorough IT security analysis. The TCS team was very supportive during this process, and they even developed a findings document that enabled us to visualize and better understand the results.

Data and coverage

To conduct this analysis, Desjardins provided a list of 50 portfolio assets, along with name, value in USD millions, reported/estimated GHG emissions, and location (address or latitude and longitude). All asset data was provided by Desjardins (this included internal data and data collected from data suppliers and desktop research.) No additional data was required to conduct the physical and transition risk analysis with the Climanomics® platform software platform.

In terms of portfolio coverage, Desjardins has US\$289 billion in total assets and our list of 50 assets used in this demo represents less than 1% of our investments or loan books. Our sample included assets primarily in Canada but also in the United States, Europe, Australia and Asia (see figure below) with a variety of sectors represented including, agriculture, renewable energy, fossil fuels, manufacturing, retail, corporate and residential real estate.



Figure 1: Locations of the 50 real assets analyzed in this demo with color coding representing relative climate risk

Risk factors and scenarios

The Climanomics® platform conducts physical and transition risk hazard modelling. The risk hazards included in the assessment are shown in the table below:

Table 1. Physical and Transition hazards in the Climanomics® platform

Physical hazards	Transition hazards
Temperature	Carbon pricing
Drought	Litigation
Wildfire	Reputational damage
Coastal flooding	New technology
Fluvial basin flooding	Markets
Tropical cyclones	
Water stress	

The platform currently reports risks for 10-year increments and the user can view the modelled average annual loss (MAAL), that is the sum of expected financial losses resulting from climate change for the designated period by selecting the desired decade in the drop-down menu (see figure below). A dropdown menu is available to select the desired RCP scenario (8.5 or 4.5). The resulting MAAL in absolute and percentage terms will be shown per risk, with aggregated values for physical and transition risks overall.



Figure 2: Climanomics® dashboard view and modeled average annual loss breakdown

The Climanomics® platform includes scenarios based on the Representative Concentration Pathways (RCPs) from the International Panel on Climate Change (IPCC). Two scenarios are currently included in the platform: RCP 8.5 and 4.5; other scenarios (RCP 2.6 and RCP 6.0) are currently being integrated to the platform and are scheduled to be available by the end of September 2021. According to the Climanomics® platform methodology document, the RCP 8.5 scenario constitutes the high emissions scenario with an assumption that no major global efforts are made to limit emissions resulting in a global mean surface temperature that will be in the range of 4.2 to 5.4°C. On the other hand, the RCP 4.5 constitutes the lower emissions scenario by implying coordinated action to limit emissions and achieve a global temperature warming limit of about 2°C; the estimated mean surface temperature used for this scenario is 1.7 to 3.2°C.

Shared Socioeconomic Pathways (SSP) are integrated in the platform to model carbon pricing. For the RCP 8.5 scenario, the Climanomics® platform uses scenario SSP3-60. SSP3 scenarios assume high challenges to both adaptation and mitigation at different degrees. The price is available at the regional level, for 5 regions: OECD, REF, ASIA, MAF and LAM. The SSP3-60 scenario shows carbon prices starting at \$8/tonne CO_2e in 2010 and increasing to \$82/tonne CO_2e by 2100. On the other hand, for the RCP4.5 scenario, the Climanomics® platform uses scenario SSP3-45 with prices starting at \$8/tonne CO_2e in 2010 and increasing to \$440/tonne CO_2e by 2100. Among other sources,

Organisation for Economic Co-operation and Development and EU member states and candidates (OECD), Reforming Economies of Eastern Europe (REF), Asian countries with the exception of the Middle East, Japan and Former Soviet Union states (ASIA), Middle East and Africa (MAF) and Latin America and the Caribbean (LAM)

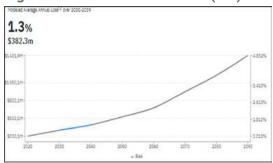
these scenarios are available at the SSP Database from the International Institute for Applied Systems Analysis (IIASA). The platform calculates carbon pricing risk for each asset depending on their location and the GHG emissions data entered.

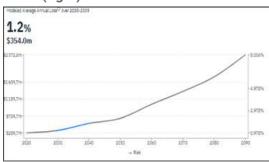
Outputs and insights

The Climanomics® platform generates an aggregated portfolio result and an asset-level result. Overall, the highest physical risks faced by Desjardins based on the sample data provided is fluvial flooding and the highest transition risk is carbon pricing. Both top risks increase over time at different degrees for both RCP scenarios. The high-level results from the asset sample uploaded for this demo can be found in the table below for the 2030s 10-year window.

Priority	RCP 8.5 "High emissions"	RCP 4.5 "Low emissions"
Тор	 The highest physical risk overall is faced from fluvial flooding and the highest transition risk is faced from carbon pricing in the 2030s. Two natural gas-fired power plants face the highest total risk in the 2030s. 	 The highest physical risk overall is faced from fluvial flooding and the highest transition risk is faced from carbon pricing in the 2030s. Two natural gas-fired power plants face the highest total risk in the 2030s.
Medium	 Drought poses the second highest physical risk, while Technology poses the second highest transition risk in the 2030s 	 Drought poses the second highest physical risk, while Technology poses the second highest transition risk in the 2030s.
Low	 Wind farm 1 has the lowest total risk in the 2030s. 	 Wind farm 2 has the lowest total risk in the 2030s.

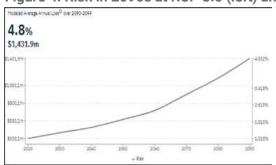
Figure 3: Risk in 2030s RCP 8.5 (left) and RCP 4.5 (right)

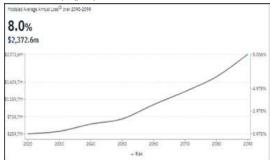




In 2030, the RCP 8.5 scenario shows a slightly higher overall risk than RCP 4.5 primarily because of higher physical risk with MAAL at \$190.3m (0.6%) compared to \$143.8 (0.5%). On the other hand, the RCP 8.5 scenario shows a slightly lower transition risk than RCP 4.5 with \$192.0m (0.6%) compared to \$210.2m (0.7%); this difference is due to higher carbon pricing projected in RCP 4.5, despite slightly higher reputation and litigation risk for Desjardins in this decade with RCP 8.5. This trend continues to the 2090s, with physical risks being higher in RCP 8.5 and transition risks higher in RCP 4.5. As shown in the figure below, the incremental risk of carbon pricing in RCP 4.5 surpasses the risk of physical risks in RCP 8.5, resulting in an 8% MAAL compared to a 4.8% in the 2090s.

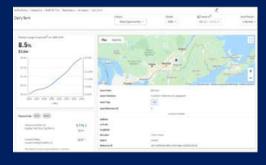
Figure 4: Risk in 2090s at RCP 8.5 (left) and RCP 4.5 (right)





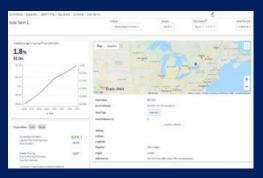
The results of this demo and the lessons learned are aligned with our current climate change risks analysis perspectives. We are using this experience to learn about the methodologies available and decide how to best conduct this type of quantitative analysis for different sets of assets, faster and at a larger scale than our capabilities allow. The outputs generated by the Climanomics® platform and other similar platforms might inform decision-making for longer term investments and financing in multiple sectors. The results further validate our net-zero strategy and the need to expand our nascent climate change adaptation analysis. We will also showcase internally a comparative view of carbon-intensive assets versus ones with low emissions to continue to build awareness on transition risk. As part of our climate action plan, we have identified carbon intensive sectors for which we are engaging with our clients to support their transition to low carbon scenarios. The outcomes and ease of use of this tool can support discussions with clients in these sectors who have not already quantified their potential transition risk.

Asset-level outlook for a dairy farm and a solar farm in the 2050s



Solar Farm: Located between the cities of Toronto and Montreal at an elevation of 140 meters, this solar farm will face a MAAL of 0.6% to 1.8% for RCP 4.5 and RCP 8.5, respectively. Most of the risk faced will be from fluvial flooding in both RCP 4.5 and RCP 8.5 scenarios. Transition risks are very close to zero, primarily because estimated emissions are zero. Overall, and when compared with other assets, the solar farm faces very low risk. To put things into perspective, for the same time period, a natural gas-fired power plant in Canada in our sample asset list will face a MAAL of 32.2% and 64.6% for RCP 8.5 and RCP 4.5, respectively. This very high risk is almost entirely dependent on the high amount of emissions generated by the asset and the projected carbon pricing.

Dairy Farm: Located about 1.5 hours northeast from Montreal at an elevation 110 meters and close to a river, the dairy farm will face a modeled average annual loss (MAAL) of 6.7% to 8.5%, for RCP 4.5 and RCP 8.5, respectively. The highest risks faced are from temperature extremes, followed to a lesser degree by fluvial flooding and drought at both the RCP 4.5 and RCP 8.5 scenarios. The largest difference among the two is temperature extremes representing a 5.7% MAAL in RCP 8.5 and 3.9% MAAL in RCP 4.5. Regarding transition risks, at this point, with the emissions estimated for the farm, there are no significant risks. However, if actual emissions are higher than estimated, or if carbon prices are higher, transition risks may become significant.



Suggested enhancements for providers

The demo was effective at demonstrating the climate risk analysis capabilities of the Climanomics® platform for several asset types. The tool is easy to understand, and the methodology document and overview provided were very helpful. The data entry function is user-friendly as well as the navigation throughout the platform. For physical risks. the methodology is perceived as robust by our team with a good coverage of hazards. The two RCP scenarios included are good options to test assumptions. Transition risk analysis is more complicated to conduct and utilize as there are multiple variables to consider and scenario data is limited. Out of the five hazards, carbon pricing is the only hazard linked to a shared data scenario (SSP3) with a key limitation being that SSPs are done at the regional level, as explained above in Risk factors and scenarios. Upon discussion with the TCS team, we were informed that carbon pricing can be modified to include more granular projections for which data is available, upon request from the user. It would certainly be an enhancement for this and other platforms to provide carbon pricing projections at the national/sub-national level. The other transition hazards, including litigation, reputational damage, new technology and markets are calculated with a highlevel approach that will be refined as data and granular approaches become available. Automating a granular transition risk analysis seems to be a key challenge for this type of tools currently and in the near future.

Overall, Desjardins was satisfied with the Climanomics® platform and the TCS team. Since this is an evolving science, we will continuously explore the methodologies and data used to improve the accuracy of the projections.

Lastly, we have developed a wish list of enhancements that could be good additions to the Climanomics® platform or to other similar climate risk analysis platforms:

- A variable to incorporate remaining asset life (years) per asset or update the projected portfolio every 10–20 years
- A variable to incorporate projected emissions reduction per asset or asset type
- A variable to incorporate planned adaptation measures impacting the vulnerability per asset or asset type
- A benchmarking view on how the risk level is distributed for similar assets modelled (e.g. risk curve, or x% of similar assets in the same region or worldwide more/less exposed). This benchmarking capability is in development by TCS.
- Heatmaps to indicate where some risks (physical and transition) are higher for each asset type. This capability is in development by TCS.
- Guidance and practical examples on how to best incorporate results into existing risk analysis models in the financial sector
- A qualitative description explaining the resulting MAAL per hazard at the asset level. For instance, an automatic text box that could answer the question "why is this particular farm more exposed to flooding and drought than this other farm"?

Participant:

TD Asset Management

Provider:

The Climate Service (TCS)

Risk types covered by tool: Physical risk

Introduction

TD Asset Management Inc. (TDAM, a wholly-owned subsidiary of The Toronto-Dominion Bank) considers climate change a systemic risk affecting economies, companies, and investors. Our approach to climate change is aligned with our overall philosophy of integrating all sources of risk and return in our investment processes.

As an investment manager of diversified asset classes, we consider climate change as an important area of research to fulfill our fiduciary responsibility on behalf of our clients. We actively engage with companies as well as our partners, and leverage our asset ownership positions to encourage improvements in company disclosures on climate-related risks and opportunities facing their businesses. In addition, we participate in numerous industry collaborations including Climate Action 100+, Carbon Disclosure Project, and the UNEP FI TCFD investor pilots, with the first two furthering our company engagement efforts, and the latter developing a better understanding of climate-related investment risks. Our approach continues to evolve to help position our portfolios to capitalize on investment opportunities arising from an accelerated transition to a low carbon economy and manage undue climate-related physical and transition risks.

About TDAM's Global Real Estate Strategy

TDAM's Global Real Estate Strategy was seeded in 2019. The strategy is invested in over 800 properties in 140+ cities throughout the United States, Europe, and the Asia-Pacific. This provides broad diversification globally by regions, property type, and risk strategy (core, value-add and opportunistic). The strategy focuses on developed metropolitan areas and urban, transit-linked, office, multi-unit residential, retail, and logistics/distribution-oriented industrial assets. The comprehensive diversified exposure of a global non-listed real estate portfolio can add significant diversification benefits to multi-asset class portfolios.

These risks and opportunities are present within all our portfolios, but are especially notable within non-listed real estate investments. Physical buildings play an integral role in climate change since properties not only contribute to, but are impacted by, their environment and their communities. However, the commercial real estate industry is at the beginning of its journey to measure and adapt to the full financial and operational

impacts of climate change. Governments and tenants, increasingly concerned about physical property's contributions to climate change, are likely to mandate changes. And these changes are happening concurrently with an increase in the acute and chronic physical risks that threaten buildings. As a result, building owners are likely to be presented with additional costs, risks, and opportunities.

Part and parcel of deeply understanding risks residing in the portfolios we manage, we first seek to understand the tools and methodologies available, and then increase awareness around the strengths and potential gaps in such evaluations. As part of our efforts, members of TDAM's Investment Risk team participated in the UNEP FI Landscape Review module to gain insight into climate-related physical asset risks for a portion of our Global Real Estate Fund. We were paired with The Climate Service (TCS), who provided an estimate of the financial impacts of the physical risks due to climate change for a sample of assets from the fund's non-listed indirect Asia-Pacific Real Estate investments. Risk was estimated as an annual loss, for each decade from the 2020s to the 2090s, across two climate scenarios.

Overall, the results of the analysis were insightful and enabled the naming and quantification of vulnerabilities at the asset, metro, and region level, encouraging further locale-specific research and conversations with our investment teams and fund managers. The trial also highlighted a handful of potential improvements which could enhance the accuracy and applicability of the results.

Process Overview

After being paired with TCS, we met with them to review scope and data requirements, and subsequently populated an excel-based template with internally sourced asset data. After some processing time, we were provided logins to their web-based platform (Climanomics®) and met with TCS to review the results. We performed an exploration of the results within their platform as well as loaded the raw data into an internal database, performing our own portfolio-level analysis. We then reported our findings to internal stakeholders.

Data and Coverage

TCS requested market value, emissions, property type, and location information for each asset participating in the trial. For location, we submitted latitude and longitude, but they would have also accepted a street address, from which a latitude and longitude could be derived. Elevation was also a required input and was calculated automatically by the Climanomics® platform.

We were able to source all data internally, except for emissions data. For emissions data, we sourced it from the GRESB platform, within which some of our managers make information available to us as investors. However, mapping the data from GRESB to internal data was an arduous process. Property types also required translation from internal types to TCS sub-types.

The number of assets we could include in the trial was limited. Because of this, we narrowed our focus to the Asia-Pacific region of our Global Real Estate Fund. Within that region we selected 75 assets from the 200+ available. They spanned the industrial, office, hotel, multi-unit residential, and retail property types. In order to achieve coverage across metros and property types, we selected at least one asset per metro and type. In the event there were multiple that met these criteria, we selected based on value and/or if there was something else of interest, like having high intensity greenhouse gas emissions, being close to sea level, or having a large weight in the region. This selection method enabled us to achieve 100% coverage on 13 out of the 24 Asia-Pacific metros to which our fund is exposed, and over 70% of the value of the Asia-Pacific region of the portfolio.

Risks factors and scenarios

At a high-level, TCS covered global transition risks, physical risks, and opportunities for physical assets such as real estate, energy and power generation infrastructure, transportation, and agriculture. More specifically, the risks and opportunities covered included:

- Physical risks: extreme temperature, drought, wildfire, water stress, coastal flooding, fluvial basin flooding, and tropical cyclones
- Transition risks: carbon pricing, litigation, reputational damage, new technology, and markets
- Opportunities: resource efficiency, energy source, products and services, markets and resilience

We opted to focus exclusively on physical risks since we were participating in a parallel UNEP FI module focused on transition risks.

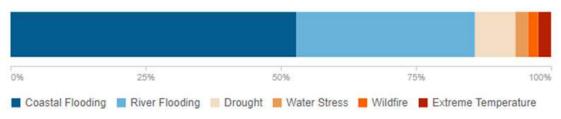
At the time of the trial, TCS supported two Intergovernmental Panel on Climate Change (IPCC) Representative Concentration Pathways (RCP) scenarios: RCP 8.5 "High Emissions" and RCP 4.5 "Low Emissions". The RCP 8.5 scenario assumes that there will be no major global effort to limit greenhouse gas emissions and the RCP 4.5 scenario implies a coordinated action to limit greenhouse gas emissions such that global warming is limited to approximately 2°C. TCS plans to add two additional climate scenarios, RCP 2.6 and RCP 6.0, by the end of September 2021.

Outputs and insights

The principal output of TCS's platform was *Modeled Average Annual Loss*, represented in two forms: a quantitative dollar amount (in millions, USD) and an annual loss presented as a percent of total asset value. Both measures were estimated for each decade, up-to and including the 2090s, for both the RCP 4.5 and RCP 8.5 scenarios. Values were available via the web-based Climanomics® platform as well as a machine-readable format.

Internal analysis of the results revealed multiple insights. First, at an aggregate level, the primary contributors to physical risk within the assets were coastal and riverine flooding, as can be seen in Figure 2. Combined, these two risks comprised 86% of all physical risks.

Figure 2: All-time cumulative physical risks for all trial assets, RCP 8.5



Source TDAM, TCS

Second, by classifying the assets by their cumulative risks, we observed that there were significant physical risk exposures as early as the current decade. This is readily apparent in the assets' physical risk "fingerprints" seen in Figure 3. In these low-resolution plots, time is along the horizontal axis and percentage risk is represented on the vertical axis. The Present Risk (High) class sees exposures commencing in the current decade whereas in the Future Risk (Medium) class, they commence mid-century. The majority of the assets were classified as Low Risk where the physical risks are low throughout the century.

Figure 3: Sample of trial asset physical risk fingerprints, by risk class, RCP 8.5



Source TDAM, TCS

The third insight we gained was with respect to location. By aggregating the individual assets' risks by metro, we were able to see which metropolitan areas were the most vulnerable—specifically, Seoul, Tokyo and Osaka, as shown below in Figure 4.

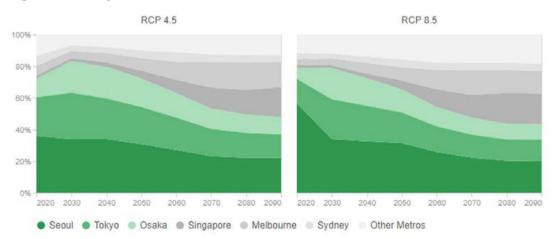


Figure 4: Metropolitan area contribution to risk in Asia-Pacific

Source TDAM, TCS

Being presented with these three insights led us to ask questions of, and seek additional information about each metro:

- What geographic and topological features were driving the risks in each metro?
- What adaptations measures are currently in place or being planned?
- Are local governments adapting to the expected increases in frequency and intensity of events? If so, how?

Seeking answers to these questions is instructive in the sense that it is these factors that ought to be considered in our investment decisions.

Lastly, we calculated a region-level risk measure. Because the trial was limited to only 75 of 200+ assets in the region, it was necessary to extrapolate values for the portion of the portfolio that was not included in the trial. To accomplish this, we calculated the average risk for each metro and then applied that average to each out-of-trial asset before weighting the assets by their investment exposure. This method was not particularly sophisticated, but it served as a good-enough first order approximation. Having a region-level measure enabled us to contextualize its magnitude by contrasting it against the region's cash dividend yield. This demonstrated that impacts due to climate change have the potential to be material to the fund's long-run income return.

Use cases

Within the investment decision making and management processes, information like that which TCS provided can be useful at two levels.

First, it can be useful at the asset level. Knowing how an asset is physically vulnerable focuses our attention by moving our understanding from the nebulous "physical risks" to the specific, like "riverine flooding". This knowledge underpins productive conversations about asset-specific adaptations and resilience.

Still at the asset level, we see it also being of utility during due diligence when acquiring an asset. Knowing the specific risks makes it possible to at least speculate about the

costs of potential adaptation measures and what impact the costs of physical risks might have on a potential asset's long-run investment returns. While the *Modeled Average Annual Loss* cannot be used directly in a discounted cash flow projection since it does not account for municipal/building adaptations or insurance, it provides at least a starting point from which we can perform sensitivity analysis.

Second, information can be useful at a metropolitan level or "locale". Commercial real estate assets are typically located in major metropolitan centers, which means that most assets within that locale are subject to similar physical risks, driven by the geography and topology. For example, both Tokyo and Osaka are coastal, situated on alluvial floodplains, and are thus enduringly vulnerable to coastal and riverine flooding. Knowing this directs our focus on civic planning and governance issues related to local adaptations and resilience measures.

Although we did not explore them, additional uses could include stress testing as well as meeting disclosure obligations.

Tool Approachability

TCS offered both a web-based platform as well as a Microsoft Excel data-download of all risk estimates for each asset, for each decade, and for each scenario. The website was clear, simple to use, and enabled basic analysis and identification of individual asset vulnerabilities. Information could be viewed at a variety of levels of detail, including at the asset or portfolio levels. If tags were provided with the data, they could be further viewed along those user-defined dimensions. In addition, their web-based platform embeds methodology details alongside the measures, which enabled interpretation of the results.

However, the amount of time we spent within the web platform was limited since we have internal analytics capabilities and gravitated towards performing our analysis using them. Importantly, TCS enabled this not only by contractually allowing it, but by providing a methodology document and then arranging to meet with us to review it within the context of their platform. Having this understanding made it possible for us to independently validate how we were using their data by proving we could calculate aggregate values as they appeared in their website.

Throughout the duration of the trial, TCS was notably transparent with respect to their modeling methodology. This transparency enabled us to tune and interpret the results of the modeling with greater understanding and confidence.

Suggested Enhancements

Over the course of the trial, a handful of potential enhancements within the platform emerged. We reviewed and discussed each of these with TCS. They acknowledged the limitations and indicated that improvements were either already in progress, or on their product roadmap:

1. Support for the RCP 2.6 scenario

With the policymakers around the world advancing commitments and changes necessary to meet the objectives of the Paris Agreement, insights from the RCP 2.6 scenario,

which is a low physical risk/high transition risk scenario, would complement the other scenarios already supported. TCS plans to incorporate two additional scenarios, RCP 2.6 and RCP 6.0, by the end of September 2021.

2. Tropical cyclone risk in the Northwest Pacific basin

Although tropical cyclone risk was covered in the Atlantic Basin (eastern North and Central American coasts), it was not yet covered in the highly active Northwest Pacific basin (Japan, China, South Korea, Singapore, etc.) where our in-trial assets were located. TCS plans to extend the tropical cyclone model to the Pacific basin by the end of September 2021.

3. Flash flooding risk

TCS had coverage for both riverine and coastal flooding, but not for flash (a.k.a. pluvial or inland) flooding due to extreme precipitation. The assets we submitted for the trial were in the Asia-Pacific region where flash flooding is a substantial risk.

4. 10km threshold for coastal flood risk

At the time of the trial, TCS's coastal flooding model had a 10km cut-off from the coastline where any asset beyond that point was assigned a risk of zero. Some of the assets submitted for the trial were in Tokyo and Osaka. These are coastal metropolitan areas situated on alluvial floodplains, meaning most of the territory is near, at, or below sea-level. These factors combined to create some curious results, such as having two assets at opposite ends of the same street, one with a very high coastal flooding risk, and the other with no coastal flooding risk at all—because it was just beyond the 10km threshold. TCS has an enhanced coastal flood model in development which will remove this limitation and be released later in 2021.

5. Coastal and riverine flooding risk-ceiling

Within TCS's model, both coastal and riverine flooding risks are measured as the probability that a 1-in-100 year flood event occurs within a given year. However, the model stops calculating additional impacts once the annual probability of such an event reaches 100% (certainty). That is, the risk impacts have a ceiling, as can be seen in Figure 5.

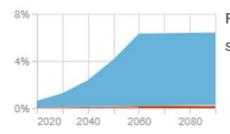


Figure 5: Example of flooding risk ceiling Source TDAM, TCS

6. Quantification of uncertainty

TCS's primary measure, the *Modeled Average Annual Loss*, is currently only available as a point estimate. They have plans to make the distribution of potential outcomes available to end-users.

7. "Missing data"—when no data value is available

The data exported from the platform was in a standard format except for when a risk was not available for an asset. For example, in the case of tropical cyclones, which were not yet covered in the region of the trial assets, the risk was assigned a value of zero. This resulted in ambiguities where a value of zero could be due to the risk actually being zero, or because the risk was not available. The only way to tell these apart was to review the asset manually within the web-based platform, where a note and explanation could be seen.

Conclusion

Participating in the UNEP FI Landscape Review module was a valuable experience that allowed us to identify assets at highest risk, begin to pinpoint the causes of that risk, and advance a conversation about how to mitigate those risk causes. Our participation in the module has also provided us an opportunity to raise awareness within both TDAM and the commercial real estate industry on the importance of understanding, measuring and mitigating climate risks. We look forward to continuing to build on the progress achieved over the past several months and collaborating with our internal and external partners to advance the conversation on the impacts of climate change.

Authors

Carlin Pohl, Associate, Investment Risk Chantal Laplante, Associate, Investment Risk Colin Lynch, Managing Director and Head of Global Real Estate Investments Priti Shokeen, Vice President & Director, Head of ESG Research and Engagement

Participant:

Folketrygdfondet (FTF)

Provider:

Willis Towers Watson (WTW) and JBA Risk Management

Risk types covered by tool: Physical risk

Introduction

In this piloting exercise, we focused on various physical climate risks and assessing how these affect a selected portfolio of Fixed Income real estate investments. We chose to analyze a portfolio of real estate companies with a primarily Nordic scope. The analysis was done in two steps; 1. analyzing how various climate hazards evolve from the present-day to future time periods in specific property locations under different temperature scenarios, and 2. Assessing how the key climate hazard identified in step 1, affects property value and business interruption, the latter reflected as loss of rental income and relocation expenses.

The piloting exercise enabled us to look at the evolution over time of climate hazards that can impact real estate. In the two temperature scenarios, we find that extreme precipitation and flooding are two key hazards that emerge and can cause disruption of business activity as well as loss of market value. The findings make clear what the key climate hazards are in the Nordic region, and thus provides guidance on what measures real estate companies should focus on to mitigate the negative effects of these climate hazards.

Process

The piloting exercise consisted of a two-step approach. First, we looked more high-level at various hazards for the real estate investments in our Fixed Income portfolio. The second step entailed a more detailed focus on one real estate company and the impact of the most important hazard expressed in financial terms.

In the first step, we used the Climate Diagnostic tool from Willis Towers Watson (WTW), to pilot a physical climate stress test for the portfolio sample, with diagnostics and ranking of climate hazards. In the second step, we used probabilistic catastrophe/flood models from JBA and analysis provided by WTW.

The Climate Diagnostic tool was applied to the real estate portfolio, and the geographic coverage was primarily the Nordic region, and some additional locations. The exercise included a wide range of cities. The climate variables evaluated were fire, heat stress, heavy precipitation, and river flood for the present-day and the 2050s under two temperature scenarios.

In the second step, to quantify property damage and business interruption in financial terms for the deep dive analysis of one real estate company, JBA's flood models for Scandinavia were used. The objective was to quantify the expected physical climate losses from asset damage and business interruption due to flooding. The models simulated thousands of events to quantify the range of physical damage and business interruption losses which the company's properties could experience, under present-day conditions and future climate scenarios.

Data and coverage

For the piloting exercise, we used publicly reported company data on property locations, market values, occupancy classes, and average rental values. WTW used their own database for the Climate Diagnostic modeling, based on locations for each property. The JBA probabilistic modelling used data based on four elements: exposure, hazard, vulnerability, and financial information.

The Climate Diagnostic tool can cover a wide range of sectors and is global in coverage. For this piloting exercise, the portfolio selection was narrowed down, due to the challenges of data collection and accessibility for our portfolio. Web scraping software was used by WTW to identify property locations for each real estate company, for input into Climate Diagnostic.

For the JBA probabilistic modelling, one company was selected for a deep dive analysis of flooding, which Climate Diagnostic had demonstrated is the key hazard for the locations of the company's investments. The modelling looked at property damage and business interruption due to flooding and quantified the impact in financial terms. Property damage assumes losses related to the reconstruction costs, including costs for material and labor. Tax values were used as a proxy for market value as real estate companies don't report market values per property, but rather they report value on an aggregated level. Since tax values are not an ideal representation for actual market losses, we chose to focus on business interruption as a metric and expression of climate risk. The input for business interruption estimates were calculated by WTW from the total area of each property multiplied by the average rental value (SEK/sq.m) for different regions and occupancy classes. For business interruption, the residential losses are estimated costs for relocation expenses, while for commercial assets the model estimates possible loss of earnings and downtime.

Both tools (Climate Diagnostic and JBA's flood model) can be applied to a range of sectors and geographic locations. The selected real estate portfolio for this exercise totaled 14 companies, constituting approximately 2,9% of the total FTF Fixed Income portfolio.

Risk factors and scenarios

The climate variables included in the first part of the pilot (Climate Diagnostic) were fire, heat stress, heavy precipitation, and river flood. Climate Diagnostic covers a broader range of variables, but not all were relevant for the portfolio selection. JBA's flood model covered scenarios related to flooding. The following climate scenarios for 2050s were assessed:

- 2°C (Representative Concentration Pathway, RCP 4.5)
- 4.5°C (RCP 8.5)

Outputs and insights

In the first step, the Climate Diagnostic tool measured climate hazards for investment locations in the present and future scenarios. The hazards were ranked 0–5 in terms of severity of their impact.

In Norway, the primary hazards from the present-day to the 2050s under the two scenarios, were heavy precipitation (which can lead to surface water flooding) and river flood. We saw increased heavy precipitation in Bergen, Sandvika and Baerum under both scenarios, and the latter two also had increased risk of flood under the RCP 8.5 scenario. There was a modest increase in fire hazard under the RCP 8.5 for areas such as Larvik. The figure below shows the climate hazards in Norway for the 2050s, ranked by importance.



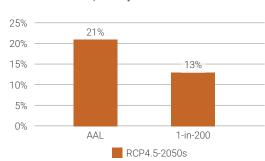
In Sweden, flood is the primary hazard at present, and remains high under future climate scenarios. There is modest increase in heat stress under RCP 8.5 for cities such as Malmo.

In Finland, the predominant hazard is river flood in Turku. There were no major changes in climate hazard factors by the 2050s, but modest increases in fire hazard and heavy precipitation were identified in selected cities.

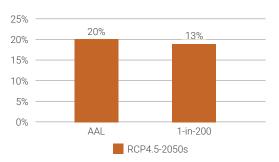
In step two, JBA's probabilistic flood modelling was used on one company to analyze in detail and quantify expected physical climate losses in financial terms as asset damage and business interruption. The model provided annual average losses (AAL) and 1-in-200-year return period losses. The figure below shows the percentage change in

property damage as market value loss, and business interruption as relocation expenses and earnings loss, in an RCP 4.5 2050s scenario compared to the present day.

Property damage: AAL and 1-in-200RP % increase by 200s, RCP4., compared to current



Business interruption: AAL and 1-in-200RP % increase by 2050s, RCP4.5, compared to current



We found this pilot to be an important tool for understanding climate risk and how these risks play out in different scenarios. The models used have provided us with a starting point for looking more closely at the connection between climate risk and financial risk.

The exercise has also identified a main challenge as it relates to the lack of granularity of reported company data. For the real estate sector in the Nordic region, most reporting on property values is done on an aggregated level. Therefore, we don't have correct values for each property, and so we used tax values as a proxy instead. The output of the models does therefore not reflect actual property value loss in monetary terms but does however more clearly reflect change in loss in percentage terms. In general, we recognize that lack of granular portfolio data remains the main obstacle to properly evaluating the financial impacts of climate change on our portfolio.

The tools presented in this case study, were quite complex, but our understanding of the tools was facilitated by the thorough presentations given by the team at WTW. The modelling was done by WTW and JBA, so our time was spent more on understanding the tools themselves and the output generated for this pilot. A challenge due to time constriction for the pilot is that it did not allow for much time for us to test the tools for ourselves. We are therefore not familiar with the full extent of the tools and its coverage and scope. The portfolio selection was narrowed down to balance the extensive data collection and analysis required against the limited scope and time at our disposal for this pilot. For this reason, we were not able to test the entire portfolio, however, the selected portfolio gave a good representation of the possibilities of the tools tested.

The pilot has connected us with industry experts, and insightful discussions have given us a better understanding of the impact of climate risks on real estate and key climate hazards in the Nordic region. This pilot is a good starting point for gaining a better understanding of climate risks and the negative financial impact it can cause. As such, this pilot has been a valuable learning experience.

Participant:

Manulife Investment Management

Provider:

Willis Towers Watson (WTW)

Risk types covered by tool:

Transition risk

Introduction

Global decarbonization efforts are underway, with a long journey ahead for both investors and issuers. Developing tools that can assist in providing clarity around the impact of decarbonization pathways is critically important, as transition risk has been shown to carry a high likelihood of negatively, or in few cases positively, affecting companies' financial statements.

This is the second UNEP FI pilot project in which Manulife Investment Management has participated. As part of the pilot, we participated in a climate tool demonstration using WillisTowersWatson's (WTW) climate transition analytics tool.

Steps taken by Manulife Investment Management for this case study

- Provided a list of global large-cap stocks across multiple industries; some are held in existing portfolios and some are not
- Analyzed an abbreviated compilation of output
- Held discussions with WTW to review the original output, take a deeper dive into the methodology, run trade simulation impacts, and review revised output

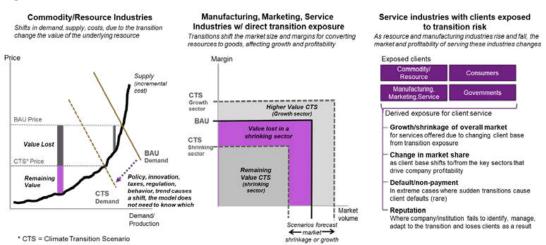
Objective of the tool

WTW's climate transition analytics tool is designed to help portfolio managers understand the explicit and unintended risks of the climate transition in an investment portfolio. It elevates the risk awareness at a company, industry, and sector level, which in turn enables the portfolio manager to create a more climate resilient portfolio through more risk-aware security substitution and/or hedging activities. The tool allows for sensitivity analysis based on the factors of security weight and selection. Consequently, a portfolio manager can model and change the portfolio, and thereby avoid unintentionally betting against the high likelihood of the global decarbonization.

Understanding the methodology

A core functionality of the tool is its methodology to measure the climate transition value-at-risk (climate VaR) of publicly listed companies (6,000 primary listings from 45 countries). Climate VaR represents the difference between the discounted free cash flow (DCF) valuation of the business under "current market expectations" (aka Business as Usual or BAU) and a climate transition scenario (CTS) consistent with a well below 2 degrees outcome (WB2C). The approach taken to estimate a company's climate VaR depends mostly on its industry, as illustrated in Figure 1, which shows how commodity-focused companies are modelled through a fundamental analysis of their underlying commodities and valuation impact to the applicable resource(s). Companies outside the resources space with direct exposure in carbon intensive businesses are modelled by business segment, assessing the potential shrinkage of the market driven by less carbon intensive alternatives.

Figure 1



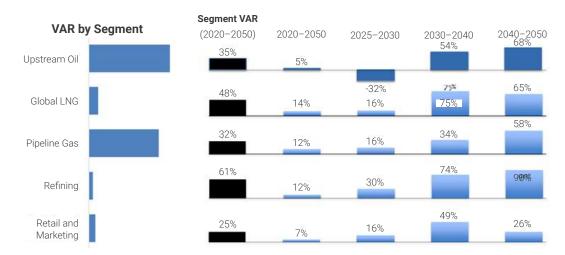
Source: WillisTowersWatson, 2021.

The resulting dataset of (debt and equity) climate VaRs is exploited by the tool in multiple ways, notably to:

- 1. Construct and periodically rebalance proprietary climate transition indices (CTIs)
- **2.** Create and manage hedging investment solutions (e.g., partial clones of CTIs)
- **3.** Improve a portfolio's resilience to climate transition risks

As previously mentioned, total decarbonization of emissions is the long-term goal, but it's important to appreciate the market and financial impacts will not be linear. The severity, as well as the growth opportunities, will become greater over time by orders of magnitude. Figure 2 below provides the climate VaR for the energy sector across industries as well as the segmentation of the impact by time periods. The quantification of climate VaR can be particularly helpful to investors as they try to assess current valuation within specific time horizons.

Figure 2:



Source: WillisTowersWatson, 2021. Not derived from Manulife Investment Management test portfolio.

Data, coverage, and output

The tool covers over 6,000 primary listings: 2,400 in North America, 1,200 in Europe, 600 in Japan, and the remaining geographically spread out across multiple countries, including Australia and emerging markets.

At the individual security level, the output from the tool consists of 4 sections:

- **1.** A **climate transition risk** tab, which reports:
 - Debt and equity climate VaR for a given transition scenario
 - Underlying CTCs (whenever applicable)
 - Market index vs. climate transition index weights
- **2.** A **signals** tab, which covers:
 - Fundamental attractiveness (fitness, value, momentum) and controversy levels
 - Global macro profile and sensitivities
 - Miscellaneous information (business description, brokers' view, peer group, etc.)
- 3. A signal timeline tab, which provides a visual representation of the above over time
- **4.** Another side tab, which offers a perspective from the point of view of the investor taking the other side of one's trade (e.g., bull/bear arguments, top institutional buyers/sellers).

Portfolio-level output

At a portfolio level, the tool offers insight into historical performance and return attribution on the one hand, and prospective risk/return on the other, with two notable features:

• "Mitigate" function: The tool singles out the largest detractors from the portfolio's climate VaR, suggests investment candidates to rotate into, and simulates the impact of the resulting turnover on the portfolio's fundamental and climate characteristics

• "Tracking error impact": which helps visualize turnover-tracking error trade-offs and run portfolio optimizations that minimize downside tracking error relative to a CTI under set constraints (mandate, turnover, minimum trade, etc.).

Market-level output

At a market level, the tool provides proprietary signals aimed at complementing the bottom-up, forward-looking security/portfolio analytics described above. This consists of a top-down "nowcast" of expectations priced in by financial markets, which informs asset allocation and factor exposure decisions.

Portfolio management viewpoints¹⁵

For the model portfolio we provided, the WTW climate transition analytics tool calculated the average transition climate VaR to be higher than that of the (Europe CTI) benchmark, with an average of -6% for the portfolio (Figure 3). In the bottom chart, BP PLC and Eni S.p.a. contribute the greatest climate exposure. In addition, of the top five contributors, four of them are in the energy industry.

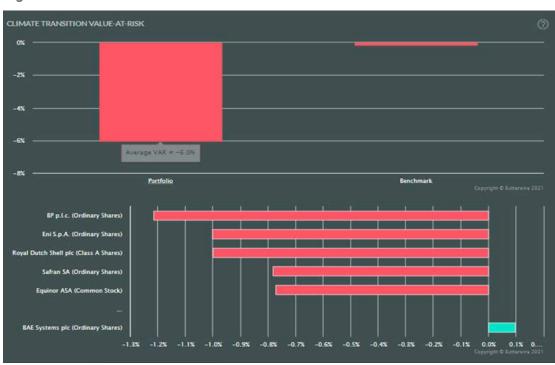


Figure 3

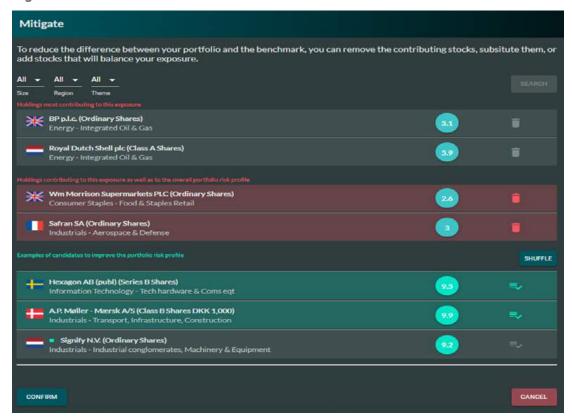
Source: WillisTowersWatson, 2021.

To mitigate the difference between the benchmark and the portfolio, these energy companies could be replaced to reduce climate VaR—for example, by divesting from BP and Royal Dutch Shell (Figure 4).

Analysis provided for illustrative purposes only to demonstrate a potential approach to understand the explicit and unintended risks of the climate transition in an investment portfolio. It is not a recommendation to buy or sell any security.

The transition tool also identifies other actions a portfolio manager could employ that would reduce climate VaR as well as tracking error (Figures 4 and 5). In this example, selling WM Morrison and Safran will reduce climate VaR and reduce the tracking error of the portfolio simultaneously.

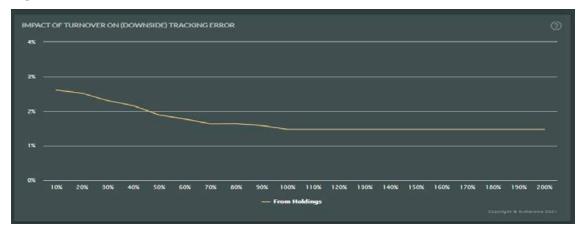
Figure 4



Source: WillisTowersWatson, 2021.

The tool enables easy optimizations to achieve certain objectives. In this example, by rotating 25% of the portfolio, which equates to 50% turnover, the tracking error declines from 2.6% to 1.9% (Figure 5).

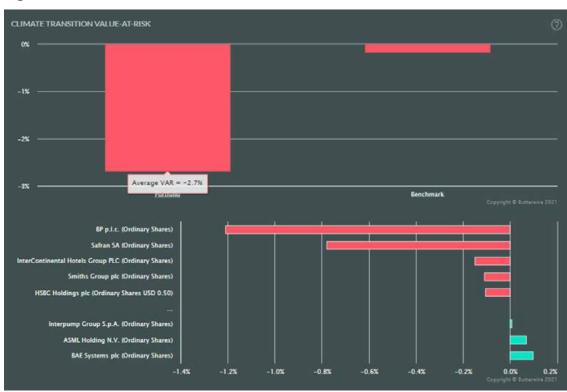
Figure 5



Source: WillisTowersWatson, 2021.

In addition, with this optimization, the portfolio's climate VaR is reduced from -6% to -2.7% (Figure 6).

Figure 6



Source: WillisTowersWatson, 2021.

Potential enhancements for the climate transition analytics tool

There are several enhancements to consider for the tool. In particular, we think it could be helpful to expand the tool's integration of proprietary climate research insights:

Expanding stock coverage

Consideration should be given to increase the number of individual stocks modelled bottom-up by sector analysts relative to the number of stocks whose climate VaRs are estimated by the tool's machine learning application. As of September 2021, 75% of the World CTI weights were set using climate VaRs ascertained by sector analysts, which means 25% were estimated by the tool utilizing machine learning. From Manulife Investment Management's perspective, we don't have high confidence in estimated climate VaRs; however, we have no quantitative evidence to support any particular shortcomings associated with the tool's estimates.

Integrating physical climate risk data

By integrating WTW physical climate risk models with the model of climate transition risk, the tool could offer a comprehensive climate risk picture that could also account for climate transition scenario assumptions. Note that Manulife Investment Management did not review the physical climate risk models and so cannot speak to their efficacy or quality.

Participant:

GLS Bank

Provider:

right. based on science

Risk types covered by tool:

Transition risk

Introduction

As a social-ecological bank, GLS Bank is firmly committed to the goal of limiting global warming to 1.5°C above pre-industrial levels. Providing full and detailed impact transparency ("Wirkungstransparenz") is a core promise we make to our customers.

We therefore partnered with right. based on science GmbH (right.) to calculate the climate impact of our "GLS Bank Aktienfonds" (DE000A1W2CK8), a mixed fund of mainly equities and bonds from particularly climate-friendly companies. right. developed the X-Degree Compatibility (XDC) Model, which is recognized by the Task Force on Climate-Related Financial Disclosures (TCFD). The XDC Model calculates the impact a company, a portfolio or any other economic entity has on global warming and expresses it in a degree Celsius (°C) value (Temperature Alignment). It answers the question: "What degree of global warming would occur by 2050 if everyone behaved as the company/ entity in question?"

Our aim with this analysis was to assess whether our *GLS Bank Aktienfonds* already meets the 1.5°C target, identify where action is still needed and potentially use the information as a basis for active engagement. The results were insightful. However, the close collaboration on this analysis also revealed the need for additional emission data, for a methodology to measure the emissions of a green bond, easier integration of emission reduction goals, as well as the "fair" consideration of scope 2 and 3 emission data.

Process

We analysed the Temperature Alignment/climate impact of "GLS Bank Aktienfonds" by using right.'s "XDC Portfolio Explorer", a web-based software built on the XDC Model. It can be accessed by registering directly on the website. Once the user is logged in, a portfolio must be uploaded for analysis.

1. We created and uploaded a csv-file containing the ISIN codes and portfolio weights of all securities in the "GLS Bank Aktienfonds".

- 2. The software then calculated XDC metrics for the fund itself as well as each security, providing
 - Temperature Alignment values (XDCs) for the fund as well as each security,
 - an indication of alignment/misalignment to a 1.5°C, 1.75°C as well as a 2.0°C scenario,
 - sector benchmarks (Sector XDCs) for each company in the fund as well as the fund itself.
- **3.** We downloaded the results, again as a csv-file.
- 4. We analysed the results and had a deeper look especially at those companies not yet aligned with the Paris Agreement in order to see whether (1) there are other reasons (e.g. on the social side) to keep them within the fund, (2) they have a climate strategy and thus in a scenario-based approach would be aligned or (3) could/should be replaced.

Main challenges encountered

At GLS Bank we have our own sector classification. However, the XDC Model and XDC Portfolio Explorer make use of the classification according to NACE (Statistical Classification of Economic Activities in the European Community). This created a need to co-develop a customized sector classification to meet our requirements.

Another main challenge was the question of dealing with Scope 3 emissions and the risks of double counting. As a default, the tool counts Scope 1 at 100%, and Scopes 2 and 3 at 50% each to compensate for double-counting. Since Scope 3 emissions usually make up the largest share of a company's carbon footprint, excluding these emissions from the analysis would mean a blind spot, neglecting all upstream and downstream activities as well as the significance of integrating the full value chain in the transition. Including Scope 3 emissions brings concerns of double-counting, since these emissions are not solely attributable to one company. We decided to follow the XDC Portfolio Explorer default here and include Scope 3 at 50%.

Data and coverage

We used the XDC Portfolio Explorer to analyse the contribution to global warming of the "GLS Bank Aktienfonds" (i) at security level (102 companies) as well as (ii) at portfolio level. The data required from our side were: unique identifiers (ISINs) and portfolio weights for all securities, provided in a csv-file.

The analysis draws on additional data to calculate the XDC metrics. These are all sourced by right. and integrated in the XDC Portfolio Explorer software:

Company level data

- Current economic productivity, as measured by gross value added (GVA). Source: FactSet Research Systems.
- Current greenhouse gas emissions for scopes 1, 2, and 3. Source: Urgentem.

Global economy data

• Current economic productivity as measured by GVA. Source: World Bank.

Growth rates ("Middle of the Road/Current Trends Continue" scenario)

• Annual growth rate of the entity's emissions and GVA. Source: Shared Socioeconomic Pathways (SSPs) or E3ME (by Cambridge Econometrics).

The tool covers all geographies and sectors. Wherever XDC values could not be calculated, this was indicated in the software. 97.4% of securities in our portfolio were covered (102 out of 105). The remaining three securities were excluded from the analysis.

To project the future developments from the base year until 2050, the XDC Model works with assumptions derived from socio-economic and climate mitigation scenarios, as well as macro-economic data. Geographically, the XDC Model and XDC Portfolio Explorer include both (i) country-specific assumptions forapproximately 185 countries as well as (ii) five world regions: OECD, Asia, Middle East & Africa, Latin America, and Reforming Economies.

The sector is defined by a NACE code; normally either a 1- or 2-digit NACE code, except in special circumstances where a higher granularity may also be used. All International Energy Agency (IEA) sectors are considered to derive sector-specific target pathways from the IEA mitigation scenarios. The IEA sectors are then converted to the more detailed NACE sector classification system.

Risk factors and scenarios

The temperature alignment analysis used here mainly focuses on the "inside-out" risk perspective of double materiality. This concept was stated by the EU Commission in June 2019 in a supplement to its Guidelines on Non-Financial Reporting (NFRD): Complementary to the "outside-in" perspective, the "inside-out" perspective describes the influence of a company on the climate, which can be financially material and therefore also has to be reported.

By this, we also followed TCFD recommendation 1 on "Portfolio Alignment"16

We recommend all financial institutions measure and disclose the alignment of their portfolios with the goals of the Paris Agreement using forward-looking metrics. Hence, the key risk factor explored was the alignment of our "GLS Bank Aktienfonds" with the Paris Agreement.

Landscape Review Paper
Case studies

¹⁶ Consultation just ended. https://assets.bbhub.io/company/sites/60/2021/05/2021-TCFD-Portfolio_Alignment_Technical_Supplement.pdf

The **target scenarios** used in XDC Portfolio Explorer are based on International Energy Agency (IEA) mitigation scenarios "2°C Scenario" (2DS), "Beyond 2°C Scenario" (B2DS) (corresponding to max. 1.75°C global warming), and "Net Zero by 2050" (NZE2050) (corresponding to max. 1.5°C global warming). The focus of the analysis conducted here was the 1.5°C benchmark. Further target benchmarks based on mitigation scenarios from the Network for Greening the Financial System (NGFS) and the One Earth Climate Model (OECM) are also available, but were not employed by us.

The **baseline scenario** used to project future development until 2050 is derived from Shared Socio-Economic Pathway 2 (SSP2), also known as the "Middle of the Road" or "Current Trends Continue" scenario. Soon, all SSPs will be available with the XDC Portfolio Explorer.

Outputs and insights

For the fund as well as each security, a range of metrics were calculated by the tool and provided for download:

Table 1: XDC metrics and results

Output	Unit	Description	
Baseline XDC	°C	The expected degree of global warming if the entire world were to operate at the same Economic Emission Intensity (EEI)* as the company/fund until 2050.	
Target XDC	°C	The sector-specific temperature benchmark for the company to be aligned to the selected target scenario (in our case 1.5°C based on IEA NZE2050).	
Sector XDC	°C	The expected degree of global warming if the entire world were to operate at the same Economic Emission Intensity (EEI) as the 'typical' company within a specific sector (sector median) until 2050.	
XDC Gap	±°C	The difference between Baseline XDC and Target XDC—it shows by how much the portfolio or the single security is aligned/misaligned with the selected scenario.	
Alignment assessment	Aligned/Not aligned	Summary of the analysis.	
*EEI is defined as emissions over gross value added ($\mathrm{CO_2e/PPP\$}$)			

Further results provided were Baseline XDC and Target XDC values per emission scope for each security (see Fig. 1) as well as a dashboard overview of the portfolio's sector breakdown and the Top/Bottom Five securities in the portfolio by XDC Gap (see Fig. 2).

Figure 1: Analytics Tab of XDC Portfolio Explorer with results for GLS Bank Aktienfonds (redacted)

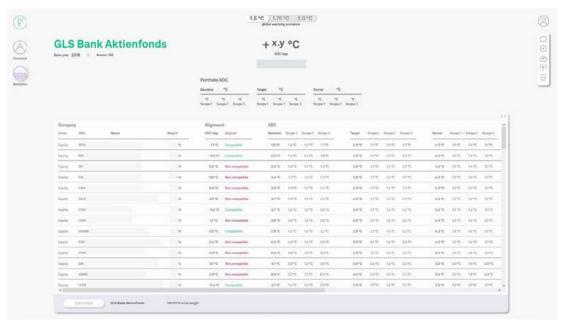
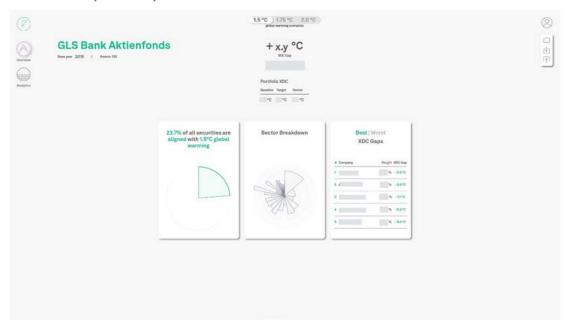


Figure 2: Overview Tab of XDC Portfolio Explorer with results for GLS Bank Aktienfonds (redacted)



The information retrieved from this analysis provides information is a strong basis for engagement with those portfolio companies that are not yet aligned to the 1.5°C target. As companies are the ultimate entities that cause emissions, this is where solutions to significantly reduce emissions must be found and implemented. The XDC Model is already used by companies and the methodology was first developed for application in the real economy. This allows us, as a financial institution, to 'speak the

same language' tocompanies and track progress in the transition with one shared approach—at the same time, this is the language that climate science and global policy have already set out: °C.

While this example analysis was conducted as a snapshot view of the Temperature Alignment/Paris Alignment of the fund, we see great potential for integrating the use of XDC Portfolio Explorer in the earlier stages of the investment process, informing decisions about e.g. portfolio allocation and optimization. The software allows fund managers to test in advance how rebalancings would affect overall Portfolio Alignment. This enables active steering towards the 1.5°C goal we have determined for the fund. The forward-looking nature of the analysis (developments until 2050) is also a key factor here.

We at GLS Bank are quite familiar with "impact transparency" (Wirkungstransparenz) and the challenges it poses. In this case, a key learning—although it almost goes without saying—is that the simplification of portfolio alignment metrics such as the XDC cannot capture the full complexity of climate change and earth system processes. However, science-based alignment metrics expressed in C—such as the XDC Model—have a great potential to close the gap between abstract climate change and financial actor's perception of how they can contribute to reaching the goal of the Paris Agreement. We have already extended the XDC analysis to include our own investment portfolio (treasury) and other investment funds, our credit portfolio, customer portfolios and our own operations.

As the XDC Model allows for conducting forward-looking scenario analysis by adapting the input data for the calculation along chosen assumptions at security level (e.g. highgrowth projections, net-zero targets, transition to green energy etc.), we aim to analyse the climate strategies of our portfolio companies. This will allow us to determine the transition companies in our portfolio and to actively engage with them on setting emission reduction targets that are ambitious enough to align with 1.5°C.

Suggested enhancements for providers

Once familiarized with the various XDC metrics (see Table 1), the tool is very intuitive to use. The data requirements are minimal and since the software is web-based, no installation or setup is needed.

The XDC Portfolio Explorer should support steering towards below 2°C through engagement or divestment by suggesting alternative securities to portfolio managers that would be suitable to replace a security which has a detrimental impact on portfolio alignment.

While the XDC Model can cover various asset classes and multi-asset portfolios, including (i) public listed equity, (ii) private equity, (iii) private debt, (iv) corporate bonds, (v) sovereign bonds and (vi) Real Estate, not all asset classes are available yet in the software. This would allow for more comprehensive analyses.

We would also like to see an uncertainty quantification of the XDC Model. Currently this is being worked on by right. but is not yet finalized.

Participant:

Standard Chartered Bank

Provider:Baringa and BlackRock

Risk types covered by tool: Transition risk

Introduction

In 2021, a number of regulatory stress tests were planned (e.g. Hong Kong Monetary Authority and Bank of England) to focus on climate change and the associated risks to financial institutions. In order to support its climate risk capability for scenario analysis, Standard Chartered Bank (Standard Chartered) worked with Baringa, using a Climate Change Scenario Model.

In June 2021, BlackRock and Baringa <u>announced</u> a long-term partnership focused on innovation and ongoing co-development of transition risk models. BlackRock acquired Baringa's Climate Change Scenario Model and integrated it within Aladdin Climate. This Climate Change Scenario Model is used by financial institutions and corporates with more than \$38 trillion of assets around the world to help them (i) understand the climate risk exposure and the value that may be lost from balance sheet or investment assets; (ii) how deployed capital and investments are impacting the climate with comparisons against benchmarks; and (iii) identify opportunities to re-allocate capital to improve impact on climate and make commercial returns. The Climate Change Scenario Model is designed to provide full integration of both physical and transition risk modelling across a range of assets. It is modularised to enable clients to select those components relevant to them and to enable straight-forward integration of third-party scenarios and physical risk analysis.

This case study focuses on the Standard Chartered pilot in early 2021 of 100 corporate clients to run though the Climate Change Scenario Model to determine Probability of Default and Temperature Alignment. Under the 2-degree orderly scenario, it showed that energy clients were the most susceptible to transition risk with Weighted Average Probability of Defaults rising to over 8% by 2050, compared to <1% as at 2019. Using the same clients, analysis produced an average temperature alignment of 3.14°C, which indicates that Standard Chartered's portfolio is broadly in line with global trends. Since the pilot, Standard Chartered has extended the Climate Change Scenario Model coverage across its corporate and sovereign portfolios, augmented its scenario analysis and has used the insight in their 2021 TCFD Report.

Collaboration process

It is possible to choose several integration options with the Climate Change Scenario Model. For a swift implementation, Standard Chartered utilised the Climate Analytics Service (CAS) which provides Data-as-a-Service output capabilities. This is where Standard Chartered pass the requisite input files containing company emissions, financials and production data, as defined by the Climate Change Scenario Model input data dictionary, to Baringa for ingestion into the model. Once Baringa has executed a modelling run and quality assurance (QA) has been performed, the results are shared back to Standard Chartered via output files, as defined by the Climate Change Scenario Model output data dictionary.

The Climate Change Scenario Model is now integrated within BlackRock's Aladdin Climate, where it is available both as an integrated Software-as-a-Service offering and Climate Analytics Service (CAS) offering for banks, asset managers, asset owners and corporates to support a range of investment and climate disclosure needs.

The data dictionaries and QA act as preventive and detective control layers in the run process. Furthermore, to help ensure the integrity of the model, rigorous internal and external validation has taken place.

The external validation was performed by Kroll, and Professor Steve Pye of the UCL Energy Institute.

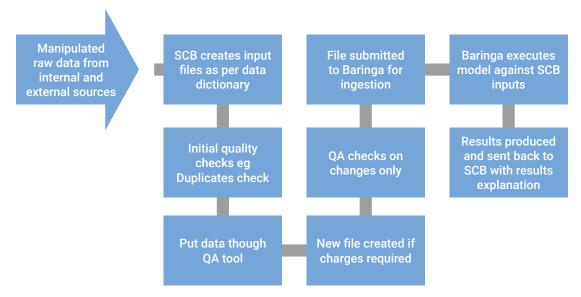


Figure 1: Flowchart showing Model execution

Outputs and insights

One of the key outputs Standard Chartered used was the evolution of Probability of Default. Here, the model assesses the changes in company financials, and consequent changes in credit ratings and probability of default under orderly and disorderly transition scenarios. From the preliminary scenario analysis work, aggregated results on

100 corporate clients, the below chart shows how Probability of Default changes over the 30-year time horizon across the different client sectors. The pathway of Probability of Default is driven by changes to underlying company earnings and debt which is modelled within Climate Change Scenario Model based on the 2 Degrees scenario (explored further under Risk Factors and Scenarios section). This Probability of Default quantifies the transition risk for each individual client and at a portfolio level for Standard Chartered. The results from the below chart highlight the largest transition risk sectors; Energy and Manufacturing.

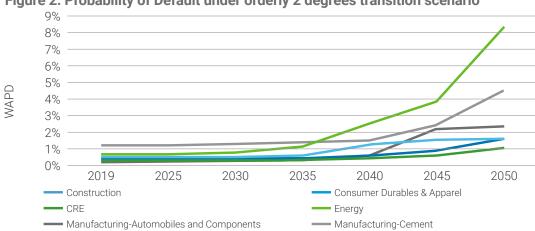


Figure 2: Probability of Default under orderly 2 degrees transition scenario

This chart is sourced from Standard Chartered's 2020 TCFD report

Another key output from the Climate Change Scenario Model is Temperature Alignment. Temperature alignment is a way of quantitatively assessing a company's impact on the climate and is calculated based on emissions intensities, and volume of hydrocarbon produced. In 2021, Standard Chartered applied the Climate Change Scenario Model to around 2000 of its clients within the corporate portfolio. Standard Chartered's portfolio Temperature Alignment is 3.10C, with Utilities and Oil & Gas sectors scoring the highest (furthest from Paris Agreement alignment). This allows Standard Chartered to assess how their portfolio compares with global and regional economies to track its progress on supporting a net-zero pathway.

3.5 3.67°C G 3.0 3.37°C 3.10°C 3.12°C 25 4 20 3.05°C 2.90°C 2.81°C 2.78°C 2.55°C ≸ 1.5 1.0 05 Other industry sectors⁶ 580 Automobiles & Transportation Construction Consumer Durables Metals & Mining

Figure 3: Temperature alignment

This chart is sourced from Standard Chartered's 2021 TCFD report: https://av.sc.com/corp-en/content/docs/tcfd-climate-change-disclosure.pdf

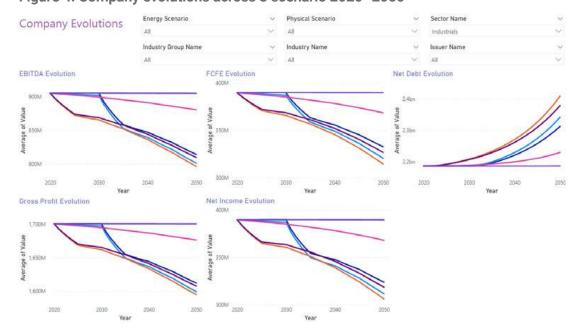


Figure 4: Company evolutions across 3 scenario 2020-2050

Data and coverage

For the initial pilot, Standard Chartered wanted to conduct scenario analysis against 100 corporate lending clients assessing transition risk, it was later extended to around 2000 clients. The data which Standard Chartered provided covered individual company financials and emissions.

To get the richest results, Standard Chartered provided additional data points for Oil & Gas and Electric Utilities companies which detailed their production figures. Outputs include remodelled company financials, equity valuations, Probability of Default evolution and temperature alignment per company. In addition to these services, the Climate Change Scenario Model also covers other asset classes such as corporate bonds,

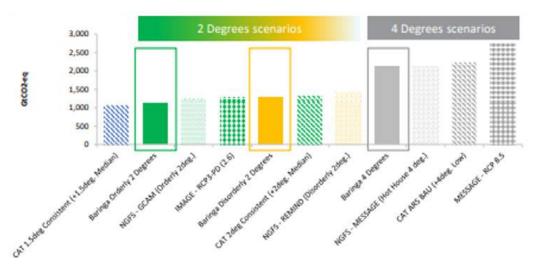
sovereign bonds, property and vehicles. The Climate Change Scenario Model can ingest physical risk outputs from other providers to create a combined view of transition and physical risk.

Risk factors and scenarios

To assess the transition risk of their corporate clients, Standard Chartered utilised three scenarios: Baringa Orderly 2 Degrees, Baringa Disorderly 2 Degrees and Baringa 4 Degrees. As Standard Chartered commented in their TCFD 2020 report, these scenarios use assumptions focused on government policies, availability and deployment of technologies to limit emissions to a certain target. Outputs from scenario analysis indicate how variables such as energy demand and supply, economic activity, macroeconomic and other socio-economic factors will evolve, based on the specified set of underlying scenario assumptions. Furthermore, specific sets of assumptions for transition risk scenarios usually surround technological advancement, timing and ambition levels of policy actions and societal preference.

To assess the temperature alignment of the Standard Chartered portfolio, the Climate Change Scenario Model uses historical emissions or production data to evaluate how a company's emissions intensity will evolve into the future. The model maps future emissions intensity and hydrocarbon production against sub-industry/region benchmarks to compute company Temperature Alignment.

Figure 5: Benchmarking of Standard Chartered—Baringa scenarios to external scenarios



Use cases

Standard Chartered utilised the Climate Change Scenario Model outputs initially to feed into TCFD 2020 disclosures where aggregated Probability of Default and Temperature Alignment were shown for the selected 100 corporate clients. Standard Chartered has since applied the Climate Change Scenario Model to almost 2000 of its corporate clients.

Beyond this, the Climate Change Scenario Model, now integrated within Aladdin Climate, has many business use cases, including:

- Probability of Default and Temperature Alignment
- Equity and debt valuation changes
- Contribution into external reporting such as TCFD and other climate/sustainability disclosures
- Multi-jurisdictional regulatory stress tests e.g. Bank of England, Hong Kong Monetary Authority
- Internal stress testing, credit and market risk assessments
- Sensitivity analysis and supports net-zero business planning.

Standard Chartered uses the Probability of Default output from the Climate Change Scenario Model in its climate stress testing and as a risk identification metric and proxy for gross transition risk. Client level climate risk assessments are being integrated into Standard Chartered credit underwriting processes. At Standard Chartered, the Temperature Alignment score helps provide a quantitative measure when evaluating potential climate related reputational risks and is used in client and transaction reviews for selected clients operating in some high carbon sectors. For more information on how Standard Chartered uses the Climate Change Scenario Model in its risk identification processes, refer to the Standard Chartered 2021 TCFD report.¹⁷

Suggested enhancements for providers

As with all models, development is ongoing and we continue to explore ways in which to enhance and expand our functionality and coverage. These can be broadly characterized into three main areas of focus within the development roadmap to enhance the:

- breadth of sectors covered by specific models
- climate specific functionality within the model, including enhancing competitive dynamics and the impact of company transition plans and costs of abatement
- operation of balance sheet, cash flow, debt and capital funding dynamics across the long term modelling horizon

Authors

Ian Clarke, Expert in Banking, Baringa

¹⁷ av.sc.com/corp-en/content/docs/tcfd-climate-change-disclosure.pdf

Participant:

European Bank

Provider:

Risk types covered by tool:

PricewaterhouseCoopers (PwC)

Physical and Transition Risk

Introduction

As part of the UNEP-FI TCFD pilot programme, we as a bank performed a climate risk analysis of our loan portfolio with the help of PwC. The Climate Excellence Tool of PwC allows us to perform a climate risk screening, enabling us to identify physical and transition risks on a sectoral, portfolio and individual asset level. These screenings can subsequently be used to calculate financial impact on asset level as well as aggregated on portfolio level. Within Climate Excellence, we can review the overall risk to the selected portfolio across time and sector exposure as well as explore company-specific vulnerabilities and resilience in a given scenario. The entire corporate client loan portfolio was analyzed. The analyses returned that the portfolio faces elevated physical risk from droughts and coastal and fluvial flooding across regions. Transition risk in the analysis depended on the hypothetical adaption activities of companies (inaction, mainstream, achiever). Under the inaction scenario, agriculture, mining, manufacturing, electricity, and real estate all faced significant transition risks. Based on these results, further sectoral deep dives were proposed from PwC to analyse the asset-specific impact within sectors.

Process

- 1. In an onboarding session, the dashboard is introduced, including the different possible views for the relevant stakeholders to learn about the tool functions and features (such as the scenario and time filters, the different views on adaptive capacity pathways of companies etc.)
- 2. In a next step, we choose the preferred scenarios (both for transition and physical risks) and the scope for the analysis (time horizon, depth of analysis, define the portfolio for analysis)
- **3.** After the log-in to the Climate Excellence Tool, we can see a template for preparing the portfolio in the according structure for the upload
- 4. After uploading the portfolio, the results can be analyzed on different levels within the tool. The tool is structured top-down for different use cases. At first, there is a portfolio overview showing the different sectors present in the portfolio as well as an overall materiality assessment at the sector- or region level for the identification of risk and opportunity hotspots in the portfolio. On the next window, individual companies can be benchmarked across or within sectors and lastly individual companies' results can be split into the different risk drivers (e.g. what sectoral activities, geographies or also technologies (transition) and hazards (physical) drive the changes).

- **5.** The Climate Excellence Tool provides the option to download the scenario analysis results for further evaluation and integration into the bank's processes.
- 6. To aid the interpretation of results, a degree of upfront effort is required to foster understanding on the different levels of the analysis and the underlying model assumptions and scenario narratives. Furthermore, for the successful integration in the internal processes, additional effort and collaboration across departments is highly recommended.

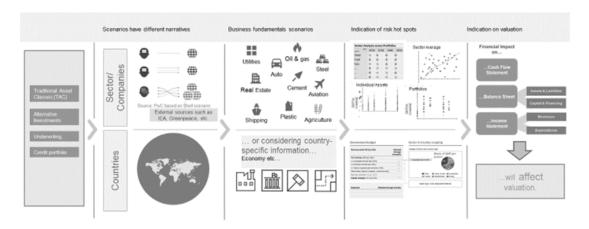


Figure 1 Conceptual image of Climate Excellence analysis

Data & Coverage

- **Data upload:** For the analysis with Climate Excellence, the loan portfolio data is required to be transformed according to the provided template. Furthermore, if not available internally already, the internal sector classification needs to be translated to the NACE sector logic.
- **Input required:** The entire corporate loan portfolio was analyzed and the following data for the portfolio was required:
 - Company Identifier: ISIN, LEI OR Company Name
 - Classification: Main NACE Code and country of operations
 - Exposure: Loan Amount

Coverage of the analysis:

- 99% of the analyzed portfolio of our corporate clients was covered in the tool
- The Climate Excellence tool covers all NAICS (translation into NACE sectors is performed and used in the Tool) sectors up to the most granular level (given NAICS is the most granular sector classification system) and all world regions are covered.
- The results for the high-emitting sectors are based on granular sector models, while the results for sectors with lower relevance are based on factor models (e.g. price changes), which are in turn derived from the high-impact sectors.

	Risk types	Time horizon	Scenarios	Sectoral coverage	Regional coverage	Addi- tional Feature
Transition	Market, technology, regulation	2025, 2030, 2040, 2050	1.8°C, 2.0°C, 3.0°C	Full sectoral coverage	Worldwide cover- age, with regional partly national granularity	Company specific analysis incl. asset level data with technology breakdown
Physical	Both acute and chronic: Heatwaves, Thunder- storms, Droughts, Hurricanes, Flood, sea level rise, fire	2030, 2050, 2100	2.0°C, 3.0°C, 4.0°C	Full sectoral coverage	Worldwide cover- age, with national granularity	Company specific analysis

Table 1: Climate Excellence Coverage

 Results integration: The scenario analysis results in Climate Excellence provide sufficient depth of analysis and a high degree of portfolio coverage for potential subsequent integration in the user's organization, e.g. in Probability of Default (PD) calculations.

Risks factors and scenarios

During the trial period demo, the **key risk drivers** for high-risk sectors were analyzed in focused sector deep dives

- We are able to see the sectoral, regional and technological drivers for individual companies: the analysis happens down to NACE-level 4, depending on materiality, further results are presented, with a driver analysis (e.g. on the sector, country and technology level (transition) and hazard-level (physical), where applicable and meaningful
- Technology-level outputs are based on Asset-Level Data and the technological mix of the company (e.g. for a steel company it's the mix of different steel ovens in the company's portfolio)



Figure 2 Climate Excellence Transition Outputs

Temperature pathways and scenarios analyzed:

Focus during trial period on one scenario for transition and physical risks respectively:

- 1.8°C (triggering transition risks) based on IEA ETP B2DS and ETP WEO SDS
- 3.0 4.0°C (triggering physical risks) based on IPCC RCP 6.0

Outputs and insights

Output

- During the trial period, the focus was on EBITDA changes compared to the base year for individual counterparties
- Where data availability does not allow for granular counterparty analysis EBITDA results are based on sector-geography combinations
- Sales (for transition) and EBIT (for physical) are also available as additional output variables

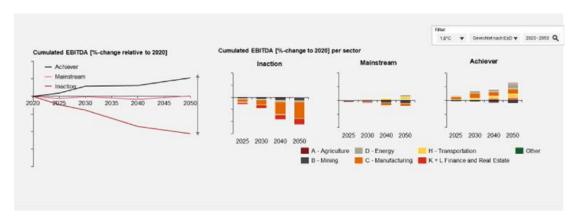


Figure 3 Illustrative results view on portfolio level

- The tool provides insights into the order-of-magnitude financial impacts within and across scenarios
- Sector- and scenario- or even geography-specific risk drivers with significant financial impacts based on changes to revenues and costs
- Understanding of the company-, project-, plant- or product-specific characteristics that imply vulnerability
- The combination of physical and transitory risks helped us a lot in classifying the risks and contributed to a very good understanding of a scenario future world.

Insights on integration options

- Company results as EBITDA change (and Sales) can, for example, be integrated in the respective Probability of Defaults (PD) and Loss given Default (LGD) models of the individual institutions. In this way, for example, a risk premium and its variance can be determined via the modelled adjustment capabilities of companies. Alternatively, based on company results, clusters of risk factors can be integrated.
- Based on the analysis, knowledge is built up across the bank w.r.t. to sector-specific transition and physical risks. Content insights are used for sectoral outlooks and understanding of the required changes in a low-carbon future. Insights are condensed and used to ask further, climate-related questions in the credit processes. Additionally, results are included in future steering concepts.
- The analysis can be directly linked to our Net Zero strategy, thereby covering both sides of the double materiality.
- Optional extension: Evaluation of capex requirements over time (see parallel project: Pathways to Paris) and also embed this for PD and LGD considerations

Suggested Enhancements for the tool provider

The performed analysis of the Financial Institution's portfolio provided a comprehensive geographic and sectoral overview over transition and physical risks within the time period of 2020–2050 and 2020–2100 respectively. The procedure and methodology were well-documented and easy to understand. Outputs provided by the Climate Excellence Tool were integrated within a wider scenario narrative to aid interpretation. Climate Excellence focuses on the financial impact, thus risks and opportunities from climate scenarios. In future versions, the impact side could be included in the tool.

As of now (31.12.2021), PwC has extended the functionality of Climate Excellence modules and now includes the IEA NZE 1.5°C scenario, as well as various Network for Greening the Financial System (NGFS) scenarios. Also, an upgrade of functionality to allow for the analysis of combined impact (thus aggregate transition and physical risk) is available. The analysis' backend has been fed with more recent portfolio data to improve the baseline fidelity of its outputs. Also, the Climate Excellence output has been integrated to generate a climate risk score based on the client's PD model.

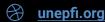
An extension to include more extensive analyses of other parts of the client's portfolio, e.g. commercial real estate and mortgages will follow.



finance initiative

United Nations Environment Programme Finance Initiative (UNEP FI) is a partnership between UNEP and the global financial sector to mobilise private sector finance for sustainable development. UNEP FI works with more than 450 members—banks, insurers, and investors—and over 100 supporting institutions—to help create a financial sector that serves people and planet while delivering positive impacts. We aim to inspire, inform and enable financial institutions to improve people's quality of life without compromising that of future generations. By leveraging the UN's role, UNEP FI accelerates sustainable finance.

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ATTACHMENT 4

Bureau of Reclamation, Final Environmental Impact Statement: Continued Implementation of the 2008 Operating Agreement for the Rio Grande Project, New Mexico and Texas (2016)

RECLAMATION Managing Water in the West

Continued Implementation of the 2008 Operating Agreement for the Rio Grande Project, New Mexico and Texas

Final Environmental Impact Statement





U.S. Department of the Interior Bureau of Reclamation Upper Colorado Region Albuquerque Area Office, Albuquerque

MISSION STATEMENTS

Protecting America's Great Outdoors and Powering Our Future

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Cover photo – Elephant Butte Dam, Powerplant and Reservoir, New Mexico, (Kevin Doyle, EMPSi)

Continued Implementation of the 2008 Operating Agreement for the Rio Grande Project, New Mexico and Texas, Final Environmental Impact Statement

Lead Agency: Bureau of Reclamation, Upper Colorado Region

Responsible Official: Brent Rhees, Regional Director

Cooperating Agencies: Federal:

U.S. Section, International Boundary and Water Commission

State:

Colorado Division of Water Resources

Elephant Butte Irrigation District of New Mexico El Paso County Water Improvement District No.1

Texas Rio Grande Compact Commissioner

Abstract: The proposed Federal action analyzed in this final environmental

impact statement is to continue to implement the 2008 Operating Agreement for the Rio Grande Project and to implement long-term contracts for storage of San Juan-Chama Project water in Elephant Butte Reservoir. The Operating Agreement is a written agreement describing how Reclamation allocates, releases from storage, and delivers Rio Grande Project water to the Elephant Butte Irrigation District in New Mexico, the El Paso County Water Improvement District No. 1 in Texas, and to Mexico.

Release Date: September 30, 2016

For Information Contact: Jennifer Faler, Area Manager

Bureau of Reclamation, Albuquerque Area Office

555 Broadway NE, Suite 100 Albuquerque, NM 87103

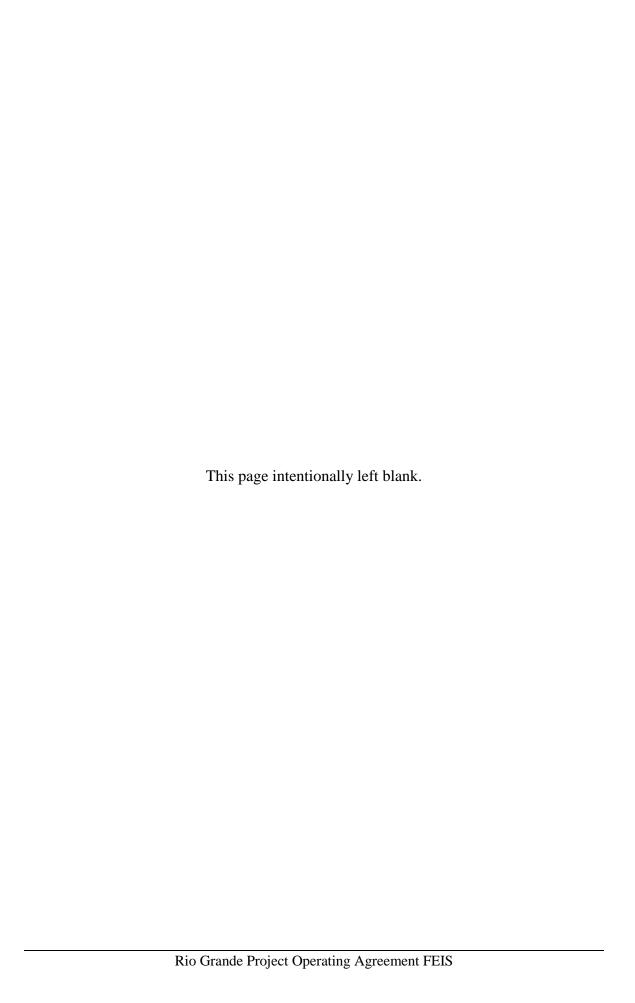
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or

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Summary

The Bureau of Reclamation (Reclamation) has prepared this final environmental impact statement (FEIS) to analyze the environmental impacts of continuing to implement the Rio Grande Project Operating Agreement (OA) through 2050. The OA is a written agreement describing how Reclamation allocates, releases from storage, and delivers Rio Grande Project (RGP) water to diversion points (headings) of the Elephant Butte Irrigation District (EBID) in New Mexico, the El Paso County Water Improvement District No. 1 (EPCWID) in Texas, and the Republic of Mexico (herinafter Mexico). In addition, Reclamation will use this FEIS to evaluate the environmental effects of a proposal to renew a contract to store San Juan—Chama Project water in Elephant Butte Reservoir.

Purpose and Need for Action

Operating Agreement

The purpose for action is to meet contractual obligations to EBID and EPCWID and comply with applicable law governing water allocation, delivery, and accounting. These obligations are currently fulfilled under the 2008 OA (Appendix A). The need for action is to resolve the long and litigious history of the RGP and enter into mutually agreeable, operational criteria that comply with applicable law, court decrees, settlement agreements, and contracts. These include the 2008 Compromise and Settlement Agreement among Reclamation, EBID, and EPCWID and contracts between the U.S. and EBID and EPCWID.

San Juan-Chama Project Storage

The purpose and need for a similar action is to respond to a request to renew a multiyear storage contract of San Juan–Chama Project water in Elephant Butte Reservoir in accordance with Public Laws 97-140 and 87-483.

The Rio Grande Project and Geographic Scope

The study area for this FEIS is the RGP in southern New Mexico and far western Texas in the Rincon, Mesilla, and El Paso Valleys (Figure 1). The study area begins in the north with Elephant Butte Reservoir and extends southward and downstream along the Rio Grande to the El Paso-Hudspeth County line in Texas. The study area includes the service areas of the two irrigation districts and also includes deliveries to Mexico at the Acequia Madre at El Paso, Texas.

Cooperating Agencies

Reclamation is the lead Federal agency in the preparation of this FEIS. Cooperating agencies include the U.S. Section of the International Boundary and Water Commission (USIBWC), the Colorado Division of Water Resources, EBID, EPCWID, and the Texas Rio Grande Compact Commissioner.

Changes since the Draft EIS

Reclamation published a notice of availability of the draft EIS (DEIS) in the *Federal Register* (81 Fed. Reg. 14886) on March 18, 2016. Notice of the availability of the DEIS was published in newspapers, on Reclamation's internet web page, social media, and e-mail. Reclamation held two public hearings during the comment period to give the public an opportunity to learn more about the alternatives and impacts and to comment on the DEIS. After receiving multiple requests to extend the public comment period, the period was extended to June 8, 2016.

During this draft public comment period, Reclamation received 148 comments in 24 comment documents from Federal, state, and local agencies, and the public. Appendix E of this FEIS includes the comments received and responses. In assessing and considering these comments, Reclamation revised this FEIS. One of the comments pointed out an error in the hydrology model, so the FEIS includes some revised water resources data in Chapter 4 and Appendix C. Chapter 4 was reorganized by resource rather than by alternative to clarify the differences due to the alternatives versus climate change. Information for most resources was edited to better define and explain potential impacts, and cumulative actions and impacts were placed in a separate chapter. In response to comments, the No Action Alternative was changed from Alternative 1 to Alternative 5, as described below and in Chapter 2 and Appendix E. Alternative 1 has been selected as the agency's preferred alternative.

Alternatives

The Council on Environmental Quality's (CEQ) regulations for implementing the National Environmental Policy Act (NEPA) require that all EISs include the alternative of no action. CEQ (1981; 46 Fed. Reg. 18026) says there are two distinct interpretations of no action. The first interpretation is "no change from current management direction" and is typically applied to management plans. CEQ explains that this interpretation of no action involves continuing with the present course of action or management until the action is changed. The second interpretation of no action is where a proposed activity would not take place and the resulting environmental effects from taking no action would be compared with the effects of permitting the proposed activity or an alternative activity to go forward. This is typically applied to construction actions.

Following CEQ's first interpretation of no action, the DEIS identfied Alternative 1 as the No Action Alternative because it involves continuation of the OA and San Juan-Chama storage contracts. The DEIS considered four other alternatives that vary in inclusion or exclusion of the allocation and accounting procedures established by the OA, the diversion ratio adjustment and carryover accounting, and storing San Juan-Chama Project water in Elephant Butte Reservoir. In the DEIS and this FEIS, Alternative 5 is consistent with past management practices prior to the OA, but based on comments received on the DEIS (see Appendix E, "Alternatives, No Action Alternative"), for this FEIS, Reclamation relabeled Alternative 5 as the No Action Alternative, applying CEQ's second interpretation of no action. The alternatives are summarized here and presented in detail in Chapter 2.

Alternative 1: Continuation of OA and San Juan-Chama Storage Contract, Preferred Alternative

Alternative 1 is Reclamation's preferred alternative. Alternative 1 includes continued implementation through the year 2050 of the operating procedures defined in the OA and corresponding Rio Grande Project Water Operations and Accounting Manual (Operations

Manual). Under Alternative 1, RGP allocation and accounting procedures would continue to include the diversion ratio adjustment and carryover accounting established by the OA and Reclamation would renew a contract to store up to 50,000 acre-feet of San Juan–Chama Project water in Elephant Butte Reservoir.

Alternative 2: No San Juan-Chama Project Storage

Alternative 2 is the same as Alternative 1 except that Reclamation would not store San Juan–Chama Project water in Elephant Butte Reservoir.

Alternative 3: No Carryover Provision

Alternative 3 is the same as Alternative 1 except that carryover accounting established by the OA would be excluded from RGP allocation and accounting procedures.

Alternative 4: No Diversion Ratio Adjustment

Alternative 4 is the same as Alternative 1 except that the diversion ratio adjustment established by the OA would be excluded from RGP allocation and accounting procedures.

Alternative 5: Prior Operating Practices, No Action Alternative

Alternative 5 (No Action) would eliminate both carryover accounting and the diversion ratio adjustment from RGP allocation and accounting procedures.

Selection of the Preferred Alternative

Based upon the analysis presented in this FEIS and after reviewing the comments and concerns of agencies, organizations and individuals (Appendix E), Reclamation's responsible official, the Regional Director of the Upper Colorado Region, selected Alternative 1 as the preferred alternative. At least 30 days after publishing a notice of availability of this FEIS, the Regional Director will sign a Record of Decision selecting an alternative and allowing implementation to proceed.

Major Conclusions

Based on the analysis of impacts of these alternatives in Chapters 4 and 5, major conclusions of the FEIS are as follows:

- **EBID's Annual Allocated Water**. Alternatives 1 and 2 would provide an average of 213,110 acre-feet under the central tendency climatic scenario. Alternative 3 would provide an average of 264,752 acre-feet; Alternative 4 would provide 272,269 acre-feet. Alternative 5 (No Action) would provide 314,327 acre-feet to EBID.
- **EPCWID's Annual Allocated Water**. Alternatives 1 and 2 would provide an average of 224,049 acre-feet under the central tendency climatic scenario. Alternative 3 would provide an average of 267,973 acre-feet; Alternative 4 would provide 207,296 acre-feet. Alternative 5 (No Action) would provide 239,317 acre-feet to EPCWID.
- **Total Storage**. Alternative 1 would provide an average of 483,445 acre-feet of total storage under the central tendency climatic scenario. Alternative 2 would provide an average of 455,233 acre-feet; Alternative 3 would provide 493,743 acre-feet; Alternative 4 would provide 465,907 acre-feet; and Alternative 5 (No Action) would provide 483,425 acre-feet.
- Elephant Butte Reservoir Elevation. Under the central tendency climate scenario, the average Elephant Butte Reservoir elevations would be 4,326 to 4,327 feet under all alternatives except that Alternative 2 would average 4,319 feet due to not storing San Juan-Chama Project water. As shown in Section 4.3, the differences in elevation would be greater

- (10 to 12 feet) due to the projected effects of future climate change than due to implementation of the alternatives.
- Special Status Species. Reclamation concluded that implementation of Alterantive 1 "may affect, and is likely to adversely affect" the Southwestern willow flycatcher (*Empidonax traillii extimus*) and Western yellow-billed cuckoo (*Coccyzus americanus occidentalis*). A "may affect, and is likely to adversely modify" determination for flycatcher critical habitat and cuckoo proposed critical habitat is based on water resources modeling presented in Sections 4.13-4.14 that shows that reservoir filling would inundate this habitat. The U.S. Fish and Wildlife Service (Service) concurred with these findings in a biological opinion issued on May 25, 2016.
- Regional Economic Impacts. Under the central tendency climate scenario, the regional economic impacts in Doña Ana and Sierra Counties, New Mexico, where EBID is located, would decrease compared to Alternative 5 for all action alternatives. The regional economic impacts estimated for El Paso and Hudspeth Counties, Texas, where EPCWID is located, would increase for all action alternatives compared to Alternative 5. Changes (positive and negative) would be small compared to the entire regional economies of the New Mexico and Texas and there would be no high or disproportionate adverse impacts on environmental justice communities.

Environmental Commitments

The EIS process will end with completion of a Record of Decision (ROD). The ROD shall explain the agency's decision and discuss plans for mitigating potential environmental effects and monitoring those commitments. Should Alternative 1 become the selected alternative, the following future commitments would be implemented.

- Under Alternative 1, Reclamation would continue to work with the USIBWC, EBID, and EPCWID to assess and determine the available supply, the release from storage, and delivery of RGP water.
- Under unforeseen or adverse conditions, Reclamation would continue to work with the USIBWC, EBID, and EPCWID under the parameters of the OA to resolve issues in an adaptive management framework.
- Reclamation has accepted the Service's biological opinion dated May 25, 2016 and would continue to monitor vegetation and listed species in coordination with the USIBWC.

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- B. Operations Manual
- C. Hydrology Technical Memorandum
- D. Consultation and Coordination Correspondence
- E. Comments-Responses

Acronyms and Abbreviations

<u>Acronym</u> <u>Full Phrase</u>

ABCWUA Albuquerque Bernalillo County Water Utility Authority

AFY acre-feet per year

CEQ Council on Environmental Quality

CFR Code of Federal Regulations
CFS cubic feet per second

Convention of 1906 Convention between the United States and Mexico

CWA Clean Water Act

DEIS draft environmental impact statement

EA environmental assessment
EBID Elephant Butte Irrigation District
EIS environmental impact statement
EPA U.S. Environmental Protection Agency

EPCWID El Paso County Water Improvement District Number 1
ESA Endangered Species Act
ET₀ Evapotranspiration

FEIS final environmental impact statement
Flycatcher Southwestern willow flycatcher

Gwh gigawatt-hour

HCCRD Hudspeth County Conservation and Reclamation District No. 1

IMPLAN IMpact analysis for PLANning

ITA Indian trust assets

MF-OWHM MODFLOW (modular finite-difference flow model);

One Water Hydrologic Model

M&I Municipal and industrial water

NEPA
National Environmental Policy Act
NHPA
National Historic Preservation Act
NMDA
New Mexico Department of Agriculture
NMDGF
New Mexico Department of Game and Fish
NMED
New Mexico Environment Department
NMEMNED
New Mexico Environment Department
NMEMNED
New Mexico Energy Minerals and Natural Resources Department

NMEMNRD New Mexico Energy, Minerals, and Natural Resources Department
NMOSE New Mexico Office of the State Engineer
NMRPTC New Mexico Rare Plant Technical Council

NMSP New Mexico State Parks

<u>Acronym</u> <u>Full Phrase</u>

OA Operating Agreement for the Rio Grande Project

Reclamation United States Department of the Interior, Bureau of Reclamation RGP Rio Grande Project, New Mexico and Texas

RMBHM Rincon and Mesilla Basin Hydrologic Model

SEA supplemental environmental assessment

Service United States Department of the Interior, Fish and Wildlife Service

TCEQ Texas Commission on Environmental Quality

U.S. United States

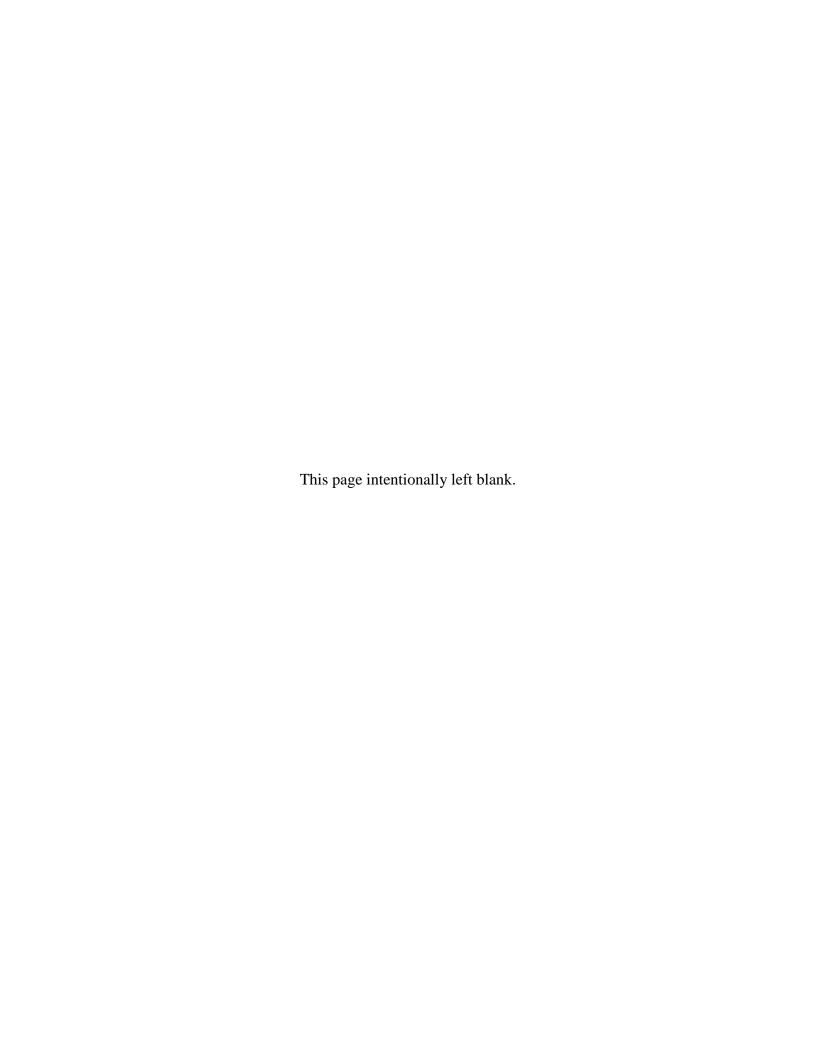
URGIA Upper Rio Grande Impact Assessment
URGSim Upper Rio Grande Simulation Model
URGWOM Upper Rio Grande Water Operations Model
USC United States Code

USDA United States Department of Agriculture USGS United States Geological Survey

USIBWC United States Section of the International Boundary and Water Commission

VIC Variable Infiltration Capacity Hydrology Model

WWCRA West Wide Climate Risk Assessment



1 Purpose of and Need for Action

1.1 Introduction

The Bureau of Reclamation (Reclamation) has prepared this FEIS to analyze the environmental effects of continuing to implement the OA for the RGP through the year 2050. The OA is a written agreement describing how Reclamation allocates, releases from storage, and delivers RGP water to two irrigation districts, the EBID and EPCWID, and to Mexico. In addition, Reclamation will use this FEIS to evaluate the environmental effects of a request to renew a multiyear contract for storing San Juan—Chama Project water in Elephant Butte Reservoir.

This FEIS has been prepared in compliance with NEPA, CEQ's NEPA implementing regulations (40 CFR 1500-1508), the U.S. Department of the Interior's NEPA regulations (43 CFR 46), and other relevant Federal and state laws, regulations, and policies.

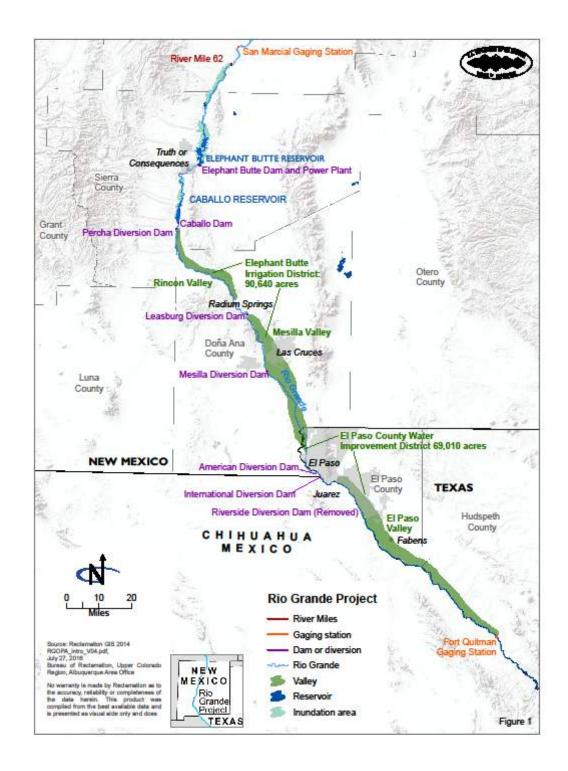
1.2 Rio Grande Project Operating Agreement

The OA is a written agreement describing how Reclamation allocates, releases from storage, and delivers RGP water to irrigation district diversion points (headings) of the EBID in New Mexico, EPCWID in Texas, and Mexico. The OA is Appendix A of this FEIS. It is described in Section 1.4.2.3 and in Chapter 2. The proposed action analyzed in this FEIS is continuing to implement the OA for the RGP for its remaining term, through 2050.

1.3 Rio Grande Project

The RGP is located in southern New Mexico and western Texas in the Rincon, Mesilla, and El Paso Valleys. Its facilities include the Elephant Butte and Caballo Dams and Reservoirs, a power generating plant, the Percha, Leasburg, Mesilla, American, and International Diversion Dams; 141 miles of canals, 462 miles of lateral ditches, and 457 miles of drains (Fig. 1). A sixth diversion dam, Riverside, was damaged by flood flows and was removed in 2003 to reduce flood hazards associated with further breaching.

Figure 1. Rio Grande Project in New Mexico and Texas.



Congress authorized the RGP under the authority of the Reclamation Act of 1902 and the Rio Grande Project Act of February 25, 1905, to serve lands in New Mexico and Texas. RGP water is made available to irrigate a variety of crops and for municipal and industrial (M&I) water uses. RGP water is also diverted to Mexico under the Convention between the United States and Mexico: Equitable Distribution of the Waters of the Rio Grande (Convention of 1906).

In 1907, Congress appropriated \$1,000,000 to pay for the portion of the RGP necessary to provide storage of water for fulfillment of the Convention of 1906. As for funding the rest of the RGP, under the Reclamation Act of 1902, Congress intended that water projects would be self-supporting: each would generate sufficient revenue to cover the costs of construction, operation and maintenance, and the total estimated costs would be equitably borne by project beneficiaries. Therefore, EBID and EPCWID were required to enter into contracts with Reclamation under which they would cover these costs. The Reclamation Act of 1902 further states that the right to use RGP water "shall be appurtenant to the land irrigated and beneficial use shall be the basis, the measure, and the limit of the right" (32 Stat. 390; 43 USC Sections 372 and 383). The contracts among Reclamation, EBID and EPCWID establish the allocation of water between the two districts based on the irrigable acreage within each district.

A history of the RGP may be found in the *Rio Grande Project* (Autobee 1994) and Appendix C of Reclamation (2013a).

1.4 Background

1.4.1 Operations Overview

The RGP provides surface water for irrigation in southern New Mexico and for irrigation and M&I use in western Texas. It also provides for the delivery of surface water to Mexico under the Convention of 1906. The RGP also provides hydropower generation as a secondary function. Operation of the RGP involves four primary functions:

- Capture and storage of Rio Grande streamflow in Elephant Butte and Caballo Reservoirs
- Allocation of RGP water to EBID, EPCWID, and Mexico
- Release of RGP water to satisfy delivery orders from EBID, EPCWID, and the USIBWC on behalf of Mexico
- Diversion of RGP water from the Rio Grande and delivery of RGP water to headings and municipal water treatment facilities for beneficial use

The Rio Grande Compact contains a schedule for water that must be delivered to Elephant Butte Reservoir every year. In addition, Reclamation allows storage of San Juan–Chama Project water in Elephant Butte Reservoir currently under annual contracts with the Albuquerque-Bernalillo County Water Utility Authority (ABCWUA).

1.4.1.1 Surface Water Supply

At the beginning of the calendar year and prior to the onset of the irrigation season, Reclamation determines the total water in RGP storage. Total storage includes Rio Grande Compact deliveries, which are comprised of any accumulated inflows, less evaporative losses in Elephant Butte and Caballo Reservoirs. Reclamation then calculates the total usable RGP water by subtracting all non-RGP storage, including San Juan—Chama Project water and Rio Grande Compact credit water, from the total water in storage.

In years when the total usable RGP water at the beginning of the calendar year is not sufficient to provide a full allocation, Reclamation reevaluates RGP storage each month during the irrigation season until a final allocation is reached.

1.4.1.2 Allocation of Rio Grande Project Water

Reclamation allocates RGP water supplies such that the diversion allocations to EBID and EPCWID are proportionate to each district's respective acreages. EBID includes 90,640 acres authorized to receive RGP water in the Rincon and Mesilla Valleys of New Mexico. EPCWID includes 69,010 acres authorized to receive RGP water in the Mesilla and El Paso Valleys of Texas. Of the 159,650 acres, 57 percent of the acreage is in EBID and 43 percent is in EPCWID.

The annual diversion allocation is the quantity of RGP water that is allocated each year for delivery to EBID, EPCWID, and Mexico at their respective diversion headings. The annual diversion allocation is calculated based on the amount of RGP water in storage available for release and the estimated amount of water available for diversion at river headings accounting for canal bypass, drainage return flows, and other inflows or losses to the Rio Grande between Caballo Dam and International Dam.

In addition to their allocations of surface water from the RGP, irrigators within EBID and EPCWID have historically relied on groundwater pumping for supplemental irrigation. It is recognized that groundwater pumping in the Rincon and Mesilla Valleys depletes RGP surface water supplies by increasing seepage losses from the Rio Grande and decreasing groundwater discharge to the Rio Grande and to the network of drains that extends throughout the RGP. The magnitude of surface water depletions due to groundwater pumping is currently being studied. While groundwater is used for supplemental irrigation in both EBID and EPCWID, estimates of pumping for irrigation within EBID are an order of magnitude larger than corresponding estimates for EPCWID.

To determine how to provide each district with its annual diversion allocation, EBID and EPCWID do most of the water monitoring in the river and of water coming into the river from drains and other sources. These data are shared between parties and are used to schedule RGP orders, releases, and deliveries. Reclamation then executes the releases determined by the districts. Under the Convention of 1906, the U.S. is obligated to deliver 60,000 acre-feet of water annually in a full allocation year. In drought years when the full allocation is not available, the allocation to Mexico is reduced in the same proportion as water delivered to the districts.

1.4.1.3 Release and Diversion of Rio Grande Project Water

Reclamation delivers water to each district's diversion headings based on their water orders. Each district then distributes water through its conveyance system to its water users for irrigation or M&I use. The two districts use RGP water to irrigate a variety of crops, including lettuce, chilies, onions, cotton, sorghum, and pecans. Through contracts with EPCWID, El Paso Water¹ also receives RGP water. These contracts allow irrigation water to be converted to M&I uses. El Paso Water owns or leases farmland with first class water rights by which it is able to convert the associated irrigation water to M&I uses (Texas Water Development Board 2016).

Drainage and tailwater from RGP lands at the terminus of the RGP (the El Paso-Hudspeth County line) provides supplemental water to 18,000 acres in the Hudspeth County Conservation and

¹ El Paso Water is the new official name for what used to known as El Paso Water Utilities. See http://www.epwu.org/public_information/news_releases/nr_160630-01.html. They are a utility that delivers water to residents of the City of El Paso.

Reclamation District No. 1 (HCCRD) in Texas. Because HCCRD only receives seepage and drainage water through a contract with Reclamation by way of the EPCWID irrigation system and does not receive a direct allocation of RGP water, deliveries to HCCRD do not affect primary RGP operations.

The USIBWC carries out and schedules the deliveries at the request of Mexico. RGP water allocated to Mexico under the Convention of 1906 is officially delivered in the bed of the Rio Grande at the point adjacent to the head works of the Acequia Madre in Ciudad Juárez, about two miles downstream of the point where the river becomes the international border.

1.4.2 Historic Operations

1.4.2.1 Project Initiation to 1979-1980

From 1908 through 1979, Reclamation operated the RGP. Reclamation determined the annual allotment of RGP water per acre of authorized land and delivered the annual allotment to farm headgates and to the Acequia Madre for Mexico.

In 1937, Congress authorized the execution of amended repayment contracts with EBID and EPCWID. These contracts reduced the repayment obligations and established a corresponding right of use to a proportion of the annual water supply, based on an established irrigated acreage in each district: 57 percent to EBID and 43 percent to EPCWID, as explained in Section 1.4.1.2.

The districts' amended repayment contracts also required three changes to occur to historical operations. First, once the two districts paid the total reimbursable costs for the RGP, they were required to take over the day-to-day responsibility for operating and maintaining the irrigation delivery and drainage system. Second, once this transfer of operation and maintenance occurred, Reclamation and the two districts agreed to formalize a set of operating procedures that would govern the operations of transferred project works. Third, on transfer, Reclamation would no longer calculate, allocate, and deliver water to project land; instead, it would deliver an annual diversion allocation to each district's headings.

In 1979-1980, the two districts paid off their construction obligations to the U.S. In 1979, Reclamation contracted with EBID to assume responsibility for operating and maintaining the Percha, Leasburg, and Mesilla Diversion Dams in New Mexico. In 1980, Reclamation contracted with EPCWID to transfer operation and maintenance for the Riverside Diversion Dam (removed in 2003) and the distribution and downstream drainage system in Texas, which delivers tailwater to the HCCRD. Both contracts required Reclamation and the districts to create a mutually agreeable, "detailed operational plan...setting forth procedures for water delivery and accounting."

1.4.2.2 Operations from 1980 to 2007

Beginning in 1980, Reclamation determined annual diversion allocations to each district and delivered water to the authorized points of diversion. The districts were then responsible for conveying water from the point of diversion to individual farm gates. Until a mutually agreeable operations plan was in place, Reclamation imposed ad hoc operating procedures to govern operations. It modified these procedures as needed between 1980 and 2007. During that time, Reclamation calculated, allocated, and delivered each district's annual diversion allocation; however, it modified and optimized the methods, equations, and procedures according to real-time water conditions. The lack of an operations plan led to conflicts and litigation during this period.

1.4.2.3 Operations from 2008 to Present

In 2008, EBID, EPCWID, and Reclamation agreed to execute and implement the OA as a settlement of the litigation then pending and filed by both districts. The three parties are the signatories of the OA. The term of the resulting 2008 OA is from January 1, 2008, until December 31, 2050 (Appendix A).

As a part of the OA, the three parties prepared the RGP Water Accounting and Operations Manual (Reclamation 2012d) that contains more detailed information regarding the methods, equations, and procedures used to implement the OA. The Operations Manual is an addendum to the OA and is found in Appendix B. It is consistent with the OA and does not modify the provisions in the OA. The parties to OA consult with each other to review the Operations Manual. The most recent revision was in 2012.

1.4.2.3.1 The OA, Operations Manual, and Diversion Ratio

The OA largely reflects historical operation of the RGP, with two key changes. First, the OA provides carryover accounting for any unused portion of the annual diversion allocations to EBID and EPCWID. Under historical operations prior to the OA, the unused portion of a district's annual allocation balance contributed to the total amount of usable water available for allocation to both districts during the following year. As a result, a portion of one district's unused allocation became part of the other district's annual allocation the following year. Under the OA, any unused portion of the annual diversion allocations to EBID and EPCWID, based on a regression line reflecting past delivery performance, referred to as the D-2 Curve, is carried over to that district's allocation balance the following year. The carryover provision of the OA is designed to encourage water conservation in the RGP by allowing each district to retain its unused allocation up to a specified limit.

Second, the OA adjusts the annual allocations to EBID and EPCWID to account for changes in RGP performance², as characterized by the diversion ratio. The diversion ratio is calculated as the sum of net allocation charges (i.e., sum of allocation charges minus allocation credits) to EBID, EPCWID, and Mexico divided by the total (cumulative) Project release from Caballo Dam over a specified period. The diversion ratio provision of the OA was developed to adjust the annual RGP allocations to the districts so as to provide RGP deliveries to EPCWID consistent with historical operations, prior to substantial increases in groundwater pumping within EBID and corresponding decreases in RGP performance. The annual RGP allocation to EBID is then adjusted to reflect current-year RGP performance as represented by the diversion ratio. When the diversion ratio is high, greater than one (>1.0), EBID generally receives an increase in allocation compared to historical RGP operations. When the diversion ratio is low, less than one (<1.0), EBID generally receives a decrease in RGP allocation compared to historical RGP operations.

While numerous factors affect RGP performance, recent changes in performance are predominantly driven by the actions of individual landowners within the EBID service area. These changes are:

- Crop selection and related effects on crop irrigation requirement
- Irrigation practices and related effects on farm irrigation efficiency

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² By "performance", we mean historical performance of the RGP. While this may not have been called "diversion ratio" in the past, historically Reclamation calculated the amount of water that was delivered to lands in relation to the amount that was released from storage to determine if there was enough water to increase the allocation to lands and Mexico.

• Widespread use of groundwater for supplemental irrigation, as permitted and regulated by the State of New Mexico

The diversion ratio provision of the OA ensures that annual allocations and deliveries to EPCWID are consistent with historical performance. Moreover, it ensures that deviations in performance relative to historical conditions would be accounted for by adjusting the annual allocation to EBID.

Under the diversion ratio provision, the annual project allocation to EPCWID is equal to the district's historical diversion allocation, based on a regression line reflecting past delivery performance, as defined by the D-2 Curve (Appendix A, Section 2.5). The annual allocation to EBID is adjusted to reflect current year (actual) project performance, as reflected by the project diversion ratio. Again, when the diversion ratio is high relative to the baseline delivery performance defined by the D-2 Curve, EBID generally receives an increase in annual allocation compared to its diversion allocation under prior operating practices. When the diversion ratio is low relative to the D-2 Curve baseline, EBID generally receives a decrease in project allocation compared to prior operating practices.

1.4.2.3.2 Principles Underlying the Operating Agreement

The provisions adopted in the OA for the RGP reflect Reclamation and the two districts' interest in equitable distribution of RGP water. These include Rio Grande surface waters and hydraulically connected groundwater in New Mexico and the portion of the Mesilla Valley in Texas. Implementing the OA fulfills contractual obligations among Reclamation and the two irrigation districts and resolves litigation in compliance with the legal settlement (Reclamation 2013a).

Surface Water/Groundwater Interaction

The interaction between the surface water and groundwater is a critical factor in understanding the OA. Previous studies (Conover 1954, Hanson et al. 2013, Haywood and Yager 2003, S.S. Papadopoulos & Associates, Inc. 2007 [henceforth SSPA 2007], Stringham et al. 2016) indicate a strong hydraulic connection between the Rio Grande and underlying groundwater aquifers in the areas served by the RGP, particularly in the Rincon and Mesilla Basins. Groundwater recharge via seepage and deep percolation of RGP water would continue under any alternative. In years when there is an increase in RGP allocation and delivery to EBID, there is a corresponding increase in recharge via seepage and deep percolation within EBID, as well as a decrease in demand for supplemental irrigation by groundwater pumping within EBID. Conversely, when there is a decrease in allocation, recharge and deep percolation decrease, demand for supplemental irrigation water increases, which may result in increased groundwater pumping within the district under permits issued by the State of New Mexico (Reclamation 2013a).

When groundwater elevations adjacent to the Rio Grande or a given drain segment are above the surface water elevation in the channel, the hydraulic gradient drives groundwater flows toward the channel (Fig. 2a). In this situation, groundwater discharge to the channel increases the available surface water supply. When groundwater elevations adjacent to the Rio Grande or a given drain segment are below the water elevation in the channel, the hydraulic gradient drives groundwater flow away from the river (Fig. 2b). In this situation, seepage from the channel into the underlying aquifer decreases the available surface water supply. In the event that groundwater elevations adjacent to a given channel segment fall substantially below the channel elevation, the channel may become hydraulically disconnected from the underlying aquifer (Fig. 2c). In this situation, seepage from the channel reaches a maximum rate and is no longer affected by fluctuations in groundwater elevation (Winter et al. 1998).

While numerous factors affect groundwater in the Rincon and Mesilla Valleys, groundwater pumping for supplemental irrigation is a primary driver of groundwater declines. In addition, irrigators within both the New Mexico and Texas portions of the RGP often supplement RGP surface water deliveries with groundwater from privately owned wells. Supplemental groundwater pumping is authorized and managed by the states, independently of the RGP and is currently the subject of litigation.

D-1 and D-2 Curves

The RGP serves irrigated lands in the Rincon, Mesilla and El Paso Valleys, as well as providing water to the City of El Paso for M&I uses. EBID provides water to 90,640 acres in the Rincon and Mesilla Valleys of New Mexico. EPCWID provides water to 69,010 acres in the Mesilla and El Paso Valleys of Texas (Fig. 1). Groundwater pumping in the El Paso Valley portion of EPCWID does not affect RGP deliveries (Reclamation 2015c). This is because the effects of pumping occur downstream of RGP diversion points for the El Paso Valley portion of EPCWID.

The OA represents mutually agreeable procedures for water delivery and accounting by Reclamation to satisfy objections by both districts in how deliveries were provided starting in 1980. The D-1 and D-2 Curves used by Reclamation to determine annual RGP allocations represent the effects of inflows and losses within the RGP on historical RGP performance.

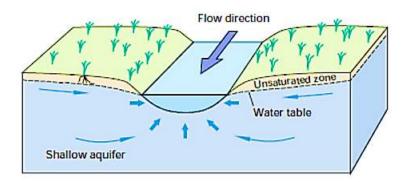
The D-1 and D-2 Curves were developed from operations data from 1951 to 1978. They reflect historical project performance during those years, including the effects of losses and inflows on project deliveries. The climatic and hydraulic conditions during these years ranged from low-flow drought conditions to high-flow full water supply. The D-1 Curve, used for making the allocation to Mexico, is a linear regression equation that represents the historical relationship between the total annual release from RGP storage and the total project delivery to lands within the U.S., plus delivery in the bed of the river at the point adjacent to the head works of the Acequia Madre. The D-2 Curve, used for making the water allocation to the districts, is a linear regression equation that represents the historical relationship between the total annual release from project storage and the total project delivery to canal headings on the Rio Grande. It includes delivery to all authorized points of diversion for EBID, EPCWID, and Mexico.

Adaptive Management

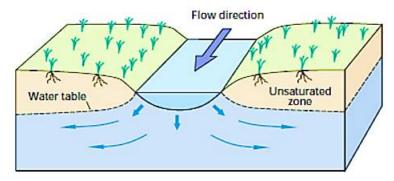
The OA and Operations Manual are intended to establish the overarching approach for management of the RGP, but it is recognized that they do not cover every possible contingency and may require adjustment. Under the principle of adaptive management (Holling 1978, Walters 1986), when unforeseen conditions or events occur in the future, the parties to the OA, consisting of Reclamation, EBID, and EPCWID, would consult and use their professional judgement and experience to adaptively manage the operations of the project.

Figure 2. Surface water and groundwater interaction; a gaining stream; b losing stream; c disconnected stream.

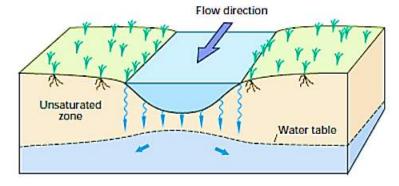
a. Gaining stream



b. Losing stream



c. Disconnected stream



Source: Winter et al. (1998).

1.4.3 San Juan-Chama Storage Contract

This FEIS evaluates the environmental effects of renewing multiyear contracts for storing San Juan–Chama Project water in Elephant Butte Reservoir, under the authority of Public Law 97-140 (95 Stat. 1718). The San Juan–Chama Project was authorized as a participating project of the Colorado River Storage Project Act in 1956. It consists of a system of diversion structures, transbasin tunnels, and a storage reservoir to transfer water from the San Juan River in the Colorado River Basin to the Rio Chama in the Rio Grande Basin. San Juan–Chama Project repayment contractors receive their annual water allocations with no provisions for carryover; therefore, these contractors may benefit by storing unused annual allocations in Elephant Butte Reservoir for future use.

1.5 NEPA Analyses History

1.5.1 Operating Agreement

Two NEPA documents were prepared for the OA before this FEIS. In 2007, Reclamation prepared an environmental assessment (EA) to evaluate the effects of the OA through 2012. This EA committed Reclamation to gather data over the first five years of implementation to evaluate effects on the environment (Reclamation 2007).

In 2013, Reclamation supplemented the 2007 EA (SEA). This SEA was initially intended to analyze the potential impacts of implementing the OA through 2050. However, given the uncertainties of persisting drought and the need to improve analytical tools, Reclamation determined that analysis of a longer period would have been of limited use (Reclamation 2013a, b). In 2013, Reclamation began developing and refining modeling tools to thoroughly analyze the effects of implementing the OA through 2050, as documented in this FEIS.

1.5.2 San Juan-Chama Storage Contract

In 2010, Reclamation prepared an EA for a 40-year contract for storing ABCWUA's San Juan—Chama Project water in Elephant Butte Reservoir. The long-term contract was never implemented because information became available that rendered the associated Finding of No Significant Impact obsolete. Since 2010, Reclamation has been executing an annual contract with ABCWUA to store up to 50,000 acre-feet of San Juan—Chama Project water in Elephant Butte Reservoir, covered by categorical exclusions. Once stored, San Juan—Chama Project water is not included in the total RGP storage for purposes of allocations, but is maintained as a separate pool until exchanged upstream. The ABCWUA has proposed extending the contract to store San Juan—Chama Project water in Elephant Butte Reservoir through 2050.

1.6 Proposed Action

Reclamation is proposing to continue implementing the 2008 OA for the RGP for its remaining term, through 2050. In addition, it is proposing a similar action (as defined at 40 CFR 1508.25(a)(3)) of implementing long-term contracts for storing San Juan—Chama Project water in Elephant Butte Reservoir. The proposed action and alternatives are described in Chapter 2.

1.7 Purpose and Need for Action

1.7.1 Operating Agreement

The purpose for action is to meet contractual obligations to EBID and EPCWID and comply with applicable law governing RGP water allocation, delivery, and accounting. The purpose is also to provide a method to mitigate for the effects on the RGP of groundwater interaction in the Rincon and Mesilla Valleys. The need for action is to resolve the long and litigious history of the RGP by having mutually agreeable, detailed operational criteria.

1.7.2 San Juan-Chama Project Storage

The purpose and need for a similar action is to respond to a request to renew a multiyear storage contract of San Juan–Chama Project water in Elephant Butte Reservoir in accordance with the Act of December 29, 1981, Public Law 97-140. A similar action is defined by CEQ's regulations (40 CFR 1508.25(a)(3)) as actions that, when viewed with a proposal, have similarities such as common timing or geography that provide a basis for evaluation together. The analysis of a long-term contract for storing San Juan–Chama Project water in Elephant Butte Reservoir is a potentially similar action sharing common timing and geography with the OA. It is considered along with the proposed action of continuing to implement the 2008 OA.

1.8 Compliance with Other Authorities

In addition to meeting the requirements of NEPA, this FEIS documents compliance with other environmental laws and policies such as:

- Endangered Species Act (ESA)
- National Historic Preservation Act (NHPA)
- Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations
- Executive Order 13007, Indian Sacred Sites
- Executive Order 13112, Invasive Species
- Executive Order 13175, Tribal Consultation

1.9 Public Scoping

Public scoping began with publication of a notice of intent to prepare an EIS in the *Federal Register* (79 FR 2691) on January 15, 2014. The public was notified of the start of the NEPA review and scoping by:

- Placing newspaper advertisements in the *Santa Fe New Mexican* on January 27 and 28, 2014, the *Albuquerque Journal* on January 26, 2014, the *Las Cruces Sun News* on January 26, 2014, and the *El Paso Times* on January 26, 2014
- Announcing the public scoping meetings via Reclamation's social media sites and the project website (http://www.usbr.gov/uc/albuq/rm/RGP/)

Scoping meetings were held on both weekday and weekend dates and during both daytime and evening. Reclamation held three public scoping meetings at each of the following locations:

- Thursday, January 30, 2014, 3:00 p.m. to 5:00 p.m.—Reclamation, Albuquerque Area Office, 555 Broadway NE, Suite 100, Albuquerque, New Mexico
- Friday, January 31, 2014, 6:00 p.m. to 8:00 p.m.—Elephant Butte Irrigation District, 530 South Melendres Street, Las Cruces, New Mexico
- Saturday, February 1, 2014, 9:00 a.m. to 11:00 a.m.—Reclamation, El Paso Field Division, 10737 Gateway West, Suite 350, El Paso, Texas

Reclamation staff conducted the meetings, prepared the handouts, and answered questions. Persons attending the Albuquerque and Las Cruces meetings were primarily representatives of government agencies, but only Reclamation staff attended the meeting in El Paso. (Therefore, a hearing on the DEIS was not held in El Paso.)

Two comment letters were received during the scoping process, one from the New Mexico Interstate Stream Commission and the other from the City of Las Cruces. More information on the scoping process, including comments received, may be found in the NEPA Scoping Summary Report (Reclamation 2014c), which is also available on the project website (http://www.usbr.gov/uc/albuq/rm/RGP/). Reclamation took these comments into consideration in preparing this FEIS. In addition, comments received on the DEIS were considered in finalizing the FEIS.

1.10 Key Issues

Key issues or resources relevant to the analysis were identified based on the SEA (Reclamation 2013a), public comments and concerns raised during scoping, from internal scoping, and outreach to Federal, state, and local agencies and tribal governments; and legal, regulatory or policy requirements. The following issues or resources are analyzed in detail in this FEIS.

- Water Resources: total storage, Elephant Butte Reservoir elevations, allocation, releases, net diversion, farm surface water deliveries, farm groundwater deliveries, groundwater elevations, water quality
- Biological Resources: vegetation communities including wetlands, wildlife, aquatic species, and special status species and critical habitat
- Cultural Resources: historic properties, Indian sacred sites, and resources of tribal concern
- Socioeconomic Resources: Indian trust assets, recreation, hydropower, regional economic impacts and economic benefits, and environmental justice.

2 Alternatives

This chapter describes five alternatives analyzed in detail in this FEIS. This chapter also explains the criteria for selecting the preferred alternative and discusses alternatives that were considered, but not analyzed in detail.

2.1 Alternatives Development Process

Formulation of alternatives began in the fall of 2014 and continued through early 2015. Reclamation received suggestions for alternatives during scoping and these were considered during the alternatives development process. Additional alternatives were proposed during the public comment period for the FEIS in 2016.

A key step in the alternatives development process was a workshop held on November 4, 2014, at Reclamation's office in El Paso, Texas. Reclamation staff, contractors, and representatives of the cooperating agencies at that time: EBID, EPCWID, USIBWC, the City of Santa Fe, and the Rio Grande Compact Commission's Texas Commissioner—participated in the workshop in person or remotely. Workshop participants reviewed and discussed the purpose and need statement to assess where there was discretion for considering alternatives to current practices. The workshop included facilitated discussions of the alternatives. It also clarified the difference between annual implementation of the Operations Manual and the overall water supply allocation process described in the OA.

Reclamation reviewed the output of the screening exercise and outlined the elements of the alternatives to be carried forward for further review. Reclamation determined that the carryover provision and the diversion ratio adjustment were the basis of the settlement agreement and represented variables or elements for creating a reasonable range of alternatives. Reclamation also determined that due to similar geography and timing, the environmental effects of storing San Juan–Chama Project water in Elephant Butte Reservoir should be analyzed in the EIS.

2.2 Description of Alternatives

The alternatives were derived from the methods, equations, and procedures that Reclamation, EBID, and EPCWID use in determining the annual diversion allocation and water accounting for the RGP. As shown in Table 2-1, the alternatives vary in inclusion of the diversion ratio adjustment, carryover accounting, and the San Juan-Chama storage contract.

2.2.1 Operational Elements Common to All Alternatives

Some elements of project operations are common to all alternatives and would not vary. Reclamation would continue to store, allocate, release, and deliver RGP water for authorized uses in the U.S. and for delivery to Mexico under all alternatives. Reclamation would continue to determine annual allocations based on the usable water in RGP storage available for release during the current year. This includes usable water in storage at the start of the year. Added to this is any usable water that becomes available during the year as inflow to RGP storage or as relinquishment of Rio Grande Compact credit waters.

Under all alternatives, annual diversion allocations to EBID, EPCWID, and Mexico would continue to be based on two linear regression relationships between RGP releases and RGP deliveries, referred to as the D-1 and D-2 Curves, as described in Section 1.4.2.3.2 of Chapter 1. Reclamation and the USIBWC developed the D-1 Curve in 1980 to calculate the annual allocation to Mexico when less than a full supply is available. In accordance with the Convention of 1906, the annual RGP allocation to Mexico is 60,000 acre feet per year (AFY), except in years of extraordinary drought or serious accident to the U.S. irrigation system. The water for Mexico is officially delivered in the bed of the Rio Grande at the point adjacent to the head works of the Acequia Madre, in cooperation with the USIBWC.

The D-2 Curve represents the total (gross) amount of water available for diversion from the Rio Grande by EBID, EPCWID, and Mexico during the year under historical RGP performance conditions. The amount of water available for diversion in the U.S. by EBID and EPCWID would be determined by subtracting the annual allocation to Mexico from the total volume of water available for diversion during the year, as calculated by the D-2 Curve. EBID would then be allocated 88/155^{ths} (57 percent) of the volume of water available for diversion and EPCWID would be allocated 67/155^{ths} (43 percent).

The annual diversion allocations to EBID, EPCWID, and Mexico would continue to be based on the D-1 and D-2 Curves. RGP releases would continue to be scheduled and managed to meet delivery orders submitted by EBID, EPCWID, and USIBWC on behalf of Mexico.

2.2.2 Alternatives

Five alternatives are carried through detailed analysis in this FEIS. Table 0-1 highlights the differences among alternatives.

Alternative 1—Continuation of OA and San Juan-Chama Storage Contract, Preferred Alternative

- Continue to implement the diversion ratio adjustment provision of the OA in computing annual diversion allocations
- Continue to implement the carryover accounting provisions of the OA, which allows carryover of unused allotment balance from one year to the next
- Continue to store up to 50,000 acre-feet of San Juan–Chama Project water in Elephant Butte Reservoir

Alternative 1 is the continued implementation through 2050 of the operating procedures defined in the OA and Operations Manual, as amended for any given year. Under these operating procedures, the carryover accounting and diversion ratio provisions would continue. Reclamation would continue to implement a contract through 2050 with the ABCWUA to store up to 50,000 acre-feet of San Juan—Chama Project water in Elephant Butte Reservoir. Details of data, inputs, and calculations used in the allocation procedure are described in Table 4 of the OA (Appendix A). Additional details on allocation calculations are provided in the Operations Manual (Appendix B).

Under the OA, representatives of EBID, EPCWID, and Reclamation consult to establish the monthly and final water allocations for the year for each district and Mexico and review the Operations Manual. The manual was last updated in 2012 to clarify calculations used in the allocation procedure and to optimize operations (Reclamation 2012e).

Alternative 2—No San Juan-Chama Project Storage

- Continue to implement the diversion ratio adjustment provision of the OA in computing annual diversion allocations
- Continue to implement the carryover accounting provisions of the OA, which allows carryover of unused allotment balance from one year to the next
- Do not store any San Juan–Chama Project water in Elephant Butte Reservoir

Alternative 2 is the same as Alternative 1, except Reclamation would not continue with contracts to store San Juan–Chama Project water in Elephant Butte Reservoir. Alternative 2 allows Reclamation to model and determine the effects of storing San Juan-Chama Project water in the RGP.

Alternative 3—No Carryover Provision

- Continue to implement the diversion ratio adjustment provision of the OA in computing annual diversion allocations
- Do not implement the carryover accounting provisions of the OA
- Eliminate the carryover allocations and relinquish the unused allotment balance at the end of each calendar year
- Continue to store up to 50,000 acre-feet of San Juan–Chama Project water in Elephant Butte Reservoir

Alternative 3 is the same as Alternative 1, except Reclamation would not implement the carryover accounting provisions of the OA. Alternative 3 allows Reclamation to model and determine the effects of the carryover provision.

Alternative 4—No Diversion Ratio Adjustment

- Do not implement the diversion ratio adjustment provision of the OA
- Compute annual diversion allocations based only on the D-1 and D-2 regression equations without adjusting for variations in RGP performance
- Continue to implement the carryover accounting provisions of the OA, which allows carryover of unused allotment balance from one year to the next
- Continue to store up to 50,000 acre-feet of San Juan–Chama Project water in Elephant Butte Reservoir

Alternative 4 is the same as Alternative 1, except Reclamation would not implement the diversion ratio adjustment provision of the OA. Alternative 4 allows Reclamation to model and determine the effects of the diversion ratio adjustment provision.

Alternative 5—Prior Operating Practices, No Action Alternative

- Do not implement the diversion ratio adjustment provision of the OA
- Compute annual diversion allocations based only on D-1 and D-2 Curves regression equations that reflect historical conditions
- Do not implement the carryover accounting provisions of the OA
- Eliminate the provision for carryover allocations for each district
- Continue to store up to 50,000 acre-feet of San Juan–Chama Project water in Elephant Butte Reservoir

For this FEIS, Alternative 5 is the No Action Alternative. It allows a comparison through 2050 of operations under the OA and a simulation of procedures prior to the OA which did not apply the carryover allocation accounting for each district and diversion ratio adjustment provisions in the calculation of the allocation to EBID. Alternative 5 is the best possible representation of prior operating practices in a modeling context and is based on strict application of the D-1 and D-2 Curves.

Table 2-1 Key elements of alternatives

			Continue Storage of San
	Continue Diversion Ratio	Continue Carryover	Juan–Chama Project
Alternative	Adjustment	Accounting	Water
1	•	•	•
2	•	•	
3	•		•
4		•	•
5			•

Because they are not part of the OA, the alternatives do not include the following:

- Changes to the dams, storage facilities, the power generating plant, diversion facilities, and delivery points
- Negate obligations under the Convention of 1906 and the Rio Grande Compact or compliance with various court decrees, settlement agreements, and contracts
- Construction of new facilities or other actions that are physically different from or that exceed the bounds of historic operations within the RGP
- Changes to the basic operation of the dams and other RGP facilities
- Changes to the channel capacity

The alternatives analyzed in this FEIS vary in including or excluding the carryover provision, diversion ratio adjustment, and the San Juan-Chama storage contract. The range of alternatives is designed to determine whether these elements would result in environmental impacts when simulated using a hydrology model described in Section 4.1 of Chapter 4.

Continuing to implement the OA is part of the settlement of litigation between Reclamation and the two districts. Since 1979 and 1980, Reclamation, EBID, and EPCWID have had contractual obligations resulting from the transfer of the irrigation and drainage facilities from Reclamation to each district to agree on a detailed operational plan, setting forth procedures for allocation, delivery, and accounting of RGP water. This need was finally satisfied in 2008 when the three parties entered into the 2008 settlement agreement, which required implementing the OA and the Operations Manual (Reclamation 2014c). Alternative 1 represents the operational procedures in place since 2008 and an existing agreement among Reclamation and the districts to continue implementing the OA through 2050. Alternative 5 represents the No Action Alternative.

2.2.2.1 Carryover Provision

The carryover provision of the OA provides for carryover accounting for the unused allocation balances remaining on EBID's and EPCWID's respective RGP water accounts at the end of each year. If either district does not use all of its total diversion allocation during a given year, for purposes of modeling for this FEIS, the corresponding quantity of water that would have been

released from RGP storage to satisfy the unused portion of the district's allocation instead would remain in storage at the end of the year.

Each district may accrue and maintain carryover balance for any period of years up to 60 percent of its respective full annual allocation under the OA. EBID, therefore, may accrue carryover balance up to a limit of 305,918 acre-feet and EPCWID may accrue carryover balance up to 232,915 acre-feet. In the event that either district accrues carryover balance in excess of their respective limit, the excess balance would be transferred to the other district's RGP water account.

The carryover provision of the OA does not affect the procedure used to determine the annual RGP allocation to Mexico. In accordance with the Convention of 1906, the allocation to Mexico would be 60,000 AFY, except in years of extraordinary drought or serious accident to the U.S. irrigation system. During extraordinary droughts, the annual allocation to Mexico would be determined based on the total release from storage and annual delivery to lands within EBID and EPCWID, plus total deliveries to the heading of the Acequia Madre, as calculated using the D-1 Curve. (See Section 1.4.2.3.2.)

2.2.2.2 Diversion Ratio Adjustment

As described in Section 1.4.2.3, the diversion ratio represents the amount of diversion allocation that is used per unit release of RGP water from Caballo Dam. It is a measure of RGP performance in meeting delivery obligations to EBID, EPCWID, and Mexico. The OA provides the method for determining the initial annual diversion allocations to EBID and EPCWID. It also includes the methods for adjusting these allocations based on RGP performance, as measured by the diversion ratio, which is affected by groundwater levels, and return flows to the Rio Grande.

As described in Section 1.4.2.3.1, Reclamation uses the diversion ratio to adjust allocations to EBID and EPCWID to account for changes in RGP performance. This is done to account for the effects of groundwater and surface water conjunctive use by irrigators in the Rincon and Mesilla Basins, on current year RGP performance. The diversion ratio adjustment ensures that the annual RGP allocation to EPCWID is consistent with historical RGP performance, as characterized by the D-2 Curve. It also ensures that deviations in RGP performance are accounted for by adjusting the annual RGP allocation to EBID.

Calculating annual allocations to EBID and EPCWID under the OA involves additional adjustments under some conditions. A positive adjustment (increase) is applied to both districts' allocations when the usable water available for current-year allocation is greater than 600,000 acre-feet and current (actual) RGP performance exceeds the historical D-2 baseline. A negative adjustment (decrease) is applied to both districts' allocations during extreme droughts. These are defined as consecutive years where RGP releases are below 400,000 AFY.

The OA implemented a minor modification to the application of the D-2 Curve. The 763,842 acre-feet for a full allocation release was increased to 790,000 AFY as specified as the normal release in the Rio Grande Compact.

2.2.2.3 San Juan-Chama Storage

Alternatives 1, 3, 4, and 5 include storing San Juan–Chama Project water in Elephant Butte Reservoir. The ABCWUA is seeking to renew a multiyear contract for storage of up to 50,000 acre-feet of San Juan–Chama Project water in Elephant Butte Reservoir through 2050.

2.3 Alternatives Eliminated from Detailed Study

This section discusses alternatives that were considered but eliminated from detailed study and explains the reasons for their elimination.

2.3.1 Removing Credits and Charges and Using Actual Deliveries of Water in Accounting

The New Mexico Interstate Stream Commission submitted an alternative during scoping and again during the DEIS comment period requesting analysis of an alternative to remove credits and charges in water accounting for the RGP. Allocation charges reflect the volume of surface water diverted from the Rio Grande; allocation credits reflect the volume of water bypassed or returned to the Rio Grande and available for diversion at a downstream diversion point. In general, allocation charges are computed as the greater of the volume of water ordered for diversion at a specified diversion point and the volume of water actually diverted; alternatively, allocation credits are computed as the lesser of the volume of water ordered or bypassed at specified bypass points and the actual volume of water bypassed or returned to the Rio Grande. Depending on the allocation charges and credits on corresponding RGP water orders promotes efficient operation of the RGP by creating an incentive to divert all water ordered or available. This was not carried forward for several reasons. First, because it would remove the incentives for efficient operations which would increase water use throughout the project area and reduce the amount of allocation for EBID due to a reduction to the diversion ratio. Second, charges are a method of tracking allocation use. If charges were removed, then there would be no way to track the allocation used by each district. This would be contrary to contracts among Reclamation and the two districts. Largely because of the second reason, i.e., being contrary to contracts, it means this alternative would not meet the purpose and need for action.

2.3.2 Change the Rio Grande Compact Accounting Point to San Marcial

During scoping, a request was made to change the Rio Grande Compact accounting point back to San Marcial. This alternative was not carried forward because it does not meet the purpose of and need for the proposed action. Specifically, changing the Compact accounting point is beyond Reclamation's authority. Such a change would require a resolution of the Rio Grande Compact Commission, such as the change that was made in 1948 which changed the accounting point from San Marcial Station to storage in Elephant Butte Reservoir.

2.3.2 Add Point of Diversion for La Mancha Wetlands

During the comment period, the Southwest Environmental Center request a new diversion point on the river to divert surface water to the La Mancha wetlands. This alternative was not carried forward because it does not meet the purpose of and need for action. It is also beyond Reclamation's authority to grant this request. New diversions on the river would require coordination with the USIBWC, EBID, and others.

2.3.3 Change Carryover Accounting to Reflect Actual Conservation

Reclamation considered a suggestion to analyze changing carryover accounting to reflect conservation. Conservation is not how carryover is determined. Accumulation of carryover in each district's account is not only dependent on conservation, but it is a summation of the water allotted at the point of diversion against the water diverted and charged against their account.

2.3.4 Changes in Drought Factor and Evaporation Calculations

Reclamation considered alternative elements to address how evaporation losses are calculated and potentially adjusting the drought factor. These elements were not carried forward as part of the

final alternatives because they are potential adjustments that could be made by revising the Operations Manual.

2.3.5 Climate Change and Compact Modeling and Analysis Assumptions

Reclamation received requests for new alternatives to account for changes in RGP efficiency caused by climate change and alternatives looking at Rio Grande Compact credit water accounting. These requests are not true alternatives, but are modeling and analysis assumptions or parameters contributing to the effects analysis in Chapters 4 and 5.

2.3.6 Impairment from Groundwater Pumping

A proposal was submitted to consider taking action if impairment from groundwater pumping depletes the RGP water supply. Actions which Reclamation may take outside the OA are outside the scope of the proposed action and are too speculative to attempt to analyze in this FEIS.

2.3.7 Mimic Natural Hydrograph

During the public comment period on the DEIS, two comments were made requesting new alternatives of modifying releases to mimic the natural flow regime, with higher water released in spring and lower water released in summer and fall to benefit native plants and wildlife. The alternative to release water for such purposes is beyond Reclamation's authority and does not meet the purpose and need for action for this FEIS.

2.3.8 Mitigation Measure to Revegetate

A request was made during the public comment period on the DEIS to add a mitigation measure of planting cottonwoods and willows in the reservoir pool following reservoir drawdowns. Reclamation considered this request, but given the cycles of filling and drawdown of the reservoirs, there would be natural regeneration occurring and such proposed revegetation would not be required. However, Reclamation has committed to monitor vegetation changes and meet with the Service to assess the habitat (cottonwoods, willows, and tamarisk) available for the Southwestern willow flycatcher and the Yellow-billed cuckoo. Revegetation would be considered in the future as needed to comply with the ESA.

2.3.9 San Juan-Chama Storage Alternative Contract Options

During scoping, Reclamation considered various alternatives for differing amounts or durations of storage of San Juan–Chama Project water in Elephant Butte Reservoir. While working on the DEIS, the ABCWUA requested renewal of a long-term contract for storing up to 50,000 acrefeet. Analysis under Alternative 2 allows comparison of the effects of this proposed San Juan–Chama Project storage.

During the public comment period on the DEIS, Reclamation received several comments suggesting expansion of the geographic scope of analysis to analyze the effect of future exchanges of San Juan-Chama Project water upstream. The modelling approach used to evaluate the San Juan-Chama Project storage provides a reasonable analysis of environmental effects within the scope of this FEIS. Any environmental effects related to San Juan-Chama Project water above Elephant Butte Reservoir or exchanges are out-of-scope for this FEIS. Any environmental effects related to San Juan-Chama water flowing downstream or exchanges upstream are out-of-scope for this FEIS, but will be analyzed when such actions are ripe for analysis. This FEIS analyzes the effects of storage of San Juan-Chama water and the resulting higher water elevations in Elephant Butte Reservoir as a result of ABCWUA's proposed contract.

2.3.10 Store Project Water in Higher Elevation Reservoirs Upstream

An environmental organization requested evaluation of an alternative of storing water in upstream reservoirs that have lower evaporation rates and could offer benefits to riparian and riverine habitats. The Rio Grande Compact (Article IV) requires New Mexico to deliver water to Elephant Butte Reservoir. The Compact contemplates storage of water in upstream reservoirs and actually requires such storage of water in upstream reservoirs to the extent of any accumulated debit in Compact deliveries, consistent with the physical limitations of such reservoirs. Article VII, however, generally prohibits increases in storage in upstream reservoirs constructed after 1929 when there is less than 400,000 acre feet of water stored in Elephant Butte Reservoir. Upstream storage does not meet the purpose and need for action and this would require a Compact amendment. Therefore, this is not analyzed in this FEIS.

2.4 Comparison of Alternatives and Selection of Preferred Alternative

Table 2-1 illustrates the differences among alternatives. The preferred alternative is Alternative 1. It incorporates carryover accounting, the diversion ratio provision, and the storage of San Juan-Chama water in Elephant Butte Reservoir. The preferred alternative is the alternative Reclamation believes would fulfill its statutory mission and responsibilities, considering environmental, technical, economic, and other factors described in Chapters 4 and 5, and best meets the purpose and need for action. See Chapters 4 and 5 for comparisons of effects of the alternatives.

3 Affected Environment

This chapter describes the water resources, biological, cultural, and socioeconomic resources that would be affected by implementation of the alternatives presented in Chapter 2 or whose review is required by law, regulation, or policy.

3.1 Resources Considered

Resources or resource topics analyzed and not analyzed in this FEIS are presented in Table 3-1. The resources considered but not analyzed may not be present in the study area or they may not be relevant to the scope of the Federal action. In other cases, any potential to affect the resource may be negligible or speculative. This determination is based on scoping, input from cooperating agencies, prior NEPA review (Section 1.5), and the experience of interdisciplinary team members.

Table 3-1 Resources and issues analyzed in the FEIS

Resource	Relevance	Agency Determination	
Aesthetics	Not included	This resource issue is not relevant to the scope of the action.	
Agriculture, Farmlands	Included	Socioeconomic analysis includes economic benefits and impacts related to agriculture, but Farmland Protection Policy Act compliance is not required because of the assumption of a constant cropping pattern and no change in farm numbers or acreage. Contract freeze RGP acreage at 159,650 acres. Furthermore, RGP delivers water to the headings and not individual farms.	
Air quality	Not included	There would be no effects to air quality related to the alternatives and no compliance with the Federal Clean Air Act is required.	
Biological resources	Included	Aquatic species, vegetation and wetlands, and wildlife and special status species, and invasive species are relevant to the scope of the action and are included in the FEIS.	
Climate change	Included	The alternatives would not affect climate change, but climate change would affect other resources and is included in the water resources modelling presented in Chapter 4.	
Cultural resources	Included	Historic properties, Indian sacred sites, and resources of tribal concern are relevant to the scope of the action.	
Environ-mental justice	Included	This is relevant to the scope of the Federal action based on the presence of minority and low-income communities in the study area per Executive Order 12898.	
Geology, soils, paleontology	Not included	There would be no effects on geology and soils related to the alternatives. Although paleontological resources have been found within Elephant Butte Reservoir, there is negligible potential to affect paleontological resources based on the scope of the action.	
Indian trust assets	Included	There are no Indian trust assets in the project area; however, Secretarial Order 3335 and Reclamation policy require description of this resource.	

Noise	Not	There are no effects on noise related to the action.	
	included		
Hydro-power,	Included	CEQ regulations at 40 CFR 1502.16 require consideration of	
Energy		energy requirements of alternatives. Hydropower is relevant	
		due to generation at the Elephant Butte Powerplant.	
Recreation	Included	Relevant due to public recreational opportunities provided by	
		RGP reservoirs, state parks, and the river.	
Socio-economics	Included	Relevant to the scope of the Federal action due to potential	
		economic benefits and regional economic indicators.	
Solid and	Not	There would be no generation of solid or hazardous wastes	
hazardous waste	included	related to the action.	
Traffic	Not	There would be no effects on traffic or transportation related	
	included	to the action.	
Water resources	Included	Surface water and groundwater are relevant to the scope of	
		the action.	
Water quality	Included	Water quality is relevant to the scope of the action.	

3.2 Geographic Scope

Geographic areas of analysis vary by resource or resource issue. For all resources, the geographic area of analysis begins with Elephant Butte Reservoir in the north and extends downstream along the Rio Grande to the El Paso-Hudspeth County line. Reservoirs located upstream of Elephant Butte Reservoir are operated independently of the RGP and any environmental effects related to operations of these reservoirs or the effects of San Juan-Chama water flowing downstream to Elephant Butte Reservoir have either been analyzed in prior NEPA reviews or would be analyzed in the future depending on the alternative selected and when such actions would be ripe for analysis.

The El Paso-Hudspeth County line forms the southern boundary for the analysis because it marks the downstream end of RGP facilities and effects of the alternatives are not measurable beyond this line.

Implementation of the alternatives would not involve constructing new facilities or other actions that are physically different from or that exceed the bounds of historical operations of the RGP. The alternatives would not change the structure of the storage or diversion dams nor change obligations under the Convention of 1906, the Rio Grande Compact, or compliance with various court decrees, settlement agreements, and contracts.

3.2.1 Rio Grande Project

As shown in Fig. 1, the RGP is located in southern New Mexico and western Texas. The constructed features of the RGP are the Elephant Butte and Caballo Dams and Reservoirs, six diversion dams, 139 miles of canals, 457 miles of laterals, 465 miles of drains, and a hydroelectric powerplant. Reclamation and multiple entities own and operate the facilities and distribution infrastructure of the RGP.

As described in Section 1.4.1.2, Reclamation allocates RGP water proportionate to the districts' respective acreages. EBID includes 90,640 acres authorized to receive RGP water in the Rincon and Mesilla Valleys of New Mexico. EPCWID includes 69,010 acres authorized to receive RGP water in the Mesilla and El Paso Valleys of Texas. RGP water allocated to Mexico under the

Convention of 1906 is delivered in the bed of the Rio Grande at the point adjacent to the head works of the Acequia Madre in Cuidad Juárez, Mexico.

The HCCRD, below the RGP boundary in Texas, uses excess flows from the RGP. Under a Warren Act contract between HCCRD and Reclamation, HCCRD has used drainage and wastewater from the RGP since 1925. The contract extends only to the return water; it does not obligate the RGP or Reclamation to deliver specific amounts of water.

3.3 Water Resources

This section summarizes existing water resources, including surface water, groundwater, and water quality. The study area includes Elephant Butte and Caballo Reservoirs, the Rio Grande between the reservoirs, and the Rio Grande below Caballo Reservoir to diversion points to EBID and EPCWID lands, and Mexico.

3.3.1 Regulatory Framework

The legal and regulatory framework governing surface water in the study area is complex. Important authorities and agreements are:

- Reclamation Act of 1902 and the Rio Grande Project Act of 1905
- 1906 Convention between the U.S. and Mexico.
- Rio Grande Compact of 1939
- Public Law 97-140, 95 Stat. 1717, Section 5(c) (authority for storage of San Juan-Chama water in Elephant Butte Reservoir)
- Public Law 102-575, Title XXXIII—Elephant Butte Irrigation District, New Mexico, Section 3301 Transfer (authority for transfer to the two districts title to easements, ditches, laterals, canals, drains, and other rights-of-way)
- Court Order No. CIV-90-95-HB/WWD of 1996 (Court order to keep Caballo Reservoir storage level below 50,000 acre-feet from October 1 to January 21 annually under most conditions)

3.3.2 Data Sources

Water resources data were compiled primarily from Reclamation sources (e.g. Reclamation 2013a; Appendix F).

3.3.3 Elephant Butte and Caballo Reservoirs Storage

Reclamation stores RGP water in Elephant Butte and Caballo Reservoirs. Elephant Butte Reservoir has a capacity of 2,024,586 acre-feet, all of which is conservation storage for later release for authorized project purposes (Reclamation 2008b). Caballo Reservoir has a total capacity of 324,934 acre-feet, which includes 224,934 acre-feet of conservation storage and 100,000 acre-feet of flood control space (Reclamation 2008b). Total conservation storage within the RGP is 2,249,520 acre-feet.

In a typical year, storage in Elephant Butte Reservoir increases in the spring due to snowmelt and decreases during the irrigation season (generally March to October), although its contents can swing dramatically due to variations in runoff from summer monsoons. Storage in Caballo Reservoir generally increases from January through March, decreases from March through April,

increases from May through June, decreases from June through October, and increases from October through December (Reclamation 2013a).

3.3.4 Releases and Rio Grande below Caballo Dam

The study area for releases from the dams includes the Rio Grande below Elephant Butte Dam and the Rio Grande below Caballo Dam to the El Paso-Hudspeth County line in Texas. This marks the geographic end of the RGP facilities.

EBID, EPCWID, and USIBWC on behalf of Mexico, place orders with Reclamation for releases from storage to meet their delivery requirements at authorized points of diversion. Orders are placed daily during the irrigation season. If the districts cannot agree on the volume or timing of releases, Reclamation makes the final determination. Reclamation releases water from RGP storage for diversion by Mexico. Reclamation determines the amount and schedule of release for Mexico to meet the delivery schedule set by Mexico at its point of delivery.

Historically, the Rio Grande between the reservoirs and below Caballo Dam dries during the nonirrigation season when no surface water is released. Portions may remain wet due to rain and snowfall, groundwater, or municipal discharges. The annual flow below Caballo Dam was constant from 1960 to 2013 with the exception of a few wet and dry periods. The most significant dry period occurred during the mid-1960s, while the two wettest periods occurred during the mid-1980s and mid-1990s. In a typical year, flow below Caballo Dam is low in January, gradually increases until March, decreases during April and May, peaks in July, and decreases until December.

3.4 Groundwater

In addition to the background information in Chapter 1, this section summarizes existing conditions for groundwater in the Rincon Valley of New Mexico, the Mexilla Valley of New Mexico and Texas, and the El Paso Valley of Texas. The Mesilla Valley extends from Radium Springs, New Mexico, to the El Paso Narrows in El Paso, Texas, near the New Mexico-Texas-Mexico border. El Paso Valley is the low-lying area containing the Rio Grande channel, from south of the El Paso Narrows to near Fabens, Texas.

3.4.1 **Regulatory Framework**

Groundwater in New Mexico is regulated by the New Mexico Office of the State Engineer (NMOSE). In 1980, NMOSE recognized the Lower Rio Grande Underground Basin and imposed a permit system on well drilling. Before this declaration, there were no restrictions on well drilling in this area. The volume of groundwater that may be pumped under pre-basin groundwater rights³ is currently being determined through a basin adjudication process by the State of New Mexico.

Groundwater within Texas is managed and regulated by local or regional groundwater conservation districts, if present.⁴ The portion of the study area in Texas is governed by the rule of capture and a landowner needs no authorization or permit to pump.

⁴ No Texas groundwater conservation districts currently exist in the RGP study area (Texas Water Development Board 2016).

³ That is, under water rights established by groundwater use prior to the basin being declared.

3.4.2 Data Sources

Groundwater information was reviewed from Conover (1954), Frenzel (1992), Frenzel and Kaehler (1992), Reclamation (2013a, 2015c), and Stringham et al. (2016). Groundwater data also came from the following sources:

- Groundwater elevation data by the USGS using records extracted for individual groundwater measurement sites from a geo-database compendium (Burley 2010).
- Groundwater recharge data estimated by assessing deep percolation of irrigation water, channel seepage from the Rio Grande and RGP conveyance facilities, and mountain-front and slope-front recharge from surrounding areas. Values have been extracted from the final model input files for the NMOSE and collaborators' groundwater model of the Rincon and Mesilla Basins (SSPA 2007).
- Groundwater pumping for irrigation in the Rincon and Mesilla Basins has been estimated based on the Lower Rio Grande Groundwater Flow Model. While metering of groundwater pumping has occurred since the 1980s and has been required since 2009, comprehensive metering records of groundwater pumping for irrigation in the Rincon and Mesilla Basins are unavailable.

3.4.3 Existing Groundwater Conditions

As described in Chapter 1, adapting to and managing for the impact on the RGP supply caused by groundwater pumping by irrigators in the RGP service area was a purpose of the OA.

3.4.3.1 Aquifers

As described in Section 1.4.2.3.2, the shallow unconfined aquifer systems in the Rincon and Mesilla Valleys are hydraulically connected to the Rio Grande; therefore, groundwater pumping from these aquifers in New Mexico and Texas has the potential to affect RGP supply and deliveries. The unconfined aquifer system in the El Paso Valley is also hydraulically connected to the Rio Grande. However, most of the RGP diversions and return flows occur upstream of the portion of this aquifer system that is affected by groundwater pumping and are not substantially affected by fluctuations in groundwater conditions in the El Paso Valley (Reclamation 2013a; Appendix F).

3.4.3.2 Groundwater Recharge and Demand

Groundwater use and recharge are currently affected by factors including drought, increasing demands, and changing farm irrigation efficiencies (Stringham et al. 2016). In the Lower Rio Grande Underground Water Basin (NMOSE 2015), including the Rincon and Mesilla Valleys of New Mexico, groundwater use has recently been estimated to range from 50,000 to 100,000 AFY in years of full RGP surface water supply and from 200,000 to 300,000 AFY in years of low RGP supply. Groundwater use for supplemental irrigation depends on irrigated acreage, crop distribution, and weather conditions during the growing season in addition to RGP supply (Barroll 2005, Reclamation 2013a). Average seasonal groundwater pumping is greater from March through October than from November to February, which reflects the use of the groundwater for supplemental irrigation. Pumping has varied over time with the volume in years of extremely heavy pumping up to six times that of years with the lowest pumping. Accurate estimates of historical and current groundwater pumping for supplemental irrigation of RGP lands in the Texas portion of the Mesilla Valley and in the El Paso Valley of Texas are not available at this time. Water quality considerations and other factors limit the groundwater use on RGP lands in the El Paso Valley of Texas, which overlies the Hueco Bolson groundwater aquifer.

In general, an increase in RGP allocation and surface water diversions to either district is expected to increase groundwater recharge from canal seepage and deep percolation of irrigation water in that district, along with a corresponding decrease in groundwater demand for supplemental irrigation. Conversely, a decrease in RGP allocation and diversions to either district is expected to decrease groundwater recharge in the district and increase groundwater demand for supplemental irrigation.

Previous analysis in the SEA determined that it was not possible to quantify the total change in groundwater recharge and demand from 2008 to 2012 nor the portion of that total change that would be attributable to the OA. An order of magnitude estimate suggests that incremental changes in groundwater recharge and groundwater demand for supplemental irrigation in the Rincon and Mesilla Valleys during this period were small compared to the total recharge and pumping in the region (Reclamation 2013a; Appendix F).

Groundwater pumping is not an authorized function of the RGP and is not directly a part of RGP operations. However, it is worth noting that groundwater pumping from aquifers hydraulically connected to the Rio Grande, or to the network of canals, laterals, ditches, drains, and wasteways used to convey RGP deliveries and return flows, is likely to affect RGP supplies and deliveries through the interaction of the groundwater and surface water systems. In addition, groundwater demand for supplemental irrigation depends in part on the availability of surface water from the RGP. Previous studies have indicated that seepage from the Rio Grande and deep percolation of irrigation water from RGP lands to the underlying aquifer system are a primary source of groundwater recharge to the shallow unconfined aquifers of the Lower Rio Grande Underground Water Basin (Hanson et al. 2013, Haywood and Yager 2003, SSPA 2007, Stringham et al. 2016).

3.4.3.3 Groundwater Trends

Analysis based on historical measurements of groundwater elevations from monitoring wells in the RGP and surrounding areas of the Rincon and Mesilla Valleys demonstrates widespread and statistically significant negative trends in groundwater elevation from 1980 to the present. Analysis of previous decades suggest that this trend is confined to the past decade, indicating that sustained groundwater pumping in excess of recharge (i.e., groundwater mining) was not prevalent in the RGP or adjacent lands before the current drought (Reclamation 2013a; Appendix F).

Other groundwater trends are:

- Trends in groundwater elevation are predominantly negative, although some wells exhibit neither negative nor positive trends over the same period. Trends in groundwater elevation at each measurement site reflect conditions near that site.
- Full allocations each year in the early 1990s to early 2000s lessened concerns about allocations and no substantial changes in RGP operations, district operations, or groundwater use for supplemental irrigation in the RGP or adjacent areas of the Rincon or Mesilla Valleys occurred between the late 1990s and early 2000s.
- Efforts to increase irrigation efficiency and to reduce distribution losses, including lining and piping portions of the distribution system, may have contributed to recent groundwater declines in some portion of the Mesilla Valley by reducing recharge from deep percolation of irrigation and canal seepage. It is likely that recent groundwater declines are associated with the severe and sustained drought conditions that have affected the RGP since 2003 (Reclamation 2013a, Appendix F).

The analysis presented in the SEA (Reclamation 2013a, Appendix F) indicates a statistically significant positive correlation between groundwater elevation and annual flow below Caballo Dam, as well as the total annual RGP diversions under both wet and dry conditions. These results are intuitively consistent with conjunctive use of surface water and groundwater in the RGP. During periods of high surface water availability, streambed recharge from the Rio Grande to the underlying aquifer increases and groundwater pumping decreases, resulting in higher groundwater elevations. Conversely, during periods of low surface water availability, streambed recharge decreases and pumping increases, resulting in declining groundwater levels. Results suggest a strong connection between surface water and groundwater resources in areas served by the RGP, particularly in the Rincon and Mesilla Basins, as indicated by numerous previous studies (Deb et al. 2012, Reclamation 2013a; Appendix F, Stringham et al. 2016).

3.5 Water Quality

This section summarizes existing water quality between Elephant Butte Reservoir and the Rio Grande at the El Paso-Hudspeth County line.

3.5.1 Regulatory Framework

The legal and regulatory framework for water quality includes:

- Federal Water Pollution Control Act or Clean Water Act (CWA; 33 USC Section 1251 et seq.)
- Public Health Service Act, Safe Drinking Water Act (Title XIV of the Public Health Service Act; Public Law 107-377)
- New Mexico Administrative Code 20.6.4
- Texas Administrative Code Title 30, Chapter 307

Under the CWA, water quality is managed by the New Mexico Environment Department (NMED) and Texas Commission on Environmental Quality (TCEQ). These state agencies have developed water quality standards based on designated uses for which the body of water is suitable. Both state agencies divide the Rio Grande into water quality segments for which standards must be met.

3.5.2 Data Sources

Water quality data are from Hogan (2013), New Mexico Environment Department (NMED 2016), Reclamation (2013a; SEA Appendix H), Texas Commission on Environmental Quality (TCEQ 2016), and the U.S. Environmental Protection Agency (EPA 2015a, b).

3.5.3 Existing Reservoir Water Quality Conditions

The NMED Surface Water Quality Bureau (2016:175-176) reports that water quality in Elephant Butte Reservoir (HUC 13020211) has improved recently and the reservoir has been taken off the state's impaired list, but there is still a fish consumption advisory due to mercury in fish tissue. Caballo Reservoir (HUC: 13030101) is impaired due to mercury in fish tissue and high levels of nutrients. Fish consumption advisories are in place (NMED 2016:176).

3.5.4 Existing Rio Grande Water Quality

The Rio Grande between Elephant Butte and Caballo Reservoirs has historically been impaired by low dissolved oxygen levels and excessive nutrients, but in 2016, no impairments were found (NMED 2016:177-178). However, the state plans to reassess the dissolved oxygen levels. The

NMED (2016:178) has listed the Rio Grande in the HUC: 13030102, El Paso-Las Cruces reach, as impaired due to exceedances of the *E. coli* criterion.

The TCEQ (2016) lists the Rio Grande River (Basin 23; AUID 2312-2) as impaired for aquatic life from the Texas-New Mexico border to International Dam due to depressed dissolved oxygen levels and a toxic substance (methylene chloride) in sediment. For general uses, total dissolved solids and nutrients exceed standards. In addition, groundwater quality may be a concern within the districts' service areas.

The Rio Grande is impaired for primary contact recreational use from Percha Dam to the Texas boundary due to exceedance of the *E. coli* bacteria standard. The Rio Grande downstream of the New Mexico border is impaired due to excessive *E. coli* and high salinity or total dissolved solids. At El Paso, the average total dissolved solids is about 750 mg/L, and at Fort Quitman it commonly is in excess of 2,000 mg/L and up to an average of 3,200 mg/L during the irrigation season (Hogan 2013, Phillips et al. 2003, Stringham et al. 2016). Total dissolved solids are typically elevated in the winter when flows are lower and are reduced in the summer when higher flows dilute concentrations (Michelsen et al. 2009).

3.6 Vegetation Communities, Wetlands and Special Status Plant Species

This section describes vegetation communities including wetlands and special status plant species within the Elephant Butte and Caballo Reservoir pools and along riverbanks between the reservoirs and down to the El Paso-Hudspeth County line. "Special-status species" includes species given varying levels of protection with the highest level of protection given to species listed or proposed for listing as endangered or threatened under the ESA.

3.6.1 Regulatory Framework

A number of laws, regulations, and policies apply to vegetation communities and plant species. These include:

- ESA
- CWA Section 404
- Executive Order 11990, Protection of Wetlands
- New Mexico Energy, Minerals, and Natural Resources Department (NMEMNRD) Forestry Division (NMEMNRD 2015) Section 75-6-1 NMSA 1978
- Texas Parks and Wildlife Department Code Chapter 88 and Sections 69.01 through 69.9 of the Texas Administrative Code

3.6.2 Data Sources

Data sources for vegetation in the study area include the U.S. Geological Survey's (USGS) Southwest Regional Gap Analysis (USGS 2011), the New Mexico Rare Plant Technical Council (NMRPTC 2015), New Mexico State Parks' (NMSP) management plans (NMSP 2000, 2006), endangered plant information from the New Mexico Energy, Minerals, and Natural Resources Forestry Division (NMEMNRD 2015), and the Service's National Wetland Inventory, and publications such as Muldavin et al. (2000).

Field surveys and aerial photography conducted by Reclamation (2003a, 2012b), USIBWC (various), and others (e.g. Sogge et al. 1997) to document habitat for the endangered Southwestern willow flycatcher (*Empidonax traillii extimus*, flycatcher) also provide data about vegetation communities in the five county biological resources study area.

3.6.3 Existing Vegetation Conditions

The study area is in the Chihauhuan Desert on the ecotone⁵ between Desert Scrub and Desert Grassland (Brown 1982, Dick-Peddie 1993). Riparian-wetland vegetation borders the study area along the shoreline of the reservoirs and the floodplain of the Rio Grande. Within the study area, the location and distribution of individual plant species depends on the soil, elevation, degree of slope, and proximity to water, etc.

The Southwest Regional Gap Analysis Project (USGS 2011) provides land cover data for the study area, classified according to the National Vegetation Classification System. Following this system, vegetation within the full-pool footprint of Elephant Butte Reservoir and its delta include the following:

- Western Great Plains Riparian Woodland and Shrubland
- North American Arid West Emergent Marsh
- North American Warm Desert Playa
- North American Warm Desert Wash
- North American Warm Desert Riparian Woodland and Shrubland

Since 1995, Elephant Butte Reservoir has receded more than 24 miles downstream, exposing thousands of acres of bare soil (Fig. 3). This area is dominated by Goodding's willow (*Salix gooddingii*), interspersed with broadleaf cattails (*Typha latifolia* L.), and marsh grasses (Muldavin et al. 2000). To the east, opposite the Low Flow Conveyance Channel outfall, dense monotypic stands of nonnative tamarisk or saltcedar (*Tamarix* spp.) are dominant (Reclamation 2012a).

Scant riparian development exists along the floodplain of the Rio Grande between Elephant Butte and Caballo Reservoirs. Vegetation in this reach is typically limited to a narrow band of tamarisk with a few overstory cottonwoods (*Populus fremontii*) (Reclamation 2012a).

Where the Rio Grande broadens into the upper delta of Caballo Reservoir, several patches of tamarisk and overstory cottonwoods and a variety of herbaceous and grass species persist (Reclamation 2012a). The broadening of the floodplain and Caballo Reservoir account for the relatively high water table that supports this vegetation.

Little vegetation is found in and around Caballo Reservoir due to annual mowing and management (Reclamation 2012a). However, a 40-acre parcel has been fenced to exclude livestock. This parcel, known as the Las Palomas site, supports a mosaic of native riparian and wetland vegetation that provides wildlife habitat. Downstream of the Las Palomas site, several large patches of native willows (*Salix* spp.) have developed in the bottom of the reservoir pool. Several of these patches are comparable to the high-quality wildlife habitat in the Elephant Butte Reservoir and consist of young to middle-aged coyote willow (*Salix exigua*) and Goodding's willow. These patches are classified as North American Arid West Emergent Marsh, North American Warm Desert Playa, and North American Warm Desert Riparian Woodland and Shrubland.

⁵ A transitional area between two biological communities

Downstream of Percha Dam (2.0 miles below Caballo Dam) to the American Dam at El Paso, the affected environment is the floodway managed by the USIBWC. The floodway ranges in width from approximately 50 to 2,100 feet for over 100 miles. In most of the floodway there is little to no vegetation, but portions of it are described by USIBWC (2003, 2009b) as a combination of farmland and North American Arid West Emergent Marsh and North American Warm Desert Riparian Woodland and Shrubland.

Through the years, the USIBWC has managed vegetation to reduce erosion potential, remove potential obstructions that could reduce flood containment capacity, help stabilize stream banks, control weeds and brush including saltcedar, and provide wildlife habitat at suitable locations. The USIBWC's Record of Decision for River Management Alternatives for the Rio Grande Canalization Project (USIBWC 2009a) calls for enhancing native vegetation within the floodway by reducing mowing and revegetation.

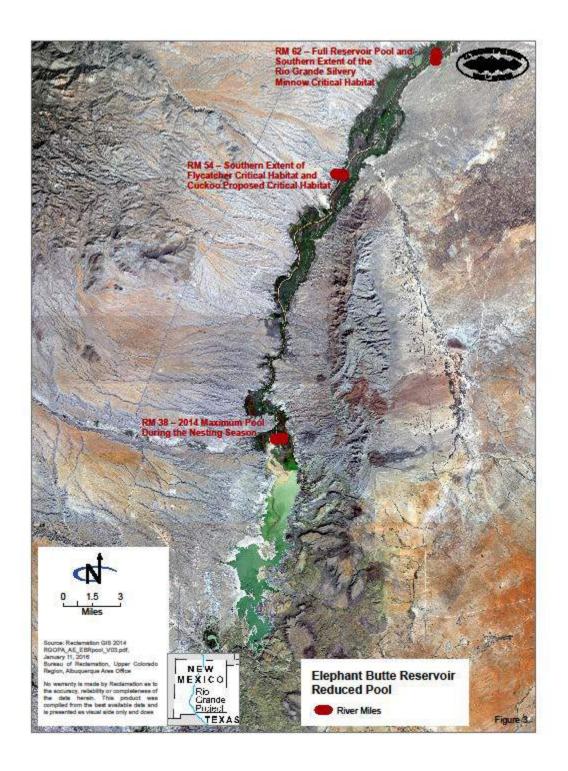
3.6.4 Vegetation Trends

The recession of Elephant Butte Reservoir over the last decade has allowed the development of a mosaic of native and nonnative vegetation (Fig. 3, Reclamation 2012a). Downstream, at the sediment delta of Caballo Reservoir, several patches of tamarisk and overstory cottonwoods and a variety of herbaceous and grass species have grown, including the densely vegetated Las Palomas site referenced in Section 3.6.3 (Reclamation 2012a). These vegetated patches within the full pool footprint of both reservoirs are dynamic due to both natural succession and to changes brought about by fluctuating reservoir levels.

While defoliation of tamarisk due to the tamarisk leaf beetle (*Diorhadba* spp.), has yet to occur in the study area, it is likely that individual trees and patches of dense, monotypic tamarisk will become defoliated as the beetle expands over time.

Below Caballo Reservoir, there is minimal native vegetation along the Rio Grande. The river is channelized to accommodate agricultural and urban land uses, but additional acres adjacent to the river has recently been allocated for riparian restoration and managed grasslands. Approximately 350 additional acres may be designated as no-mow zones in future years to accommodate new conditions, such as increased flycatcher habitat buffer areas or new restoration sites (USIBWC 2014b).

Figure 3. Elephant Butte Reservoir reduced pool, 2014



3.6.5 Special Status Plant Species

There are 13 Federal- or state-listed special status plant species in the five counties in the biological resources study area, but based on habitat requirements and soil associations, only the Pecos sunflower (*Helianthus paradoxus*) and Wright's marsh thistle (*Cirsium wrightii*) have any potential to occur in the study area. To date, no occurrences of either species have been reported. These species are discussed in more detail below.

3.6.5.1 Pecos sunflower (Helianthus paradoxus)

The Pecos sunflower is a wetland species that requires saturated saline soils of desert wetlands. It is usually associated with desert springs (cienegas) or the wetlands created from modifying desert springs at 3,300 to 6,600 feet of elevation. Some activities that degrade or destroy wetlands and therefore threaten Pecos sunflower are channel incision that reduces water tables, groundwater depletion, water diversions, filling, and saltcedar invasion. Livestock will eat Pecos sunflower, especially the flower heads, when other green forage is scarce. Disturbance may facilitate hybridization (NMRPTC 2015).

3.6.5.2 Wright's marsh thistle (Cirsium wrightii)

Wright's marsh thistle grows in wet, alkaline soils in spring seeps and marshy edges of streams and ponds at elevations of 3,450 to 8,500 feet. Desert springs (cienegas) are susceptible to drying up or being diverted. Populations in the City of Roswell, Chavez County, at Lake Valley, Sierra County, and at the San Bernardino Cienega in Arizona appear to be extirpated. Introducing insects as biological control for weedy thistles may pose a grave hazard for non-weedy thistle species. The effects of fire and livestock grazing on this species have not been studied (NMRPTC 2015).

3.7 Wildlife and Special Status Wildlife Species

This section summarizes existing conditions for terrestrial wildlife and special status wildlife species, including consideration of birds, mammals, reptiles, amphibians, arthropods, and gastropods. For this FEIS, special status species are those protected by the laws listed below.

3.7.1 Regulatory Framework

The primary laws protecting wildlife are:

- ESA
- Bald and Golden Eagle Protection Act (16 USC, Sections 668-668d)
- Migratory Bird Treaty Act of 1918 (16 USC, Sections 703-712), as amended
- New Mexico Wildlife Conservation Act (17-2-40.1 NMSA 1978)
- Texas Parks and Wildlife Department Code, Chapters 67 and 68, and Texas Administrative Code, Sections 65.171-65.176, of Title 31

3.7.2 Data Sources

Data sources for wildlife in the study area are based on descriptions of the vegetation communities in Section 3.6, plus data provided by the Service on special status species in the five counties: Doña Ana, Sierra, and Socorro Counties, New Mexico, and El Paso and Hudspeth Counties, Texas. Wildlife data from New Mexico State Parks' (NMSP) management plans (2000, 2006) are incorporated by reference. Reclamation also reviewed the Service's online Critical Habitat Portal (Service 2014a) and *Federal Register* notices for designated critical habitat for special status species. The New Mexico Department of Game and Fish's (NMDGF) online

database, the Biota Information System of New Mexico, was reviewed for Federal and state threatened, endangered, and species of concern (NMDGF 2015a). Also, reviewed were data from the New Mexico natural heritage program sensitive species by county database (NMDGF 2015a) and the Texas natural diversity database and rare, threatened, and endangered species of Texas by county database maintained by Texas Parks and Wildlife Division (TPW 2016).

The New Mexico Ornithological Society has an online database of bird sightings throughout the state (New Mexico Ornithological Society 2015), and there are several available lists showing documented bird species for these counties that were reviewed. Publications of the Service listing species, designating critical habitat, recovery or management plans, and biological opinions were reviewed and data from these publications are incorporated by reference (e.g. Service various).

3.7.3 Existing Wildlife Conditions

This section provides a general overview of the wildlife and bird species and their habitats that could be in the study area, with an emphasis on special status species. As with vegetation, the potentially affected habitat focused on potential inundation areas associated with reservoir pools and the effects of the frequency, timing, and extremes in reservoir elevation changes over the long term.

The vegetation in and around the two reservoirs and along the floodplain of the Rio Grande provides habitat for a diversity of wildlife species (USIBWC 2001; Reclamation 2002, 2003b). Common wildlife at both Elephant Butte and Caballo Reservoirs are mule deer, coyote, rabbits, pocket gopher, ground squirrel, chipmunk, raccoon (NMSP 2000, 2006). NMSP (2000, 2006) has documented more than 250 species of birds in and around the reservoirs, with common species including woodpecker, egret, killdeer, quail, great blue heron, and shorebirds.

The reservoirs and shorelines support many species of reptiles, amphibians, and invertebrates. Among the invertebrates, currently no tamarisk leaf beetles (*Diorhadba* spp.) have been documented in the study area, but the beetle has been dispersing in Texas and New Mexico since at least 2010. *Diorhabda* has been known to defoliate over 90 percent of tamarisk at some sites, with possible tamarisk mortality after 3-5 years of repeated defoliation. The defoliation of tamarisk could affect the use of the study area by birds including the endangered flycatcher, as described below.

Downstream of Caballo Reservoir, typical wildlife includes the black-tailed jackrabbit, desert cottontail, cotton rat, ground squirrel, mourning dove, meadowlark, kestrel, red-tail hawk, skunk, burrowing owl, several species of waterfowl, other migratory birds, and non-game animals (USIBWC 2007, 2014a).

Riparian areas constitute less than one percent of the land area in the arid Southwest, yet provide habitat to a greater number of wildlife species than any other ecological community in the region. These areas are also critical corridors for migratory species, especially migratory birds. When analyzing the river portion of the study area from Caballo Reservoir to El Paso, USIBWC assessed the quality of wildlife habitat in the area as below average to poor (USIBWC 2003).

Some riverine wetlands in the river channel offer high-quality habitat, but these are small and far apart. Wildlife habitat along the river, from the Elephant Butte Dam to El Paso, has been impacted by agricultural and urban development. In general, the remaining high-value wildlife habitat is associated with the Elephant Butte and Caballo Reservoirs and a riparian strip next to the Rio Grande. The dynamic nature of flooding and drying at the upper portions of the Elephant Butte Reservoir has allowed large areas of riparian vegetation to establish itself, which provides

important wildlife habitat. Smaller patches of similar vegetation have developed on the drought-exposed bed of Caballo Reservoir.

3.7.4 Special Status Wildlife Species

The endangered flycatcher and the threatened Western yellow-billed cuckoo (*Coccyzus americanus occidentalis*; cuckoo) are seasonally present within the study area/action area. Reclamation also considered potential for the endangered New Mexico meadow jumping mouse (*Zapus hudsonius luteus*; mouse), the endangered Interior least tern (*Sterna antillarum*), and the threatened piping plover (*Charadruis melodus*; plover) in the action area. For the mouse (see Section 3.7.4.3), the Service (2014c, 2013c) indicates it could be present in Socorro County, New Mexico, but surveys for the species, as well as examination of its potential habitat based on vegetation communities, indicate this species is not present in the action area. While migrating individual Interior least tern and plover could occur during transitory stopover periods, no habitat for these species has been found along the riverine portion of the action area.

3.7.4.1 Southwestern Willow Flycatcher

The flycatcher is a small perching bird (order Passeriformes), about six inches long, with a life span of generally one to three years; some live four to seven years (Langridge and Sogge 1997, Netter et al. 1998, Paxton et al. 1997). They winter in neotropical areas of southern Mexico and Central America and begin to arrive at New Mexico breeding sites in early May. Flycatcher habitat along the Rio Grande has two primary functions: habitat for breeding and feeding during the breeding season and stopover habitat while migrating.

The flycatcher was originally listed as endangered due to loss of habitat, brood parasitism, and lack of adequate protective regulations (Service 1995). The greatest ongoing threats to flycatchers in the Rio Grande are the decline in the quality of critical nesting habitat related to drought and loss of dense riparian vegetation, invasion of the saltcedar leaf beetle (*Diorhabda* spp.), and nest predation by brown-headed cowbird (*Molothrus ater*).

The Service published the final rule designating critical habitat for the flycatcher in 2013 and included about 14.4 kilometers (9.0 miles) of the upper part of Elephant Butte Reservoir in the Middle Rio Grande Management Unit (Service 2013a:380).

Regarding the sediment delta at the north of Elephant Butte Reservoir, the Service reported that:

"Over time, as the lake at Elephant Butte has declined, there has been an increase of willows and other trees in the delta of Elephant Butte Reservoir, and also an increase in flycatcher territories within the reservoir pool and north of the reservoir pool where the habitat is supported by the low-flow conveyance channel. The area within and north of Elephant Butte Reservoir supports the largest known population of flycatchers in the range of the subspecies." [Service 2013a:365]

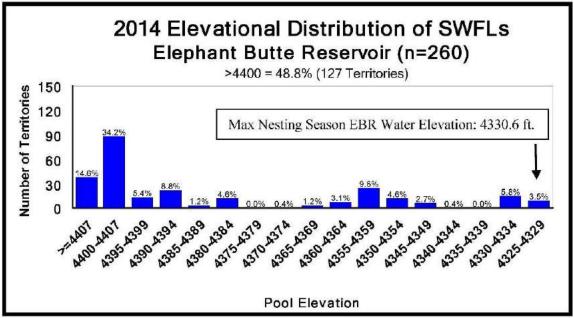
The final rule also found that the southerly margin of Elephant Butte Reservoir contains some elements of flycatcher habitat (Service 2013a:380). However, the Service determined that this southern segment in the active conservation pool of the Elephant Butte Reservoir is not necessary for the conservation of flycatcher and it was not designated as critical habitat (Service 2013a:349).

3.7.4.1.1 Presence

The upper or northern part of Elephant Butte Reservoir is located in the Service's Middle Rio Grande Management Unit. Patches of vegetation at the northernmost extent within the historic

reservoir (considered south of River Mile 62) became suitable for flycatchers in the mid-1990s. Flycatcher habitat is dynamic system, with the birds requiring dense patches of vegetation with tall trees. High-quality flycatcher habitat within the reservoir that has developed is a result of more recent reservoir recession that continues to improve and is providing new habitat for nesting and migrant flycatchers (Reclamation 2015a).

Figure 4. Elevational distribution of Southwestern Willow Flycatcher territories within Elephant Butte Reservoir, 2014, with maximum water levels.



Source: Reclamation (2015d).

Percent EBR SWFL Territories Above 4400 ft. Elevation 2007-2014 100% 76.7% 80% 66.8% 63.1% 58.3% 58.8% 58.2% 60% 50.6% 48.8% 40% 20%

Figure 5. Percentage of Southwestern Willow Flycatcher territories above the high pool of Elephant Butte Reservoir, 2007-2014.

Source: Reclamation (2015d).

2007

2008

2009

0%

During the 2014 surveys, 598 resident flycatchers were documented throughout the Middle Rio Grande Management Unit, which included resident birds forming 234 pairs and establishing 364 territories (Reclamation 2015a). Consistent with previous years, the San Marcial reach was the most productive, with 307 territories and 205 pairs. The 2014 surveys showed a second consecutive year of increased territory numbers after a large drop in 2012. The 2014 monitoring included nesting success rates, productivity, and brown-headed cowbird (*Molothrus ater*) parasitism. The San Marcial reach was again most productive, with 255 nests and 151 flycatcher fledglings. Overall, nesting success for all of the Middle Rio Grande Management Unit was the lowest observed in the past 16 years of monitoring, with most failures due to depredation (Reclamation 2015a).

2010

2011

2012

2013

2014

Figure 4 presents the distribution of flycatchers by elevation in Elephant Butte Reservoir during 2014. Because the elevation of the full reservoir is approximately 4,400 feet, the reservoir is important in providing flycatcher habitat. Figure 5 shows the percent of flycatcher territories above the high reservoir pool from 2007 to 2014.

3.7.4.2 Yellow-Billed Cuckoo

Cuckoos are insect specialists but also prey on small vertebrates, such as tree frogs and lizards; they are also known to be nest parasites of other bird species, including flycatchers. In the arid west, cuckoos are usually found in cottonwood-willow riparian associations along watercourses. The cuckoo requires large tracts of willow-cottonwood or mesquite (*Prosopis* spp.) forest or woodland for its nesting season habitat. Hydrologic conditions at cuckoo breeding sites can vary between years. This year-to-year change in hydrology can affect food availability and habitat suitability for cuckoos. Extended inundation reduces habitat suitability because the larvae of

sphinx moths pupate, and the eggs of katydids are laid underground; prolonged flooding kills the larvae and eggs (Service 2014b), thus removing important food sources.

The cuckoo was listed as threatened due to the "habitat loss associated with [man-made] features that alter watercourse hydrology so that the natural processes that sustained riparian habitat in western North America are greatly diminished" (Service 2013b:59992). In addition to habitat loss, reduction of prey insect abundance due to the use of pesticides has been identified as a major threat to the cuckoo (Service 2014e).

In 2014, the Service proposed designating critical habitat for the cuckoo, which included the Middle Rio Grande Unit NM-8 (Service 2014b). It is 61,959 acres in extent and is an approximately 170-mile-long continuous segment of the Rio Grande, from the Elephant Butte Reservoir in Sierra County at approximately River Mile 54, upstream through Socorro, Valencia, and Bernalillo Counties to below Cochiti Dam in Cochiti Pueblo in Sandoval County, New Mexico. This unit is consistently occupied by a large number of breeding cuckoos and currently is the largest breeding group of the species north of Mexico. The site also provides a movement corridor for cuckoos moving farther north. Tamarisk, a nonnative species that reduces habitat quality for cuckoos, is a major component of habitat in this unit. The Service has not yet finalized critical habitat designation for the species, including identifying actual boundaries at Elephant Butte Reservoir.

3.7.4.2.1 Presence

In Reclamation's 2013 survey of cuckoos from State Highway 60 downstream to the Elephant Butte Reservoir, the San Marcial Reach (River Mile 68.5 to 38.5) had the most cuckoo habitat of any of surveyed reaches (Reclamation 2014b). In 2013, the exposed pool of the Elephant Butte Reservoir constituted 86 percent of all cuckoo detections and 86 percent of all territories found within the San Marcial Reach. This subset of San Marcial also contained 48 percent of all cuckoo detections and 50 percent of all territories found in the entire Middle Rio Grande study area. The biological assessment (Reclamation 2015d) includes more information on the cuckoo and its distribution in the study area. The distribution of cuckoos by elevation in Elephant Butte Reservoir during the 2014 surveys is provided in Fig. 6.

2014 Elevational Distribution of YBCU Detections Elephant Butte Reservoir (n=161) 60 Number of Detections 50 Max Nesting Season EBR Water Elevation: 4330.6 ft. 40 30 12.4% 9.996 20 9.3% 6.2% 5.6% 10 1.2% 0 >4407 4400 to 4407 4370 to 4375 1360 to 4365 1350 to 4355 1340 to 4345 4335 to 4340 1325 to 4330 4395 to 4400 1390 to 4395 1385 to 4390 1380 to 4385 4365 to 4370 1355 to 4360 1345 to 4350 4330 to 4335 4375 to 4380

Figure 6. Elevational distribution of Yellow-billed Cuckoo detections within Elephant Butte Reservoir, 2014.

Source: Reclamation (2015d).

3.7.4.3 New Mexico Meadow Jumping Mouse

There have been relatively few studies of this endangered mouse and its natural life history. The mouse is unique in that it hibernates about eight to nine months out of the year, longer than most mammals, and it is active for only three to four months during the summer. Within this short time frame, it must breed, give birth, raise young, and store up sufficient fat reserves to survive the next year's hibernation period. As a result, if resources are not available in a single season, populations may be greatly impacted. In addition, New Mexico meadow jumping mice live three years or less and have one small litter annually, with seven or fewer young, so the species has limited capacity for high population growth rates due to this low fecundity.

According to the Service (2013c), the New Mexico meadow jumping mouse has specialized habitat requirements in that it appears to only utilize two riparian community types: 1) persistent emergent herbaceous wetlands (beaked sedge and reed canarygrass); and 2) scrub-shrub wetlands found in riparian areas along perennial streams that are composed of willows and alders. It especially uses microhabitats or patches or stringers of tall dense sedges on moist soil along the edge of permanent water. Habitat requirements are characterized by tall (averaging at least 24 inches) dense herbaceous riparian vegetation, composed primarily of sedges and forbs. This suitable habitat is found only when wetland vegetation achieves full growth potential associated with perennial flowing water

The mouse was originally listed as endangered due to the "present or threatened destruction, modification, or curtailment of its habitat or range; the inadequacy of existing regulatory mechanisms; and the natural and manmade factors affecting its continued existence" (Service 2014c:33120). In addition, isolated populations make natural recolonization of impacted areas highly unlikely or impossible in most areas (Service 2014c). Because the species occurs only in areas that are water saturated, populations have a high potential for extirpation when habitat dries due to ground and surface water depletion, draining of wetlands, or drought.

In April 2014, the Service reopened comment on proposed designated critical habitat for the mouse along the Rio Grande Valley (Service 2014d). Areas proposed for critical habitat for the mouse in this unit incorporate the Bosque del Apache National Wildlife Refuge, which is the only habitat believed to be occupied by the subspecies in the Middle Rio Grande with the capability to support its breeding and reproduction. Final designation of critical habitat has not yet occurred.

3.7.4.3.1 Presence

Based on work conducted in support of delta channel maintenance (Reclamation 2013c), the New Mexico meadow jumping mouse is not expected to occur in the study area. Frey and Kopp (2014) completed a preliminary assessment of mouse habitat down to River Mile 38 using GIS-based vegetation mapping and field evaluations of irrigation drains and the Low Flow Conveyance Channel. Mapping did identify potentially suitable habitat (herbaceous and regenerating willow) next to the Low Flow Conveyance Channel. Because of the quality of available data, this was a conservative effort that overestimated the amount of habitat. Further assessment and surveys have not found potentially suitable mouse habitat (Frey and Kopp 2014).

3.8 Aquatic Resources and Special Status Fish Species

This section summarizes existing conditions for aquatic habitats, the fish community, and special status fish species in this potentially affected environment. The area of analysis includes the full-pool of Elephant Butte and Caballo Reservoirs, the Rio Grande between the reservoirs, and the Rio Grande downstream of Caballo Dam to diversion facilities for the irrigation districts and the American Diversion Dam. Hydrological modeling simulates reservoir filling and drying affecting aquatic habitats along the Elephant Butte Reservoir delta reach, from River Mile 62 to River Miles 38 to 36, and the Elephant Butte and Caballo Reservoirs. Such habitat changes can affect the numbers and life stage of fish.

3.8.1 Regulatory Framework

The same laws applicable to wildlife apply to aquatic species.

3.8.2 Data Sources

No original aquatic resource or fish data were collected for the FEIS. Data used to describe existing conditions for aquatic resources and special status fish species in the study/action area include Reclamation sampling surveys for the endangered Rio Grande silvery minnow and habitat, including maps. Additional data were derived from NMDGF reports on sport and game fish species (NMDGF 2015b). Aquatic resource conditions are described through 2014, which marked the baseline for consultation with the Service.

3.8.3 Existing Fisheries Conditions

Beyond the irrigation season, except for relatively limited durations of stormflow input from the watershed, the Rio Grande channel between the reservoirs and downstream of Caballo Dam has long periods of low to no flows. The reaches of the Rio Grande below the reservoirs do not develop a sustainable or transient fishery or aquatic community, precluding needs for aquatic life assessment. Consequently, fisheries and other aquatic life resources of concern included in this assessment are limited to those in the delta reach inflows through the full-pool footprints and within the changing wetted perimeters of the two reservoirs.

3.8.3.1 Elephant Butte Reservoir Headwaters

With the drawdown of the water surface elevation since 1995, more than 24 miles of channel formed through the delta reach at Elephant Butte Reservoir, from River Mile 62 to River Miles 38 to 36. Reclamation surveyed fish populations in this channel from 2010 through 2012 (Table 3-2). In 2010, minnows were the most abundant fish collected from this temporary delta channel. They were captured in a variety of habitat types at the four survey sites selected, based on accessibility between River Miles 45.8 and 51.3.

Table 3-2 Fish species collected during September sampling in the temporary channel in Elephant Butte Reservoir, 2010-2012

	2010 2011		2011	2012		
		Number per		Number per		Number per
Species	No.	100 m^{2}	No.	100 m^{2}	No.	100 m^2
Rio Grande	233	24.07	65	2.83	0	0
silvery minnow						
Red shiner	78	6.68	219	9.53	1044	29.74
Western	41	3.70	26	1.13	1287	36.66
mosquitofish						
Channel catfish	24	1.93	55	2.39	11	0.31
Flathead chub	2	0.30	3	0.13	2	0.06
Threadfin shad	1	0.09	0	0	0	0
Yellow bullhead	1	0.08	0	0	0	0
River carpsucker	0	0	7	0.30	0	0
Common carp	0	0	0	0	2	0.06
Logperch	0	0	0	0	2	0.06
Fathead minnow	0	0	0	0	1	0.03

Source: Reclamation 2013a; Key m^2 = square meters

In 2011, silvery minnow was the second most abundant fish collected; however, overall fish densities were much lower than those observed in 2010. In October 2012, Reclamation sampled four sites from River Miles 46 to 52 and captured seven fish species. No silvery minnows were captured during any of the 2012 field season. Sampling at two sites produced no fish and there were no dry sites. Western mosquitofish were the most abundant, followed by red shiners. Red shiners were distributed evenly across the sites and mosquitofish were slightly more abundant at the downstream sites.

3.8.3.2 Elephant Butte Reservoir

Elephant Butte Reservoir is New Mexico's largest lake and most popular state park for recreation. The fish community is monitored annually, in the spring and fall. The most recent available spring fish electroshocking survey reports provide information for the years 2007 through 2010 and fall experimental gill net surveys for 2007 to 2011 (NNDGF 2012). Ten fish species were reported in these surveys, as follows:

- Smallmouth bass (*Micropterus dolomieu*)
- Largemouth bass (*M. salmoides*)
- Bluegill (*Lepomis macrochirus*)
- Longear sunfish (*Lepomis megalotis*)
- Green sunfish (*L. cyanellus*)
- White crappie (*Pomoxis annularis*)

- Black crappie (*P. nigromaculatus*)
- White bass (*Morone chrysops*)
- Striped bass (*M. saxatilis*)
- Walleye (Sander vitreus)

Although based on a relatively small sample size, the collection data for smallmouth bass indicated a relative imbalance, dominated by older, larger fish (NNDGF 2012). The condition was most likely the result of "poor habitat, due to fluctuating water levels during the spring spawn, poor spawning substrate, water clarity, and inadequate forage fish" (NMDGF 2012). In contrast, collection data for largemouth bass indicated that their population had shifted to larger, healthier fish until 2010, when this trend reversed. It appeared that natural recruitment was very low (NMDGF 2012).

Capture rates for other centrarchids (white bass, crappie, sunfish, striped bass, and walleye) were low. Catch data for populations for these fish was inconsistent between years, most likely due to sample bias, inappropriate habitat in the survey sites, and relatively low densities of many of these fish. Overall, Reclamation concluded that habitat quality undoubtedly restricted the abundance of centrarchids at Elephant Butte Reservoir, with the lack of suitable spawning habitat and escape cover attributable to the age of the lake and water use practices (NMDGF 2012).

The fall gill net surveys, conducted during November from 2007 to 2011, found the number of fish captured remained stable (NMDGF 2012). However, gizzard shad, normally the most commonly captured and abundant forage fish, showed a substantial population decrease through the survey period, and with an increase in size, makes the population potentially less available as forage. Blue catfish became the most abundant fish in the reservoir based on percent captured data, with their abundance more than doubling from 2009 to 2011. The relative abundance of both striped bass and white bass declined appreciably throughout the survey period.

Table 3-3 Fish in Elephant Butte Reservoir, 2014

Name	Number	% Caught	% Biomass
Blue catfish	597	52.09	27.08
Gizzard shad	207	18.06	9.38
Smallmouth			
buffalo	98	8.55	42.05
Channel catfish	48	4.19	1.26
Common carp	29	2.53	6.01
Walleye	23	2.01	4.95
White bass	18	12.04	7.34
Striped bass	1	0.09	1.71
Largemouth bass	1	0.09	0.18
Freshwater drum	1	0.09	0.03
Longear sunfish	1	0.09	0.01
Bluegill	1	0.09	0.01
Threadfin shad	1	0.09	0.01

Source: Mammoser (2015).

Table 3-3 provides data from the 2014 fall fish community gill net survey in Elephant Butte Reservoir. Blue catfish, gizzard shad, white bass, smallmouth buffalo, channel catfish, common carp, and walleye comprised most of the surveyed fish community; all other species accounted for less than 2 percent of the fish caught (Mammoser 2015).

From a fish community perspective, Elephant Butte Reservoir suffers from age and management practices that have been, and will continue to be, detrimental to some species while benefitting others" (New Mexico Department of Game and Fish [NMDGF] 2012). Present day management of the fishery populations is viewed to be affected by yearly fluctuating water levels due to irrigation demands and poor habitat created by severe drought conditions; centrarchid populations (e.g., bass and sunfish) are much below state management objectives (NMDGF 2011).

The lack of submerged vegetation in the reservoir has limited the recruitment and survivorship of bass. The absence of vegetation to help filter suspended particulates, reduce the water's turbidity, and stabilize the lake's banks negatively affects many fish species, including white, largemouth, and smallmouth bass, which tend to avoid turbid areas. In contrast, other fish species, like blue catfish, can tolerate increased turbidity, with populations quadrupling in Elephant Butte Reservoir in recent years, while channel catfish populations have markedly declined.

3.8.3.3 Caballo Reservoir

Caballo Reservoir fishery data come from experimental gill net surveys in mid-November 2008 (NMDGF 2012). At that time due to very low water levels in the reservoir, only three randomly selected sites were sampled. Catfish and walleye were the main game species captured, representing most of the community in percent captured and percent of biomass. Walleye, catfish, and white bass are the primary species targeted by anglers in the reservoir.

Gizzard shad represented 17.5 percent of the fish captured in 2008, a percent similar to those captured in 2006. The capture data indicate a well-balanced population with moderate recruitment (NMDGF 2012). Walleye represented 27 percent of the 2008 fish captured. Walleye fry have been stocked in Caballo Reservoir every year since 2007. While their capture number was lower than in 2004 and 2006, their population remained abundant. Their population size reduction was attributed to the decrease in lake levels and the increase in the percent catch of blue catfish. Blue catfish capture numbers increased in 2008 from previous surveys in 2004 and 2006, and they had become the dominant game fish in 2008. The report suggested that water level effects on habitat conditions likely dictate which species are more prevalent each year.

3.8.4 Special Status Species, Rio Grande Silvery Minnow

The Rio Grande silvery minnow is the only ESA-listed fish species present in the study area. The Rio Grande silvery minnow was listed as endangered in 1994 (Service 1994, 59 Fed. Reg. 36988). Silvery minnows are pelagic spawners, 6 producing numerous semi-buoyant, non-adhesive eggs. Most spawning typically has been observed in the spring, from late April through June, accompanying the period of snowmelt runoff (Reclamation 2012c). Spawning also has been observed during runoff following summer monsoons. Both juvenile and adult minnows primarily use meso-habitats with moderate depths (15 to 40 centimeters), low water velocities (4 to 9 centimeters per second), and silt/sand substrates. During the winter, these minnows become less active and seek habitats with cover, such as debris piles and other areas with low water velocities.

During spring sampling, large concentrations of reproductively mature silvery minnows are often collected on inundated lateral overbank habitats (Hatch and Gonzales 2008). Further study is

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⁶ They lay their eggs in open water

needed to determine whether minnows exhibit preferential use of lateral habitat (including overbank) for spawning. Surveys of inundated overbank habitats often have captured large numbers of gravid females and ripe male minnows (Gonzales and Hatch 2009).

3.8.4.1 Threats

According to the Service (2010, 75 Fed. Reg. 7625 and 1994:36988), decline of the fish is due to destruction and modification of its habitat due to dewatering and diversion of water, water impoundment (including Elephant Butte and Caballo Dams), and modification of the river (channelization). Competition and predation by non-native species, water quality degradation, and other factors have contributed to its status as endangered.

Silvery minnow populations remain at risk in the Rio Grande due to:

- Channel drying and the lack of suitable perennial refugia habitat during the irrigation season and periods of drought, leading to complete desiccation of potential habitat for minnows
- The lack of abundant feeding habitat consisting of channel flows less than a half a foot per second, and high flow velocities suspending and scouring away potential benthic and other attached food supplies for minnows, decreasing survival
- Floodplain habitats that fail to connect and inundate during spawn-stimulating flows, stranding minnow eggs and developing fry in high-velocity channel flows that have long been known to produce very high to total mortality of eggs and developing fry in small-bodied fish species (Harvey 1987)

3.8.4.2 Critical Habitat

The Service (2003, 68 Fed. Reg. 8087) designated critical habitat for the Rio Grande silvery minnow from the San Acacia Diversion Dam to the headwaters of Elephant Butte Reservoir at River Mile 62. The lateral extent of critical habitat was defined as areas bounded by levees, or in areas without levees, 300 feet of riparian zone adjacent to each side of the river (Service 2003:8119). Areas other than the Rio Grande, including the study area, were excluded from the designation of critical habitat for silvery minnow under Section 4(b)(2) of the ESA.

3.8.4.3 Presence

Historically, silvery minnows were distributed throughout most of the Rio Grande, from near the Gulf of Mexico to the upper reaches of both the Pecos River and the Rio Grande, reaching into the Rio Chama. The only reach in the FEIS study area where silvery minnows currently occur is in the channel through the Elephant Butte delta reach from River Mile 62, extending south to the active pool at approximately River Miles 38 to 36; i.e., at the headwaters of Elephant Butte Reservoir.

3.9 Invasive Species

An invasive species as defined by Executive Order 13112 is a species that is non-native or alien to the ecosystem and whose introduction is likely to cause economic or environmental harm or harm to human health.

3.9.1 Regulatory Framework

Authorities for combating the introduction or spread of invasive species are:

- Executive Order 13112
- New Mexico Noxious Weed Control Act

- New Mexico Aquatic Invasive Species Control Act
- Texas Agricultural Code Chapter 71, Subchapters D and T

3.9.2 Existing Invasive Species Conditions

According to the NMDA (2009) and U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (2015), invasive species within the project area are mostly noxious weeds, or plants that are not native, that are targeted for management and control, and that have a negative impact on the economy or the environment. The New Mexico State Noxious Weed List suggests the potential presence of the following noxious weeds:

- Five Class A species—camelthorn (*Alhagi maurorum*), hoary cress/whitetop (*Cardaria* spp.), parrot feather watermilfoil (*Myriophyllum aquaticum*), ravennagrass (*Saccharum ravennae*), and Scotch cottonthistle (*Onopordum acanthium*)
- Five Class B species—African rue (*Peganum harmala*), Malta starthistle (*Centaurea melitensis*), perennial pepperweed (*Lepidium latifolium*), Russian knapweed (*Acroptilon repens*), and tree of heaven (*Ailanthus altissima*)
- Six Class C species—cheatgrass (*Bromus tectorum*), field bindweed (*Convolvulus arvensis*), jointed goatgrass (*Aegilops cylindrical*), Russian olive (*Elaeagnus angustifolia*), saltcedar (*Tamarix* spp.), and Siberian elm (*Ulmus pumila*)
- Four watch list species—crimson fountaingrass (*Pennisetum setaceum*), giant cane (*Arundo donax*), Sahara mustard (*Brassica tournefortii*), and spiny cocklebur (*Xanthium spinosum*)

In Texas, noxious weeds identified as particularly worrisome invasive species in the Trans-Pecos ecoregion and study area are camelthorn (*Alhagi maurorum*), field bindweed (*Convolvulus arvensis*), giant reed (*Arundo donax*), Japanese dodder (*Cuscuta japonica*), and tamarisk or saltcedar (*Tamarix ramosissima*).

As mentioned in Section 3.6.4, the release of tamarisk leaf beetle (*Diorhadba* spp.) at locations along the Rio Grande in Texas is expected to result in the defoliation of saltcedar as the beetles arrive in Elephant Butte and Caballo Reservoirs.

Quagga mussels (*Dreissena bugensis*) were discovered in Nevada in 2007 and have subsequently spread throughout the west. Zebra mussels (*Dreissena polymorpha*) were documented in California in 2008 and they have also been spreading throughout Western waters. NMDGF has recently adopted new rules to combat the spread of invasive mussels and other aquatic invasive species. In Texas, six lakes are infested with zebra mussels. At this time, Elephant Butte and Caballo Reservoirs are mussel-free.

3.10 Cultural Resources

Cultural resources refer to historic and prehistoric buildings, structures, sites, objects, districts, Indian sacred sites, and resources of tribal concern. Historic properties are the subset of cultural resources listed on or eligible for listing on the National Register of Historic Places. The study area or area of potential effects for cultural resources includes Elephant Butte and Caballo Dams and Reservoirs, the Rio Grande floodplain between the two reservoirs, and the Rio Grande below Caballo Dam to the El Paso-Hudspeth County line.

3.10.1 Regulatory Framework

The principal Federal law addressing cultural resources is the NHPA (54 USC 306108), formerly known as Section 106. Its implementing regulations are found at 36 CFR 800. These require Federal agencies to take into account the effects of their actions on historic properties and to allow the Advisory Council on Historic Preservation an opportunity to comment. Executive Order 13007 requires consultation with Indian tribes regarding Indian sacred sites. The executive memorandum from the White House of April 29, 1994, requires government-to-government consultation on issues of tribal concern that may include cultural resources.

3.10.2 Existing Conditions

Listed historic properties in the area of potential effects of this undertaking include Elephant Butte Dam, the diversion dams, and the Franklin Canal. Other historic properties are the Garfield Lateral (LA-111726), Pittsburg Placer Mine (LA-13557), a Mogollon pithouse site (LA-2806), and an Apache battle site (LA-132559). Class III surveys of the Elephant Butte and Caballo Reservoirs were conducted in 1998 and 1999 and there are archaeological resources in the reservoir pools (Reclamation 2013a).

As part of the tribal consultation supporting the SEA, the Mescalero Apache Tribe expressed concerns with native plants growing along the irrigation canals in the service areas of EBID and EPCWID. The Mescalero Tribe collects plant material for cultural purposes.

For this undertaking, Reclamation consulted with the New Mexico State Historic Preservation Officer and they concurred with Reclamation's determination of "no historic properties affected" (Appendix D). In addition, Reclamation consulted with the Mescalero Apache Tribe and Ysleta del Sur, but they did not identify any resources or issues of concern.

3.11 Indian Trust Assets

Indian trust assets (ITAs) are legal interests in property held in trust by the U.S. for Federally-recognized Indian tribes or individual Indians.

3.11.1 Regulatory Framework

Management of ITAs is based on the several policies:

- Secretarial Order No. 3175, Departmental Responsibilities for Indian Trust Resources
- Secretarial Order No. 3206, American Indian Tribal Rights, Federal-Tribal Trust Responsibilities, and the ESA
- Secretarial Order No. 3215, Principles for the Discharge of the Secretary's Trust Responsibility
- Departmental Manual 512 DM Chapter 2, Departmental Responsibilities for Indian Trust Resources
- Indian Policy of Reclamation

3.11.2 Data Sources

No ITAs have been identified in the project area through consultation with Indian tribes or the Bureau of Indian Affairs.

3.12 Socioeconomics

The study area for socioeconomics includes Doña Ana and Sierra Counties, New Mexico, and El Paso and Hudspeth Counties, Texas. A small portion of Elephant Butte Reservoir is in Socorro County; however, no RGP-irrigated lands are in this county so it is not included in the socioeconomic study area. Recreation facilities associated with Elephant Butte Reservoir are in Sierra County.

3.12.1 Regulatory Framework

The NEPA and its implementing regulations are the authorities requiring analysis of socioeconomics.

3.12.2 Data Sources

Data sources include the U.S. Department of Commerce, Bureau of Economic Analysis (2014, 2015)), U.S. Department of Labor (2015), Census of Agriculture (USDA 2014), U.S. Department of Commerce Bureau of Economic Analysis (2015), and IMPLAN (2013).

3.12.3 Existing Conditions, Farm Employment and Income

Indicators include employment, labor income, and output. According to the U.S. Department of Commerce, Bureau of Economic Analysis, Regional Economic Accounts (2014), during the years from 1970 to 2014, farm employment in the four counties shrank from 5,230 to 4,792 jobs, an 8.4 percent decrease, while non-farm employment grew from 174,608 to 510,948 jobs, a 192.6 percent increase. In 2014, Hudspeth County, Texas had the largest percent of total farm employment (11.9 percent), and El Paso County, Texas had the smallest (0.23 percent).

From 1970 to 2014, farm earnings grew from \$141.0 million to \$171.6 million, a 21.6 percent increase, while non-farm earnings grew from \$7,114.2 million to \$22,993.0 million, a 223.2 percent increase. In 2014, Hudspeth County, Texas had the largest percent of total earnings from farm earnings (11.52 percent), and El Paso County had the smallest (0.04 percent).

From 1970 to 2014, net income, including corporate farms, grew from \$77.6 million to \$84.2 million, an 8.5 percent increase. During this period, cash receipts from crops grew from \$214.3 million to \$301.7 million, a 40.8 percent increase.

3.12.4 Existing Conditions, Industry Output

Industry output or sales represent the value of goods and services produced by businesses within a sector of the economy. The New Mexico study area (Doña Ana and Sierra Counties) had \$12.1 billion in industry output. The Texas study area (El Paso and Hudspeth Counties) had \$2.866.6 billion in industry output. The service sectors make up the largest percentage of industry sales in both study areas. Non-service-related industries make up the second largest portion of total output. Agriculture makes up 4.4 percent and 0.9 percent of total output in the New Mexico and Texas study areas, respectively. Table 3-4 summarizes the percent of output by industry.

Table 3-4 Percent of total output by industry

Table 3-4 Percent of total output by industry		
	Doña Ana and Sierra Counties, New Mexico	El Paso and Hudspeth Counties, Texas
Non-Service Industries	28.8%	44.2%
Agriculture, Forestry, Fishing, and Hunting	4.4%	0.9%
Mining	0.3%	5.8%
Utilities	2.9%	2.3%
Construction	7.4%	6.1%
Manufacturing	13.8%	29.1%
Service Industries	54.1%	49.6%
Wholesale trade	2.4%	5.4%
Retail trade	5.3%	4.2%
Transportation and warehousing	2.7%	3.5%
Information	2.9%	3.6%
Finance and insurance	3.7%	5.6%
Real estate and rental	10.6%	7.7%
Professional, scientific, and technical services	7.1%	5.8%
Management of companies	0.1%	0.9%
Administrative and waste services	2.4%	2.4%
Educational services	0.4%	0.5%
Health and social services	9.3%	4.8%
Arts, entertainment, and recreation	0.9%	0.5%
Accommodation and food services	3.8%	2.5%
Other services	2.6%	2.2%
Government	17.1%	6.2%
Government and other	17.1%	6.2%

Source: IMPLAN (2013).

Table 3-5 Farmland by type by county, 2012

Farmland	Doña Ana	Sierra	El Paso	Hudspeth
Number of farms	2,184	256	657	167
Land in farms (acres) Average farm size	659,970	1,250,136	209,393	2,251,109
(acres)	302	4,883	319	13,480
Approximate land area (acres)	2,437,000	2,674,533	648,206	2,925,329
Approximate percent of				
land area in farms	27.1	46.7	32.3	77

Source: U.S. Department of Agriculture, National Agricultural Statistics Service, Census of Agriculture (2014b).

Table 3-6 Number of farms by type and county, 2012

Farms by type	Doña Ana	Sierra	El Paso	Hudspeth
All Farms	2184	256	657	167
Oilseed & grain	14	0	1	0
Vegetable & melon	64	9	0	4
Fruit & nut tree	1310	24	193	0
Greenhouse, nursery	29	0	2	3
Other crop	356	67	225	52
Beef cattle ranch, farm	123	110	57	74
Animal, all types	288	46	179	34
Percent of Total				
Oilseed & grain	0.6%	0.0%	0.2%	0.0%
Vegetable & melon	2.9%	3.5%	0.0%	2.4%
Fruit & nut tree	60.0%	9.4%	29.4%	0.0%
Greenhouse, nursery	1.3%	0.0%	0.3%	1.8%
Other crop	16.3%	26.2%	34.2%	31.1%
Beef cattle ranch, farm	5.6%	43.0%	8.7%	44.3%
Animal, all types	13.2%	18.0%	27.2%	20.4%

Source: U.S. Department of Agriculture, National Agricultural Statistics Service, Census of Agriculture (2014b).

3.12.6 Agricultural Conditions, Farmland and Type

Table 3-5 presents statistics for agricultural conditions in the four-county study area in 2012. As shown, Hudspeth County had the largest percent of land area in farms (77 percent) while Doña Ana County had the smallest (27.1 percent). In the four-county study area, some 50.3 percent of the land was in farms in 2012. Table 3-6 presents the number and percentage of farms by type. As shown, in 2012, Hudspeth County has the smallest number or percent of oilseed and grain farming and the largest percent of beef cattle ranching and farming (44.3 percent) and Dona Ana County had the smallest percent in beef cattle ranching and farming (5.6 percent).

3.12.7 Population Growth and Income

According to the U.S. Department of Commerce, Bureau of Economic Analysis (2015) and as shown in Fig. 7, between 1970 and 2014, Doña Ana County, New Mexico had the largest percent change in population (204 percent) and Hudspeth County, Texas has the smallest (34 percent). During this period, the population of the four county study area increased by 141 percent and the population of the U.S. increased by 56 percent.

As shown in Fig. 8, between 1970 and 2014, Doña Ana County, New Mexico had the largest percent change in personal income (372 percent) and Hudspeth County, Texas had the smallest (145 percent). During this period, the change in personal income in the four county study area was 281 percent and the change in the U.S. was 182 percent.

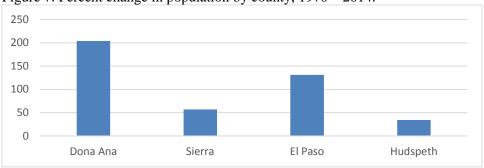


Figure 7. Percent change in population by county, 1970 – 2014.

Source: U.S. Department of Commerce, Bureau of Economic Analysis (2015)

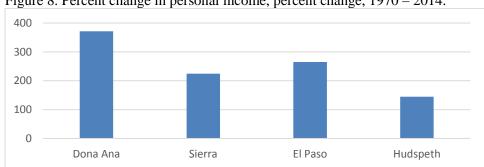


Figure 8. Percent change in personal income, percent change, 1970 – 2014.

Source: U.S. Department of Commerce, Bureau of Economic Analysis (2015)

3.13 Hydropower

3.13.1 Regulatory Framework

Energy requirements and conservation potential are required analyses under the CEQ's regulations at 40 CFR 1502.16.

3.13.2 Data Sources and Existing Conditions

The hydroelectric plant at Elephant Butte Dam generates power that is dependent on flow volume and head. Power production does not occur during the winter when RGP releases do not occur; hydropower calculations are based on the calculated average elevation from March to October only.

The Elephant Butte Powerplant has a rated head of 140 feet and is assumed to operate with 90 percent efficiency. Energy generation is calculated from reservoir elevation, with the rated head achieved at the maximum elevation over the study period and the potential energy conversion of 1.024 kilowatt-hours per acre-foot per foot of head. Calculated production based on the average March to October monthly elevation and release data for 2014 is 3 percent below the actual powerplant production of 13.4 gigawatts per hour (Gwh) reported by Reclamation (2015b).

3.14 Recreation

3.14.1 Regulatory Framework

The NEPA and its implementing regulations are the primary authorities requiring analysis of economic resources, including contributions of the travel and tourism sector to the regional economy.

3.14.2 Data Sources

Data on recreation, or travel and tourism, are from the U.S. Department of Commerce, Census Bureau (2015b).

3.14.3 Existing Conditions

In 1998, travel and tourism represented 16 percent of total employment in the four counties. By 2013, travel and tourism represented 19 percent of total employment. From 1998 to 2013, travel and tourism employment grew from 36,584 to 51,346 jobs, a 40.4 percent increase (U.S. Department of Commerce, Census Bureau 2015b).

In 2014, Fig. 9 shows that Sierra County, New Mexico had the largest percent of total jobs in industries that include travel and tourism. In 2014, accommodations and food was the largest component of travel and tourism-related employment (13.6 percent of total jobs) in the four county study area.

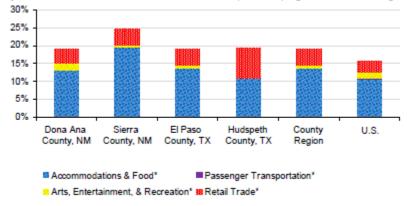


Figure 9. Travel and tourism industries by county (percent of total private employment), 2014.

Source: U.S. Department of Commerce, Census Bureau (2015b)

3.15 Environmental Justice

3.15.1 Regulatory Framework

Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations, directs Federal agencies to identify and address disproportionately high and adverse effects of its programs and activities on minority and low-income populations.

3.15.2 Data Sources

Guidelines provided by the CEQ (1997) and the Federal Interagency Working Group (2016) indicate minority communities may be defined where minorities comprise more than 50 percent of the population. Minorities include people who self-identify as Hispanic, Black or African-American, American Indian, Asian, Native Hawaiian, or some other race alone or combined. In this FEIS, the study area is the four counties, Doña Ana, Sierra, El Paso, and Hudspeth. The CEQ and Federal Interagency Working Group (2016) guidelines indicate that low-income communities may be defined following the Office of Management and Budget's Directive 14 poverty thresholds which vary by family size.

3.15.3 Low-income Populations

Table 3-7 presents the number and percent of people living in poverty during the 2010-2014 period. While none of the counties had half of their population living below the poverty threshold, based on a comparison of the percent of individuals living below the poverty threshold to the total county percentage (24.3 percent), Doña Ana County had slightly more persons living in poverty (27.8 percent), while Hudspeth County had the highest estimated percent of persons living below the poverty threshold (43.2 percent).

For families, 20.6 percent of the County families were living below the poverty threshold. Doña Ana County had slightly more than that (21.8 percent) and Hudspeth County had the highest estimated percent of families living below the poverty threshold (33.8 percent). These statistics define Doña Ana and Hudspeth Counties as environmental justice communities based on their comparatively high percentages of low-income persons or families.

Table 3-7 Poverty by county, 2010-2014

	Doña Ana	Sierra	El Paso	Hudspeth
People	207701	11486	809165	3017
Families	51778	2467	194230	742
People below poverty	57837	2037	189586	1303
Families below poverty	11304	235	39622	251
Percent of Total				
People below poverty	27.8	17.7	23.4	4302
Families below poverty	21.8	9.6	20.4	33.8

Source: U.S. Department of Commerce, Census Bureau, American Community Survey Office. (2015a). Key: Calculated using average ACS annual surveys during 2010-2014.

3.15.4 Minority Populations

In the 2009-2014 period, Table 3-8 shows Doña Ana, El Paso, and Hudspeth Counties had more than 50 percent of the population self-identifying as Hispanic or Latino. Hispanic or Latino refers to a cultural identification, not a race. In the 2009-2014 period, El Paso County, Texas had the highest estimated percent of the population that self-identify as Hispanic or Latino of any race (81.4 percent). This makes these three counties environmental justice communities.

Table 3-8 Minority populations by county, 2009- 2014

	Doña Ana	Sierra	El Paso	Hudspeth
Total Population	212,942	11,774	823,862	3,344
Hispanic of any race	141,087	3,394	670,946	2,634
White alone	62,649	7,929	110,287	671
Black alone American Indian	3,223	26	24,393	23
alone	1,702	120	2,177	0
Asian alone	2,291	113	8,331	16
Pacific Islander alone	12	0	1,014	0
Some other race	154	366	697	0
Two or more races	1,824	192	6,017	0
Percent of Total				
Hispanic of any race	66.3	28.8	81.4	78.8
White alone	29.4	67.3	13.4	20.1
Black alone American Indian	1.5	0.2	3	0.7
alone	0.8	1	0.3	0
Asian alone	1.1	1	1	0.5
Pacific Islander alone	0	0	0.1	0
Some other race	0.1	0	0.1	0
Two or more races	0.9	1.6	0.7	0

Source: U.S. Department of Commerce, Census Bureau, American Community Survey Office (2015a.)

4 Environmental Consequences

This FEIS is not intended to review the existence of the RGP or its historical operations; the focus is on how the alternatives described in Chapter 2 might change the water resources, biological, cultural, and socioeconomic resources in the study area. The temporal scope of the analysis and the proposed action extends to 2050. As such, the analyses in this chapter are based on modeling of RGP operations under each alternative through 2050 using an integrated hydrologic and water operations model. Model results are subsequently used as inputs to the evaluation of potential changes to other resources. Modeling of future RGP operations incorporates assumptions regarding future climatic and hydrologic conditions, cropping and irrigation practices, and M&I water demands. This chapter begins with a summary of the hydrologic model developed to assess the effects of the alternatives on water resources.

4.1 Water Resource Modeling Methods and Assumptions

Analyses of potential environmental consequences presented in this chapter are based on simulations of future RGP operations through the year 2050, including the storage, release, and delivery of surface water for beneficial use to EBID, EPCWID, and to Mexico under the Convention of 1906. These simulations were carried out using the Rincon and Mesilla Basins Hydrologic Model (RMBHM), as described in this section and Appendix C.

As discussed in Chapter 1, previous studies indicate a strong interaction between the Rio Grande and underlying groundwater aquifers, particularly in the Rincon and Mesilla basins (Conover 1954, Hanson et al. 2013, Haywood and Yager 2003, SSPA 2007). Groundwater pumping in the Rincon and Mesilla Basins results in depletion (capture) of surface-water supplies, including increased seepage losses from the Rio Grande as well as decreased drainage and return flows from irrigated lands. Depletion of RGP surface-water supplies, in turn, increases the amount of water that must be released from storage to meet delivery orders from EBID, EPCWID, and Mexico, and ultimately reduce the amount of RGP surface water that can be delivered to project diversion points (headings). Conversely, RGP operations affect the timing, distribution, and volume of groundwater recharge that occurs as seepage from the Rio Grande and unlined canals and laterals and as deep percolation of applied irrigation water. Simulation of future RGP operations, groundwater demand and use, and groundwater/surface-water interactions between Caballo Dam and the RGP's downstream-most diversion point at International Dam.

The RMBHM was developed by Reclamation in collaboration with USGS to allow for simulation of RGP operations under the five alternatives described in Chapter 2, while accounting for the role of groundwater/surface-water interactions on RGP operations and surface-water and groundwater resources. The RMBHM builds on previous hydrologic models of the Rincon and Mesilla Basins (SSPA 2007) and the USGS (Hanson et al. 2013). The RMBHM uses the One-Water Hydrologic Flow Model (MF-OWHM; Hanson et al. 2013), an integrated hydrologic modeling software based on the USGS Modular Groundwater Model, MODFLOW. To simulate RGP operations under each alternative, the MF-OWHM was enhanced with additional software features. These features, developed and implemented by Reclamation in collaboration with the USGS (Ferguson et al. 2014), allow for dynamic simulation of storage, allocation, release, and diversion of RGP surface water supplies according to specified allocation and accounting procedures.

The RMBHM is used to simulate RGP operations and corresponding surface-water and groundwater resources under each alternative, including surface water storage in Elephant Butte and Caballo Reservoirs; allocations to EBID, EPCWID, and Mexico; releases from Caballo Dam; and diversions to EBID, EPCWID, and Mexico at their respective diversion points (headings). A spreadsheet post-processing tool was subsequently used to calculate the maximum volume of San Juan–Chama Project water in Elephant Butte Reservoir under each alternative on a monthly basis. All alternatives were simulated under a common set of future climatic and hydrologic conditions. Model results were post-processed and compiled to facilitate comparison of RGP operations and surface water and groundwater resources under the alternatives.

Details of the RMBHM are provided in Appendix C, Hydrology Technical Memo. Model configuration and inputs to RMBHM for the FEIS are summarized below, along with verification of RMBHM with respect to simulation of historical RGP operations. Assumptions regarding future climatic and hydrologic conditions, cropping and irrigation practices, and municipal and industrial water demands and uses are also summarized below.

4.1.1 Model Configuration

Model configuration refers to the extent and discretization of the simulated area (spatial domain) and simulation period (temporal domain), as well as the specified physical and hydraulic properties (constant parameters) of the Rincon and Mesilla Basins. The spatial domain of RMBHM extends from Caballo Dam at the northern end of the Rincon Valley to below American Dam at the southern end of the Mesilla Valley. The spatial domain is discretized using a uniform horizontal grid, with each grid cell encompassing 0.25 miles by 0.25 miles (1320 feet by 1320 feet, equal to 40 acres), and five vertical layers of varying thickness. The spatial domain and discretization used by RMBHM are identical to previous models (SSPA 2007) and USGS (Hanson et al. 2013).

For the FEIS, the temporal domain of RMBHM extends from the start of the 2007-2008 non-irrigation season (November 1, 2007) through the end of the 2050 irrigation season (October 31, 2050). There are 43 years in the simulation. Each simulated year is divided into a non-irrigation season from November through February (120.25 days) and an irrigation season from March through October (245 days). Each season is simulated using approximately monthly time step, with four time-steps of equal length during each non-irrigation season and eight time-steps of equal length during each irrigation season. Model results are output for 516 approximately monthly time steps. Representation of the simulation period based on irrigation and non-irrigation seasons is consistent with previous models (SSPA 2007) and USGS (Hanson et al. 2013); however, previous models used four time steps of varying length for each season rather than the monthly time steps used by RMBHM.

RMBHM requires constant parameters representing physical and hydraulic properties throughout its spatial domain, including subsurface properties (e.g., aquifer hydraulic conductivity, specific storage, and yield), channel properties (e.g., hydraulic conductivity of channel beds, channel slope and geometry, and channel roughness), and vegetation-related parameters (e.g., soil properties, root profiles). RMBHM also requires parameters related to irrigation practices, including on-farm irrigation efficiency. The majority of constant parameters used in RMBHM are identical to those used in the previous model by USGS (Hanson et al. 2013). Parameters related to subsurface and channel bed hydraulic conductivities, aquifer specific storage and specific yield, capillary fringe depth, and on-farm irrigation efficiency were adjusted on a trial-and-error basis during model evaluation to provide better agreement between simulated and observed reservoir storage, releases, and diversions as summarized in Appendix C.

4.1.2 Model Inputs

Model inputs refer to specified time-varying values representing hydrologic, climatic, and anthropogenic stressors to the surface-water and groundwater systems over the simulated area. Hydrologic stressors in RMBHM include surface water inflows to RGP storage. Climatic stressors include reservoir precipitation and evaporation rates and climate factors affecting irrigation demands (e.g., precipitation and temperature). Anthropogenic stressors include human factors affecting irrigation demands (e.g., cropping patterns and irrigated acreage), as well as onfarm irrigation efficiency of agricultural lands, M&I groundwater pumping rates and locations, and discharge of treated effluent from municipal wastewater treatment facilities.

In addition to hydrologic, climatic, and anthropogenic stressors, the storage and relinquishment of Rio Grande Compact credit water in Elephant Butte Reservoir is represented as a time-varying input. The amount of water available for allocation and release by the RGP is equal to the total RGP storage less any non-project water in storage, including Rio Grande Compact credit water. The amount of credit water in Elephant Butte Reservoir at any given time is determined according to Rio Grande Compact accounting procedures, which are not represented in RMBHM. The volume of compact credit water in Elephant Butte Reservoir must therefore be specified for each time step as an input to RMBHM. Certain provisions of the Rio Grande Compact may affect reservoir storage and releases upstream of Elephant Butte Reservoir—and thus inflows to Elephant Butte Reservoir—when RGP storage falls below a specified threshold. RMBHM does not consider the potential feedbacks under the Rio Grande Compact between RGP operations, storage in Elephant Butte Reservoir, and reservoir operations upstream of Elephant Butte Reservoir.

The simulation period for the FEIS extends through November 1, 2050. Model inputs are therefore based on projected future conditions, rather than observed historical conditions. It is not possible to reliably predict the year-to-year and month-to-month evolution of climate and hydrologic conditions through the end of the simulation period, such as the timing, duration, and severity of wet and dry periods. Similarly, it is not possible to reliably predict future cropping and irrigation practices or changes in future municipal, industrial and domestic (collectively referred to as M&I) water demands. Therefore, model inputs for the FEIS were based on a combination of recent historical conditions and projections of effects of future climate change.

Model inputs representing hydrologic and climate stressors over the simulation period were obtained from previous analyses carried out by Reclamation and others as part of the West Wide Climate Risk Assessment (WWCRA; Reclamation 2011a, 2011b) and Upper Rio Grande Impact Assessment (URGIA; Reclamation 2013d). Projections of monthly precipitation and temperature throughout the simulation area were obtained from downscaled projections of future climate developed as part of WWCRA (see Reclamation 2011a, 2011b). Projections of monthly inflows to Elephant Butte Reservoir and monthly reservoir precipitation and evaporation were obtained from simulations carried out for URGIA with the Upper Rio Grande Simulation Model (URGSim; Roach 2007). Analyses of future climate change and its impacts on surface water supplies and management in the upper Rio Grande Basin carried out by WWCRA and URGIA are based on a set of 112 projections of future climate conditions. Three sets of model inputs were developed to represent the range of projected climate and hydrologic conditions over the simulation period, including one representing the drier end of the projected range, one representing the wetter end, and one representing the central tendency (median). Climate projections consistently indicate drier conditions over the Rio Grande Basin over the simulation period; as a result, the average annual inflow to Elephant Butte Reservoir over the simulation period is less than the observed average annual inflow over the past several decades, even under the scenario representing the wetter end of the projected range of future conditions. Additional

details regarding model inputs representing future climate and hydrologic conditions are provided in Appendix C and references therein.

Model inputs representing future M&I water uses were based on recent estimates of M&I groundwater pumping within the simulated area. All M&I demand within the simulated area is met by groundwater. Estimates of M&I groundwater pumping exist through 2004 (SSPA 2007) and were subsequently updated through 2009 by USGS (Hanson et al. 2013). For the FEIS, model inputs representing future M&I groundwater pumping were developed based on average annual M&I pumping over the period 2000-2009. See Section 4.1.4 for additional discussion of assumptions regarding future M&I water uses.

Lastly, model inputs representing future irrigation demands throughout the simulated area were developed based on recent estimates of consumptive irrigation requirements⁷ for the water year 2000 irrigation season, adjusted based on projected changes in reference evapotranspiration (ET_0) and effective precipitation. Projected changes in ET_0 and effective precipitation were calculated from projected monthly precipitation and temperature from the three climate projections selected for the FEIS. Additional details regarding model inputs representing future irrigation demands are provided in Appendix C. See Section 4.1.4 for additional discussion of assumptions regarding future irrigation demands.

4.1.3 Model Evaluation

The suitability of RMBHM for simulating RGP operations and their interaction with surface-water and groundwater resources in the Rincon and Mesilla Valleys was evaluated by simulating RGP operations under historical hydrology, climate, and cropping conditions for the period 1960-2009 and comparing simulation results to observed historical operations during this period. Historical hydrology and climate conditions were represented through time-varying model inputs, including historical inflows to Elephant Butte Reservoir, historical reservoir precipitation and evaporation rates, and historical crop irrigation requirement computed based on historical meteorology, crop distribution, and irrigated acreage data. For evaluation purposes, historical project operations were represented by implementing a consistent set of project allocation and accounting procedures representative of historical operations for the period 1990-2006. It should be noted that RMBHM uses a fixed set of operating rules over the duration of the evaluation period (1960-2009), whereas actual operating procedures varied over this period. Simulated operations are therefore not expected to perfectly match historical operations.

Model results were compared to historical records of project storage, releases, diversions, and flow in the Rio Grande below Caballo Dam and at El Paso, and to previous estimates of project surface-water deliveries and groundwater deliveries for supplemental irrigation in the Rincon and Mesilla Valleys. Project operations simulated by RMBHM closely match historical operations. As illustrated in Fig. 10, simulated total project storage is well correlated with observed historical storage (R² = 0.94) and exhibits little systematic bias. Similarly, Fig. 11 shows that simulated annual releases from Caballo Dam also agree well with observed historical releases. The simulated average annual project release is within one percent of the historical average, and the simulated average annual total project diversion from the Rio Grande is within five percent of the historical average. Simulated surface-water and groundwater deliveries to irrigated lands in the Rincon and Mesilla valleys also agree well with previous estimates (SSPA 2007). Strong agreement of RMBHM with historical records and previous modeling studies suggests that RMBHM accurately represents the key operational and hydrologic factors that drive surface-

⁷ The quantity of irrigation water, exclusive of precipitation, stored soil moisture, or groundwater that is required consumptively for crop production.

water and groundwater management and use in the Rincon and Mesilla Basins. See Appendix C for additional details.

Figure 10. Observed and simulated monthly total project storage in Elephant Butte and Caballo Reservoirs (acre-feet), 1960-2010

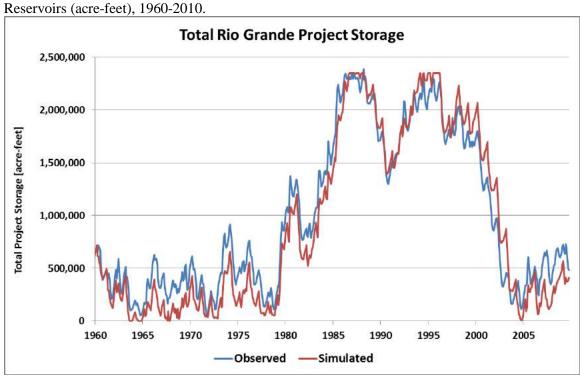
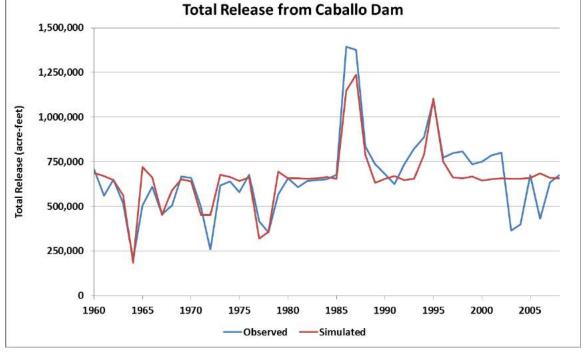


Figure 11. Observed and simulated annual release from Caballo Dam (acre-feet), 1960-2010.

Total Release from Caballo Dam



4.1.4 Simulation of Alternatives

Each alternative evaluated in this FEIS was simulated by modifying the portion of the RMBHM source code that computes allocations to EBID, EPCWID, and Mexico, including calculation of annual allocations as well as carryover allocations where applicable. All other aspects of the RMBHM source code, configuration, and inputs are identical across all alternatives. Modifications implemented to simulate each alternative are summarized in Table 4-1. Additional discussion of modeling methods and assumptions is provided in Appendix C.

4.1.5 Modeling Assumptions

The simulation period for the FEIS extends through November 1, 2050. As discussed in Section 4.1.2, it is not possible to reliably predict the evolution of climate and hydrologic conditions, cropping and irrigation practices, M&I water uses, and other stressors through the end of the simulation period. Simulation of future RGP operations therefore requires reasonable assumptions regarding future conditions within the simulated area.

Modeling assumptions were consistent across all alternatives. Key assumptions used in developing model inputs representing future climate and hydrologic conditions, crop irrigation requirements, and M&I water use in Rincon and Mesilla Valleys are summarized below. Additional modeling assumptions are discussed in Appendix C.

Table 4-1 Simulation of FEIS alternatives using RMBHM

Alter-			Summary of Modifications to
native	Alternative Name	Alternative Description	RMBHM
1	Preferred	Continue to implement the	Calculation of annual
	Alternative,	OA and continue to store up	allocations to EBID and
	Continuation of	to 50,000 acre-feet of San	EPCWID incorporate diversion
	OA and San Juan–	Juan–Chama Project (SJCP)	ratio adjustment. Calculation
	Chama Project	water in Elephant Butte	of total allocations to EBID
	Storage	Reservoir.	and EPCWID incorporate
			carryover accounting.
			Calculation of maximum SJCP
			storage calculated via post-
			processing.
2	No San Juan–	Continue to implement the	Same as Alternative 1, except
	Chama Project	OA but do not store SJCP	that SJCP storage is equal to
	Storage	water in Elephant Butte	zero (eliminates SJCP storage).
		Reservoir.	
3	No Carryover	Implement only 1 of the 2	Same as Alternative 1, except
		components of the OA and	that RMBHM source code
		continue to store up to 50,000	modified to exclude carryover
		acre-feet of SJCP water in	accounting from calculation of
		Elephant Butte Reservoir.	total allocations to EBID and
			EPCWID.
4	No Diversion	Implement only 1 of the 2	Same as Alternative 1, except
	Ratio Adjustment	components of the OA and	that RMBHM source code
		continue to store up to 50,000	modified to exclude the
			diversion ratio adjustment

Alter- native	Alternative Name	Alternative Description	Summary of Modifications to RMBHM
		acre-feet of SJCP water in Elephant Butte Reservoir.	from calculation of annual allocations to EBID and EPCWID.
5	No Action Alternative, Prior Operating Practices	Revert to operations before the OA (as summarized for the modeling) into the future.	Same as Alternative 1, except that RMBHM source code modified to exclude the diversion ratio adjustment from calculation of annual allocations to EBID and EPCWID and to exclude carryover accounting from calculation of total allocations to EBID and EPCWID.

4.1.5.1 Climate and Hydrology Inputs

As summarized in Section 4.1.2, model inputs representing future climate and hydrologic conditions were obtained from previous analyses of projected climate and hydrologic conditions (Reclamation 2011a, b; 2013c). Previous analyses consider the range of projected climate change over the Rio Grande basin from its headwaters to Elephant Butte Reservoir and corresponding changes in surface water supplies and management. Projected climate conditions were developed based on an ensemble of 112 statistically downscaled climate projections. Projected surface water supplies and management were then developed by using the Variable Infiltration Capacity (VIC) hydrology model to simulate changes in runoff and streamflow and the Upper Rio Grande Simulation Model (URGSim) to simulate corresponding changes in surface water management and use. In addition to reservoir operations, URGSim represents interstate water delivery obligations and accounting under the Rio Grande Compact. While there is considerable uncertainty regarding future climate and hydrologic conditions and water management in the simulated area, the projections developed by WWCRA and URGIA constitute the best available information on future inflows to Elephant Butte Reservoir and Compact credit water in Elephant Butte Reservoir over the simulation period.

It should be noted that under Article VII of the Rio Grande Compact, the volume of water in RGP storage could influence the operation of upstream reservoirs and thus the inflow to Elephant Butte Reservoir. RMBHM, which was developed for this FEIS, does not simulate this interaction between RGP storage and inflow to Elephant Butte Reservoir under the Compact. As discussed in Section 3.2, interactions between RGP operations and water management and use upstream of Elephant Butte Reservoir are beyond the scope of this analysis. Furthermore, despite the availability of existing models representing surface-water management and use upstream of Elephant Butte Reservoir (e.g., URGWOM and URGSim), modifying these models to interact with RMBHM would require very significant technical efforts, including substantial involvement from the agencies who lead development of these models. Reclamation, in consultation with the cooperating agencies, determined that such efforts are not necessary to accurately evaluate potential changes to resources resulting from implementation of the five alternatives.

4.1.5.2 Crop Irrigation Requirement Inputs

Model inputs representing future irrigation demands throughout the simulated area were developed based on estimates of crop irrigation requirement for the water year 2000 irrigation

season. Crop irrigation requirements for each year of the simulation period were calculated by adjusting the year 2000 crop irrigation requirements to reflect projected changes in annual reference evapotranspiration (ET_0) and effective precipitation, where changes in ET_0 and effective precipitation were derived from projected monthly precipitation and temperature from the three climate projections selected for the FEIS. This approach implicitly assumes that irrigated acreage and cropping patterns over the duration of the simulation period remain consistent with water year 2000.

Previous studies have assumed that any shortage in RGP surface water supply relative to crop irrigation requirements in Rincon and Mesilla Valleys is made up for by the use of groundwater for supplemental irrigation (e.g., Appendix F of SSPA 2007). Under this assumption, widespread use of groundwater to supplement RGP surface water supplies precludes the need to fallow land or shift to lower water-use crop during periods of low surface water supply. Analysis of irrigated acreage in Rincon and Mesilla Valleys over the past several decades shows no relationship between irrigated acreage and RGP surface water supply. Similarly, year-to-year fluctuations in cropping patterns (percent of acreage in a given crop) exhibit no relationship with RGP surface water supply. Historical cropping and acreage data thus support the assumption that cropping decisions are primarily influenced by market drivers, rather than by RGP surface water supplies. As a result, it is not possible to reliably predict future changes in cropping patterns and irrigated acreage based on simulated changes in RGP supplies.

4.1.5.3 M&I Groundwater Pumping Inputs

While plans of the cities of Las Cruces and El Paso are discussed in Chapter 5 as cumulative actions with potential cumulative impacts, there is considerable uncertainty regarding future M&I water demands and use in the study area. As noted in Chapter 5 (Section 5.3.10), future M&I water demands or use will depend on population growth, economic development, and other factors or actions that are not reasonably foreseeable. Given the large uncertainties related to M&I water demands and use through the year 2050, model inputs representing groundwater pumping for M&I use were developed based on estimates of M&I groundwater pumping for the period 2000-2009. This assumption is consistent with the fact that despite significant population and economic growth over the past two decades, water conservation programs have reduced per capita water demands and resulted in little change in actual M&I water use over this period (Hanson et al. 2013, McCoy et al. 2007, SSPA 2007). This assumption is also supported by the possibility that any further increases in pumping could be offset by fallowing of agricultural land or other conservation measures.

4.1.6 Analysis and Presentation of Model Results in FEIS

Potential environmental consequences of each alternative are evaluated based on simulations of future RGP operations and corresponding surface-water and groundwater resources. RMBHM was used to simulate the effects of the alternatives over the 43-year simulation period (November 2007 to October 2050), including year-to-year fluctuations in hydrology and climate and resulting fluctuations in water supplies, demands, and operations. Detailed results are in Appendix C, Hydrology Technical Memorandum.

Sections 4.2 to 4.11 summarize data from Appendix C, presenting averages for each simulated water resource variable (RGP allocations, releases, diversions, deliveries, etc.). Tables 4-2 to 4-13 are organized such that each column presents a single alternative and each row presents a single climate scenario with three climate scenarios presented to characterize uncertainties in future RGP operations and surface water and groundwater resources. Differences between alternatives may be evaluated by comparing columns in these tables. Differences due to potential climate change may be evaluated by comparing row. In addition, effects of climate change may be

evaluated as the difference in a given water resource variable or indicator between historical (observed) climate conditions and projected future climate conditions.

The three climate scenarios considered in the FEIS—the drier scenario (P25), central tendency or median scenario (P50), and wetter scenario (P75)—are all based on the best available projections of future climate and hydrologic conditions in the Rio Grande Basin and are each considered equally likely projections of future conditions. To assess impacts on special status species in Elephant Butte Reservoir, Reclamation used the wetter climate scenario. The wetter scenario represents a conservative worst case for the species and their habitat in the reservoir pool due to the impact of fluctuations of the water surface elevation and area, but the drier scenario would be the worst case for biological resources downstream of Caballo Dam.

4.2 Reservoir Storage

Total storage is the total volume of water (acre-feet) in Elephant Butte and Caballo Reservoirs at the end of each month. Project storage is the total volume of RGP water⁸ in the reservoirs at the end of each month, excluding Rio Grande Compact credit water and San Juan–Chama Project water. Table 4-2 presents average monthly total storage by alternative and climate scenario. Table 4-3 presents average monthly storage in Elephant Butte Reservoir and Table 4-4 presents average monthly storage in Caballo Reservoir.

As shown, the FEIS alternatives are not likely to have a strong effect on reservoir storage. Differences in average monthly storage among the alternatives range from 38,421 to 44,360 acrefeet, while differences among future climate scenarios range from 175,224 to 193,452 feet. In other words, uncertainties in future climate conditions are significantly greater than the effect of implementing one or another alternative.

Table 4-2 Average monthly total storage (acre-feet) by alternative and climate scenario

	Alternative				
Climate	1	2	3	4	5
Drier	311,875	279,081	317,502	281,367	293,084
Central	483,445	455,233	493,743	465,907	483,425
Wetter	487,099	462,627	506,987	464,527	486,536

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⁸ Project storage is the combined capacity of Elephant Butte Reservoir and all other reservoirs actually available for the storage of usable water below Elephant Butte and above the first diversion to lands of the RGP, but not more than a total of 2,638,860 acre-feet (http://www.wrri.nmsu.edu/wrdis/compacts/Rio-Grande-Compact.pdf).

Table 4-3 Average monthly Elephant Butte Reservoir storage (acre-feet) by alternative and climate scenario

	Alternative				
Climate	1	2	3	4	5
Drier	293,148	259,152	298,307	264,678	275,596
Central	449,822	419,547	458,839	433,580	449,601
Wetter	447,860	421,558	465,693	426,740	446,448

Table 4-4 Average monthly Caballo Reservoir storage (acre-feet) by alternative and climate scenario

	Alternative				
Climate	1	2	3	4	5
Drier	18,727	19,929	19,195	16,689	17,488
Central	33,624	35,686	34,904	32,327	33,825
Wetter	39,238	41,068	41,294	37,786	40,088

4.2.1 Alternative 1: Continued OA and San Juan-Chama Storage, Preferred Alternative

Under Alternative 1, Table 4-2 shows the average monthly total storage would be 483,445 acrefeet under the central tendency future climatic scenario. Alternative 1 would be almost identical to Alternative 5 (No Action) under central tendency or wetter conditions, but under drier conditions, the average monthly storage under Alternative 1 would be 18,791 acre-feet higher than Alternative 5 (No Action).

4.2.2 Alternative 2: No San Juan-Chama Project Storage

Under Alternative 2, the average monthly total storage would be 455,233 acre-feet under the central tendency climatic scenario. Alternative 2 would be 14,002 acre-feet, 28,192 acre-feet, or 23,909 acre-feet below Alternative 5 (No Action) under drier, central tendency, or wetter climatic conditions respectively.

4.2.3 Alternative 3: No Carryover Provision

Under Alternative 3, the average monthly total storage would be 493,743 acre-feet under the central tendency climate scenario. Alternative 3 would be 24,418 acre-feet, 10,318 acre-feet, or 20,451 acre-feet higher than Alternative 5 (No Action) under drier, central tendency, or wetter conditions respectively.

4.2.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the average monthly total storage would be 465,907 acre-feet under the central tendency climate scenario. Alternative 4 would be 11,716 acre-feet, 17,518 acre-feet, or 22,009 acre-feet below Alternative 5 (No Action) under drier, central tendency, or wetter conditions respectively.

4.2.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5 (No Action), the average monthly total storage would be 483,425 acre-feet under the central tendency climate scenario. It would range from 311,875 to 447,099 acre-feet under drier to wetter climates.

4.3 Elephant Butte Reservoir Elevation

Because of the biological importance of the elevation of the water surface in Elephant Butte Reservoir, Table 4-5 provides the simulated average monthly water surface elevation in feet above sea level. As shown, the simulated maximum difference in average Elephant Butte Reservoir water surface elevation among the five alternatives is 7 to 9 feet, while the simulated maximum difference among the three future climate scenarios is 10 to 12 feet.

Table 4-5 Average monthly Elephant Butte Reservoir elevation (feet above sea level) by alternative and climate scenario

			Alternative		
Climate	1	2	3	4	5
Drier	4,316	4,307	4,316	4,313	4,315
Central	4,326	4,319	4,327	4,325	4,326
Wetter	4,325	4,319	4,327	4,324	4,325

4.3.1 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, Table 4-5 shows the average monthly elevation of the water surface in Elephant Butte Reservoir would be 4,326 feet above sea level under the central tendency climatic scenario. Alternative 1 would be almost identical to Alternative 5 (No Action) under all climatic scenarios.

4.3.2 Alternative 2: No San Juan-Chama Project Storage

Under Alternative 2, the average monthly elevation would be 4,319 feet under the central tendency climatic scenario. Alternative 2 would be an average of 7 feet lower than Alternative 5 under central tendency climatic conditions or 8 feet under drier conditions. There would be no difference from Alternative 5 under wetter conditions.

4.3.3 Alternative 3: No Carryover Provision

Under Alternative 3, the average monthly elevation would be 4,327 feet under the central tendency climatic scenario. Alternative 3 would be 1 to 2 feet higher than Alternative 5 (No Action) under all climate scenarios.

4.3.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the average monthly elevation would be 4,325 feet under the central tendency climatic scenario. Alternative 4 would be 1 to 2 feet lower than Alternative 5 (No Action) under all climate scenarios.

4.3.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5, the average monthly elevation would be 4,326 feet under the central tendency climatic scenario, 4,315 feet under the drier climate scenario and 4,325 under the wetter climate scenario.

4.4 Annual Allocation to EBID and EPCWID

Table 4-6 shows the simulated average annual allocations in acre-feet to the two districts by alternative and climate scenario. The maximum difference to EBID among the alternatives would be 91,665 acre-feet under drier conditions, 101,217 under central tendency conditions, and 90,915 acre-feet under wetter conditions. The maximum difference to EPCWID among the alternatives would be 64,668 acre-feet under drier conditions, 60,677 acre-feet under central tendency conditions, and 59,925 acre-feet under wetter conditions.

Table 4-6 Average annual allocation (

District &	Alternative					
Climate	1	2	3	4	5	
EBID						
Drier	176,988	176,988	207,180	230,319	268,652	
Central	213,110	213,110	264,752	272,269	314,327	
Wetter	271,315	271,315	298,875	320,104	362,229	
EPCWID						
Drier	196,833	196,833	240,025	175,357	204,542	
Central	224,049	224,049	267,973	207,296	239,317	
Wetter	258,768	258,768	303,640	243,716	275,788	

4.4.1 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, the mean annual allocation to EBID would be 213,110 acre-feet under the central tendency climatic scenario. The mean annual allocation to EPCWID would be 224,049 acre-feet under the central tendency climatic scenario.

4.4.2 Alternative 2: No San Juan-Chama Project Storage

As shown in Table 4-6, Alternative 2 would be the same as Alternative 1.

4.4.3 Alternative 3: No Carryover Provision

Under Alternative 3, the mean annual allocation to EBID would be 264,752 acre-feet under the central tendency climatic scenario and 267,973 acre-feet to EPCWID.

4.4.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the mean annual allocation to EBID would be 272,269 acre-feet under the central tendency climatic scenario and 207,296 acre-feet to EPCWID.

4.4.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5 (No Action), the mean annual allocation to EBID would be 314,327 acre-feet under the central tendency climatic scenario. The mean annual allocation to EPCWID would be 239,317 acre-feet under the central tendency climatic scenario.

4.5 Total Allocation to EBID and EPCWID

Table 4-7 shows the simulated average total allocation in acre-feet to the two districts by alternative and climate scenario. The total allocation to each district is calculated as the sum of its annual allocation and carryover allocation. The maximum difference to EBID among the alternatives would be 63,354 acre-feet under wetter conditions, 59,177 acre-feet under central tendency conditions, and 61,472 acre-feet under wetter conditions. The maximum difference to EPCWID among the alternatives would be 97,650 acre-feet under central tendency conditions, 97,352 acre-feet under wetter conditions, and 80,013 acre-feet under drier conditions.

Table 4-7 Average total allocation (acre-feet) to districts by alternative and climate scenario

District &	Alternative					
Climate	1	2	3	4	5	
EBID						
Drier	222,539	222,539	207,180	278,015	268,652	
Central	255,150	255,150	264,752	321,955	314,327	
Wetter	335,499	335,499	298,875	410,996	362,229	
EPCWID						
Drier	284,556	284,556	240,025	260,666	204,542	
Central	336,967	336,967	267,973	310,152	239,317	
Wetter	373,140	373,140	303,640	356,520	275,788	

4.5.1 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, the mean total allocation to EBID would be 255,150 acre-feet under the central tendency climatic scenario. The mean total allocation to EPCWID would be 336,967 acrefeet under the central tendency climatic scenario. The mean total allocation to EBID would range from 222,539 acre-feet under the drier climate scenario to 335,499 acre-feet under the wetter scenario. The mean total allocation to EPCWID would range from 204,542 acre-feet under the drier scenario to 275,788 acre-feet under the wetter climate scenario.

4.5.2 Alternative 2: No San Juan-Chama Project Storage

As shown in Table 4-7, Alternative 2 would be the same as Alternative 1.

4.5.3 Alternative 3: No Carryover Provision

Under Alternative 3, the mean total allocation to EBID would be 264,752 acre-feet under the central tendency climatic scenario. The mean total allocation to EPCWID would be 310,152 acrefeet under the central tendency climatic scenario.

4.5.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the mean total allocation to EBID would be 321,955 acre-feet under the central tendency climatic scenario. The mean total allocation to EPCWID would be 310,152 acrefeet under the central tendency climatic scenario.

4.5.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5 (No Action), the mean total allocation to EBID would be 314,327 acre-feet under the central tendency climatic scenario with a range from 268,652 to 362,229 acre-feet under the drier to wetter climate scenarios respectively. The mean total allocation to EPCWID would be 239,317 acre-feet under the central tendency climatic scenario with a range from 204,542 to 275,788 acre-feet under the drier to wetter climate scenarios respectively.

4.6 Rio Grande Project Releases

Figure 11 shows that simulated releases from Caballo Dam agree well with observed historical releases. Table 4-8 shows the simulated average annual project release in acre-feet by alternative and climate scenario. The maximum difference to EBID among the alternatives would be 91,665 acre-feet under drier conditions, 101,217 acre-feet under central tendency climatic conditions, and 90,915 acre-feet under wetter conditions. The maximum difference to EPCWID among the alternatives would be 64,668 acre-feet under drier conditions, 60,677 acre-feet under central tendency climatic conditions, and 59,925 acre-feet under wetter conditions.

Table 4-8 Average annual RGP release (acre-feet) by alternative and climate scenario

	Alternative					
Climate	1	2	3	4	5	
Drier	479,601	479,601	478,320	482,903	480,759	
Central	529,170	529,170	525,808	531,229	527,421	
Wetter	585,623	585,623	578,858	587,718	527,421	

4.6.1 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, Table 4-8 shows the central tendency annual project release would be 529,170 acre-feet under the central tendency climatic scenario and the total release would average 541.019 acre-feet.

4.6.2 Alternative 2: No San Juan-Chama Project Storage

As shown in Table 4-8. Alternative 2 would be the same as Alternative 1.

4.6.3 Alternative 3: No Carryover Provision

Under Alternative 3, the average annual project release would be 525,808 acre-feet under the central tendency climatic scenario and the total release would average 539,140 acre-feet.

4.6.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the average annual project release would be 531,229 acre-feet under the central tendency climatic scenario and the total release would average 543,089 acre-feet.

4.6.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5 (No Action), the average annual project release would be 527,421 acre-feet under the central tendency climatic scenario and the total release would average 539,807 acre-feet.

4.7 Net Diversions

Table 4-9 shows the simulated average annual net diversions in acre-feet to the two districts by alternative and climate scenario. The simulations for EPCWID are for Rincon and Mesilla Valleys only. The maximum difference to EBID among the alternatives would be 49,426 acrefeet under wetter conditions, 49,165 acre-feet under central tendency conditions, and 41,220 acrefeet under drier conditions. The maximum difference to EPCWID among the alternatives would be 14,720 acre-feet under central tendency conditions, 12,794 acre-feet under drier conditions, and 7,678 acre-feet under wetter conditions.

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District &	Alternative					
Climate	1	2	3	4	5	
EBID						
Drier	148,818	148,818	154,454	190,038	189,864	
Central	179,198	179,198	198,287	227,069	228,363	
Wetter	223,271	223,271	217,316	266,742	256,654	
EPCWID						
Drier	34,155	34,155	30,554	24,968	21,361	
Central	40,262	40,262	34,805	29,491	25,543	
Wetter	37,075	37,075	36,805	30,701	29,397	

4.7.1 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, the mean annual net diversion to EBID would be 148,818 acre-feet under the central tendency climatic scenario. The mean annual net diversion to EPCWID would be 40,262 acre-feet under the central tendency climatic scenario.

4.7.2 Alternative 2: No San Juan-Chama Project Storage

As shown in Table 4-9, Alternative 2 would be the same as Alternative 1.

4.7.3 Alternative 3: No Carryover Provision

Under Alternative 3, the mean annual net diversion to EBID would be 198,287 acre-feet under the central tendency climatic scenario. The mean annual net diversion to EPCWID would be 34,805 acre-feet under the central tendency climatic scenario.

4.7.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the mean annual net diversion to EBID would be 227,069 acre-feet under the central tendency climatic scenario. The mean annual net diversion to EPCWID would be 29,491 acre-feet under the central tendency climatic scenario.

4.7.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5 (No Action), the mean annual net diversion to EBID would be 228,363 acrefeet under the central tendency climatic scenario. The mean annual net diversion to EPCWID would be 25,543 acrefeet under the central tendency climatic scenario.

4.8 Farm Surface Water Deliveries

Table 4-10 shows the simulated average farm surface water deliveries in acre-feet to the two districts by alternative and climate scenario. The simulations for EPCWID are for Mesilla Valley only. The maximum difference to EBID among the alternatives would be 31,194 acre-feet under wetter conditions, 26,728 under central tendency conditions, and 23,908 acre-feet under drier conditions. The maximum difference to EPCWID among the alternatives would be 2,259 acre-feet under drier conditions, 2,058 acre-feet under central tendency conditions, and 1,699 acre-feet under wetter conditions.

Table 4-10 Average farm surface water deliveries (acre-feet) to districts by alternative and climate scenario

District &	Alternative					
Climate	1	2	3	4	5	
EBID						
Drier	66,053	66,053	70,101	89,961	88,532	
Central	84,054	84,054	94,477	110,782	110,314	
Wetter	101,217	101,217	99,232	130,426	123,473	
EPCWID						
Drier	13,259	13,259	12,416	11,949	10,999	
Central	15,954	15,954	15,029	14,964	13,896	
Wetter	17,156	17,156	16,553	15,935	15,456	

4.8.1 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, the mean annual farm surface water delivery to EBID would be 84,054 acrefeet under the central tendency climatic scenario. The mean annual farm surface water delivery to EPCWID would be 15,954 acre-feet under the central tendency climatic scenario.

4.8.2 Alternative 2: No San Juan-Chama Project Storage

As shown in Table 4-10, Alternative 2 would be the same as Alternative 1.

4.8.3 Alternative 3: No Carryover Provision

Under Alternative 3, the mean annual farm surface water delivery to EBID would be 94,477 acrefeet under the central tendency climatic scenario. The mean annual farm surface water delivery to EPCWID would be 15,029 acre-feet under the central tendency climatic scenario.

4.8.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the mean annual farm surface water delivery to EBID would be 110,782 acre-feet under the central tendency climatic scenario. The mean annual farm surface water delivery to EPCWID would be 14,964 acre-feet under the central tendency climatic scenario.

4.8.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5 (No Action), the mean annual farm surface water delivery to EBID would be 110,314 acre-feet under the central tendency climatic scenario. The mean annual farm surface water delivery to EPCWID would be 13,896 acre-feet under the central tendency climatic scenario.

4.9 Groundwater

Based on the assumptions described in Section 4-1 and Appendix C, Table 4-11 shows the simulated change in total groundwater storage in Rincon and Mesilla Valleys in acre-feet over the 43-year simulation period by alternative and climate scenario. The change in total groundwater storage is calculated as the difference in the total groundwater storage, summed over the simulated area of RMBHM, at the end of the simulation period compared to the start of the simulation period. The maximum difference among alternatives in the simulated change in groundwater storage would be 9,875 acre-feet under the wetter climate scenario, 5,513 acre-feet under the central tendency scenario, and 3,444 acre-feet under the drier scenario.

Table 4-11 Change in total groundwater storage (acre-feet) by alternative and climate scenario

	Alternative					
Climate	1	2	3	4	5	
Drier	-56,632	-56,632	-56,162	-44,472	-46,575	
Average	-29,470	-29,470	-28,055	-25,657	-23,957	
Wetter	-2,277	-2,277	-4,361	937	-2,508	

4.9.1 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, the total volume of groundwater storage in Rincon and Mesilla Valleys would decline by 29,470 acre-feet between 2007 and 2050 under the central tendency climatic scenario. The total volume of groundwater storage would decline by 56,632 acre-feet under the drier scenario and by 2,277 acre-feet under the wetter scenario.

4.9.2 Alternative 2: No San Juan-Chama Project Storage

As shown in Table 4-11, Alternative 2 would be the same as Alternative 1.

4.9.3 Alternative 3: No Carryover Provision

Under Alternative 3, the total volume of groundwater storage in Rincon and Mesilla Valleys would decline by 28,055 acre-feet between 2007 and 2050 under the central tendency climatic scenario. The total volume of groundwater storage would decline by 56,162 acre-feet under the drier scenario and by 4,361 acre-feet under the wetter scenario.

4.9.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the total volume of groundwater storage in Rincon and Mesilla Valleys would decline by 25,657 acre-feet between 2007 and 2050 under the central tendency climatic scenario. The total volume of groundwater storage would decline by 44,472 acre-feet under the drier scenario and increase by 937 acre-feet under the wetter scenario.

4.9.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5, the total volume of groundwater storage in Rincon and Mesilla Valleys would decline by 23,957 acre-feet between 2007 and 2050 under the central tendency climatic scenario. The total volume of groundwater storage would decline by 46,757 acre-feet under the drier scenario and by 2,508 acre-feet under the wetter scenario.

4.10 Farm Groundwater Deliveries

Irrigation requirements that are not satisfied by RGP surface water deliveries are assumed to be met through supplemental groundwater pumping. As a result, combined total delivery of RGP surface water and supplemental groundwater to RGP lands in the Rincon and Mesilla Valleys would be nearly identical under all alternatives. Table 4-12 shows the simulated average annual farm groundwater deliveries in acre-feet to the two districts by alternative and climate scenario. The simulations for EPCWID are for Rincon and Mesilla Valleys only. The maximum difference to EBID among the alternatives would be 31,194 acre-feet under wetter conditions, 26,728 acrefeet under central tendency conditions, and 23,908 acre-feet under drier conditions. The maximum difference to EPCWID among the alternatives would be 2,259 acre-feet under drier conditions, 2,058 acre-feet under central tendency conditions, and 1,699 acre-feet under wetter conditions.

Table 4-12 Average annual farm groundwater deliveries (acre-feet) to districts by alternative and climate scenario

District &		Alternative				
Climate	1	2	3	4	5	
EBID						
Drier	243,662	243,662	239,489	217,637	219,276	
Central	214,370	214,370	202,791	184,273	185,061	
Wetter	194,619	194,619	197,481	161,595	169,660	
EPCWID						
Drier	15,563	15,563	15,951	16,406	17,357	
Central	11,850	11,850	12,486	12,533	13,607	
Wetter	10,593	10,593	10,859	11,454	11,939	

4.10.1 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, the mean annual farm groundwater delivery (pumping of groundwater) to EBID would be 214,370 acre-feet under the central tendency climatic scenario. The mean annual farm groundwater delivery to EPCWID would be 11,850 under the central tendency climatic scenario.

4.10.2 Alternative 2: No San Juan-Chama Project Storage

As shown in Table 4-12, Alternative 2 would be the same as Alternative 1.

4.10.3 Alternative 3: No Carryover Provision

Under Alternative 3, the mean annual farm groundwater delivery to EBID would be 202,791 acre-feet under the central tendency climatic scenario. The mean annual farm groundwater delivery to EPCWID would be 12,486 acre-feet under the central tendency climatic scenario.

4.10.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the mean annual farm groundwater delivery to EBID would be 184,273 acre-feet under the central tendency climatic scenario. The mean annual farm groundwater delivery to EPCWID would be 12,533 acre-feet under the central tendency climatic scenario.

4.10.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5, the mean annual farm groundwater delivery to EBID would be 185,061 acre-feet under the central tendency climatic scenario. The mean annual farm groundwater delivery to EPCWID would be 13,607 acre-feet under the central tendency climatic scenario.

4.11 Groundwater Elevations at Selected Wells

Water elevation data for 15 wells in the Rincon and Mesilla Basins were used for simulation analysis (Appendix C). Simulated fluctuations in groundwater elevations are qualitatively similar among all wells within each basin, so data from only one well in each basin are presented here. The mean monthly groundwater elevation for the representative well in the Rincon Basin (Rin-2) is shown in Table 4-13, along with the data from the well in the Mesilla Basin (Mes-6). As shown, the maximum difference in well elevations among the alternatives would be 3 feet for the Rin-2 well under central tendency climatic conditions, and 1 foot for the Mes-6 well under all climate scenarios.

Table 4-13 Average annual farm groundwater elevations at selected wells (feet above sea level) by alternative and climate scenario

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Well &	Alternative						
Climate	1	2	3	4	5		
Rin-2							
Drier	4,059	4,059	4,060	4,062	4,062		
Central	4,061	4,061	4,062	4,063	4,063		
Wetter	4,063	4,063	4,063	4,065	4,065		
Mes-6							
Drier	3,813	3,813	3,813	3,814	3,814		
Central	3,814	3,814	3,815	3,816	3,815		
Wetter	3,816	3,816	3,816	3,817	3,817		

4.11.1 Alternative 1: Continued OA and San Juan-Chama Storage, Preferred Alternative

Under Alternative 1, the mean elevation in the Rincon-2 well would be 4,061 feet under the central tendency or central tendency climatic scenario with the mean under drier conditions of 4,059 feet to 4,063 feet under wetter climate conditions. The mean elevation in the Mesilla-6 well would be 3,814 feet under the central tendency climatic scenario with the mean under drier conditions of 3,813 feet to 3,816 feet under wetter conditions.

4.11.2 Alternative 2: No San Juan-Chama Project Storage

As shown in Table 4-13, Alternative 2 would be the same as Alternative 1.

4.11.3 Alternative 3: No Carryover Provision

Under Alternative 3, the mean elevation in the Rincon-2 well would be 4,062 feet under the central tendency or central tendency climatic scenario. The mean elevation in the Mesilla-6 well would be 3,815 feet under the central tendency climatic scenario.

4.11.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the mean elevation in the Rincon-2 well would be 4,063 feet under the central tendency or central tendency climatic scenario. The mean elevation in the Mesilla-6 well would be 3,816 feet under the central tendency climatic scenario.

4.11.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5, the mean elevation in the Rincon-2 well would be 4,063 feet under the central tendency or central tendency climatic scenario. The mean elevation in the Mesilla-6 well would be 3,815 feet under the central tendency climatic scenario.

4.12 Water Quality

4.12.1 Analysis Methods and Assumptions

This FEIS incorporates by reference the water quality analysis from SEA (Reclamation 2013a). Assumptions are that increased reservoir storage or increased releases to the river would improve water quality. Other assumptions include:

- Water is generally not released from Caballo Reservoir in the non-irrigation season under any alternative. As such, water quality may fluctuate during this period but is not related to the alternatives.
- Water used by municipal users is treated, and the level of treatment would not change under the various alternatives.
- Changes in nonpoint source runoff would be the same under the various alternatives.

4.12.2 Effects Common to All Alternatives

Water quality effects are common to all alternatives. These are identified and described below.

4.12.2.1 Mercury and PCBs in Fish

Concentrations of methylmercury and other contaminants in fish would not be affected by the alternatives. Mercury and other contaminants in water bioaccumulate in fish due to complex ecological and biogeochemical processes and would not be affected by the volume of water in storage.

4.12.2.2 Dissolved Oxygen

Low dissolved oxygen below the two dams is a seasonal condition caused by upstream sources of deoxygenated water and nutrient levels, as well as release patterns. Given the common volumes and timing of released water among the alternatives, none of the alternatives would alter the existing seasonally low dissolved oxygen concentrations.

4.12.2.3 Total Dissolved Solids, Salinity and Nutrients

As shown in Section 4.6 and Table 4-8, across all alternatives, the differences in releases would be minor and insufficient to change the existing impairment of water quality due to high concentrations of dissolved oxygen, dissolved solids, nutrients, or salinity.

4.12.2.4 Groundwater Quality

As noted by the Texas Water Development Board (2016), groundwater quality issues in the study area are generally related to naturally high concentrations of total dissolved solids (TDS) or to the occurrence of elevated concentrations of individual dissolved constituents, and while there are local instances of groundwater quality degradation, there are no major trends suggesting a widespread water quality problem due to the downward percolation of surface contaminants. The groundwater well elevations may be suggestive of groundwater water quality. Results presented in Section 4.11 and Table 4-13 show the differences among alternatives in groundwater elevations are likely too small to result in any measurable differences in groundwater quality.

4.13 Vegetation and Wetlands

This section projects changes to vegetation communities and wetlands due to implementation of the alternatives. (No special status plants are present, as described in Chapter 3.) The study area for vegetation is the action area for special status aquatic and wildlife species and their designated or proposed critical habitats under the ESA. The action area is defined as all areas affected directly or indirectly by the Federal action (50 CFR 402.02) and is subdivided into the following reaches or segments:

- Elephant Butte Reservoir from full pool to dead pool
- The Rio Grande downstream from Elephant Butte Dam to Caballo Reservoir
- Caballo Reservoir from full pool to dead pool
- The Rio Grande from Caballo Dam downstream to International Dam

While vegetation in all these reaches was considered, the analysis focuses on vegetation in and around Elephant Butte Reservoir for three reasons. One, upland desert shrub communities further from the river would be unaffected by the alternatives because none of the alternatives would change the volume or pattern of releases from the dams to the extent that these vegetation communities would be affected.

Two, there is only a narrow band of riparian vegetation, including some wetlands, along the river banks between the reservoirs and downstream of Caballo Dam that could be affected by releases and this vegetation has been previously considered by Reclamation in the SEA (Reclamation 2013a) or by the USIBWC (various). Release data from Section 4.6 and Table 4-8 are provided below, but the vegetation communities and wetlands along the river would be unaffected by implementation of one or another alternative.

Three, Caballo Reservoir pool levels would be relatively stable under all alternatives. The vegetation in and around this reservoir is relatively constant: it is dense near the water's edge and gradually reduces in density away from the water line. For these reasons, the analysis focuses on Elephant Butte Reservoir vegetation.

4.13.1 Analysis Methods and Assumptions

The RMBHM hydrologic modeling of reservoir elevations (Appendix C, Section 4,3) and surface area (Table 4-14) is used to project changes in vegetation communities in and around Elephant Butte Reservoir because, as noted by Dick-Peddie et al. (1999:27-32), moisture availability is the primary factor influencing vegetation patterns in New Mexico, although climatic regime and disturbances such as fire, flood, grazing, plowing, etc. influence the distribution of individual plants and some vegetation communities. However, the moisture availability caused by fluctuating water levels of Elephant Butte, like all reservoirs (cf. Lesica and Miles 2004), creates habitats different from those associated with natural riparian systems due to the repeated cycles of inundation that tend to prevent vegetation from proceeding beyond the earliest stages of succession.

Section 4.3 and Table 4-5 describe the projected average Elephant Butte Reservoir elevations by alternative and Table 4-14 shows the surface area of the reservoir, but the indicator for change in vegetation is the duration of cycles of inundation or drawdown, shown by the time series simulations for reservoir elevations (Figs. 12, 13).

4.13.1.1 Drawdown and Low Reservoir

Presently most of the vegetation at Elephant Butte Reservoir occurs in the sediment delta, from full pool at River Mile 62 to where the Rio Grande enters into the current baseline pool at River Miles 38 to 36, and there is a gradient in density/quality from west to east and south to north. In the future, as simulated by the RMBHM and Section 4.3, reservoir levels will fluctuate and the assumption is that when the reservoir recedes, as it has over the last decade, it will expose moist, bare alluvium that is rapidly colonized by annuals, biennials, short-lived perennials, as well as woody species such as cottonwood, willow, and tamarisk. If the water level of the reservoir remains low, without periodic inundation, the vegetation upstream and adjacent to the reservoir pool would mature over time through natural succession and would eventually shift to longer-lived, more xeric, upland species.

Tamarisk appears to be better adapted to colonizing drawdown reservoir pools, but tamarisk greater than five years old rarely grow in most reservoirs because three months of inundation may kill them (Ellis et al. 2008, Lesica and Miles 2004).

4.13.2.2 Inundation and High Reservoir

Historically, Elephant Butte Reservoir has fluctuated and this is expected to occur under all alternatives and all climate scenarios. In the future when the reservoir water surface elevation rises, some plants (including mature cottonwoods) and patches of riparian vegetation would benefit from the rising water table. Habitat that is partially inundated could be enhanced through deposition of new sediments and nutrients, flushing of accumulated salts, and irrigation of the respective site.

However, prolonged or complete inundation could result in the total loss of particular plants and patches of riparian habitat, with the losses depending on the particular species and age class. Based on monitoring of Elephant Butte Reservoir vegetation, young Goodding's willows are more flood tolerant than saltcedars (Reclamation 2009). Following a period of six months of inundation with 18 to 24 inches of water over the terminal bud primarily during the dormant

season, Goodding's willow densities and heights increase. Similar observations have been reported by Ellis et al. (2008), who reported a die-off of saltcedar understory and survival of Goodding's willow at Roosevelt Lake, and by Lesica and Miles (2004) who found that tamarisk in reservoir pools were destroyed after two summers (three months) of inundation.

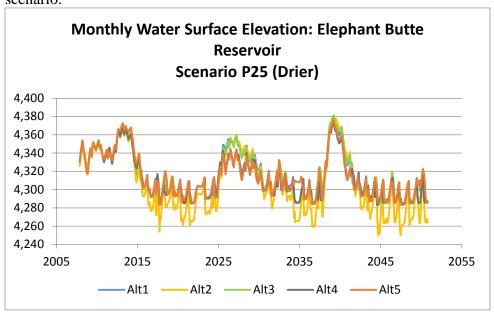
Prolonged or complete inundation, which is expected to occur during the analysis period, could result in the loss of some riparian habitat, and survivability would depend on species composition and age class. Ellis and others (2008) also found that most species were not able to survive more than one year of complete inundation. Reclamation (2009) has also previously reported that partial (10 to 15 feet) and temporary (less than six months) flooding would likely cause a reduction in woody vegetation. The shrub layer, if present, could be slow to recover.

Figures 12 and 13 provide the time series outputs from the hydrological model, showing projected durations of time or cycles when Elephant Butte Reservoir would be rising or falling. These figures, combined with the data on surface area of the reservoir in Table 4-14, are used to project vegetation effects of the alternatives. As shown by Table 4-14, the maximum difference in average values among the alternatives would be about 1,000 acres.

Table 4-14 Elephant Butte Reservoir mean surface area (acres) by alternative and climate scenario

Area &		Alternative					
Climate	1	2	3	4	5		
Drier	8,780	7,637	8,878	8,299	8,533		
Average	11,425	10,493	11,570	11,127	11,404		
Wetter	11,349	10,478	11,661	10,958	11,306		

Figure 12. Time series of Elephant Butte Reservoir by alternatives under a drier climate scenario.



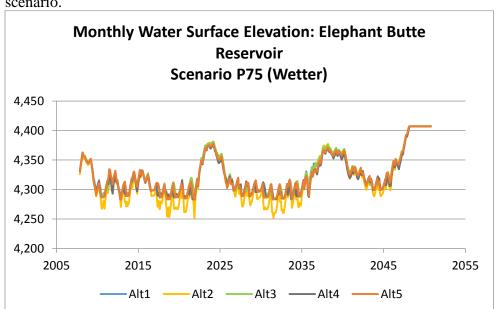


Figure 13. Time series of Elephant Butte Reservoir by alternatives under a wetter climate scenario.

4.13.3 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Alternative 1 is projected to have three periods of reservoir drawdown that could affect vegetation under all climate scenarios. As shown in Table 4-14, under Alternative 1, the average surface area of Elephant Butte Reservoir under the central tendency climate scenario would potentially cover or inundate 11,425 acres. The difference from No Action is projected to be an average of only 21 acres under central tendency climate conditions. Under central tendency climate conditions, releases under Alternative 1 would tend to be slightly higher (1,212 acre-feet) than Alternative 5 (No Action), but for the reservoir and river, there would be no difference to vegetation between Alternative 1 (Preferred) and Alternative 5 (No Action).

4.13.4 Alternative 2: No San Juan-Chama Project Storage

Alternative 2 would also have the same three periods of reservoir drawdown, but would tend to remain at lower levels than the other alternatives. Under Alternative 2, average surface area of Elephant Butte Reservoir under the central tendency climate scenario would be 10,493 acres, a difference of 910 acres from Alternative 5 (No Action). Releases would be the same as Alternative 1.

4.13.5 Alternative 3: No Carryover Provision

Alternative 3 would have the same three periods of reservoir drawdown that could affect vegetation. Average surface area under central tendency climate would cover or inundate 11,570 acres. Under the wetter climate scenario, vegetation would be the most affected with a projected mean of 11,661 acres inundated. For vegetation, the releases would be virtually the same as Alternative 5; the average difference in total releases would be -667 acre-feet.

4.13.6 Alternative 4: No Diversion Ratio Adjustment

Alternative 4 would tend to be the same as Alternative 5, which exhibits the same three periods of reservoir drawdown periods as the other alternatives. Average surface area under the central tendency climate scenario would cover or inundate 11,127 acres; i.e., 298 acres less than Alternative 1 and 277 acres less than Alternative 5. Under Alternative 4, releases would vary the most from Alternative 5 (No Action), with the average total release under the central tendency climate condition 3,282 acre-feet higher than Alternative 5.

4.13.7 Alternative 5: Prior Operating Practices, No Action Alternative

Alternative 5 (No Action) is projected to have the same three periods of reservoir drawdown that could affect Elephant Butte Reservoir vegetation. Average surface area under the central tendency climate scenario would cover or inundate 11,404 acres, less vegetation (surface acres) than Alternatives 1, 2, or 3, but it would tend to cover more surface acres than Alternative 4. Releases would be most similar to Alternative 3, with slightly higher total releases under Alternatives 1, 2, and 4, but again, no differences in moisture availability to riverine plants or wetlands is expected under any of the alternatives.

4.14 Wildlife and Special Status Species

Effects on wildlife are mostly based on how the alternatives would affect vegetation that serves as wildlife habitat in and around Elephant Butte Reservoir, especially the delta reach. The analysis focuses on the potential effects to flycatcher and the cuckoo. The endangered mouse is not expected to occur in the study area because of the lack of suitable habitat. Further, there is no proposed critical habitat for the mouse in the study area; the nearest proposed critical habitat is approximately 16 river miles upstream, at Bosque del Apache National Wildlife Refuge.

4.14.1 Analysis Methods and Assumptions

The analysis method for special status species is to determine the potential for the alternatives, particularly Alternative 1, the Preferred Alternative, to affect listed species or their critical habitat. Reclamation prepared a biological assessment of the effects of Alternative 1 on listed species and their critical habitat and consulted with the Service. The Service's biological opinion is provided in Appendix F.

In addition to how the cycles of rising or falling reservoir levels affect vegetation or wildlife habitat, indicators specific to wildlife include:

- Decline in reservoir elevations, which degrades the riparian habitat along the outside edge of the reservoirs, but also enhances and creates riparian habitat within the reservoir area from River Mile 62 to River Miles 38 to 36
- Death or decreased reproductive success of wildlife species due to habitat alteration

Current and historical information from field surveys conducted by Reclamation or others, as well as a literature review, was used to document the status of the species and their habitat in 2014—the environmental baseline for consultation with the Service under the ESA. If the presence of a listed species or supporting habitat features were determined to be likely, then the alternatives' potential effects were analyzed to determine whether they would affect the species or associated habitat. The following considerations apply:

• Fluctuations in Elephant Butte Reservoir and Caballo Reservoir water levels up to the full pool have historically been a normal feature of the reservoirs.

- The habitat that currently supports the largest flycatcher population in the Southwest was created when the Elephant Butte Reservoir receded, allowing various age classes of vegetation to develop.
- Based on hydrologic data collected since 2004, a large part of the northern portion of
 the reservoir pool receives water throughout the year. The source of this water is
 agricultural return from the outfall of the low flow conveyance channel (Reclamation
 2005) and not from the river channel into the Elephant Butte Reservoir. Though
 habitats are changing, suitable habitat in this portion of the reservoir pool remains
 relatively abundant.
- The revised designated critical habitat for the flycatcher and proposed critical habitat for the cuckoo includes a part of the Elephant Butte Reservoir delta reach, downstream to River Mile 54. Above River Mile 54, the reservoir inundates designated critical habitat.
- The flycatcher and cuckoo are presently restricted to elevations in Elephant Butte Reservoir above 4,325 feet, which was the baseline for consultation with the Service. Flycatcher designated critical habitat and cuckoo proposed critical habitat extends to River Mile 54, at approximately the 4,380-foot elevation. The action's primary determinant of effect on birds would be months when Elephant Butte Reservoir surface elevation rises and remains greater than 4,325 feet. Above this elevation, rising waters might inundate and potentially affect flycatcher.
- Based on the 2014 flycatcher surveys, approximately 31 percent of the flycatcher territories (260) and 65.1 percent (161) of cuckoo territories would be affected by the reservoir rising to 4,380 feet (Moore and Ahlers 2015, Reclamation 2015b). The reservoir elevations typically begin rising in November, after minimum storage occurs in October, continuing to maximum storage peaks for the year as the spring releases begin, following irrigation demands. Thus, reservoir levels typically increase in the fall after flycatchers and cuckoos have departed for over-wintering territories and higher reservoir levels due to runoff end in the spring when the birds begin to establish breeding territories.

4.14.2 Effects Common to All Alternatives

References such as Reitan and Thingstad (1999) and the simulated reservoir water surface elevations presented in Section 4.3 and Table 4-5, were used to extrapolate potential effects of the alternatives into the future, relative to the range in water surface elevations from full pool (4,407 feet) to the 4,325 foot elevation level where flycatcher and cuckoo territories are currently, and the 4,380 foot elevation at River Mile 54 where the flycatcher designated critical habitat and the proposed cuckoo critical habitat extend into Elephant Butte Reservoir. The modeling simulates recurring cycles during which Elephant Butte Reservoir elevation would rise above the 4,325-foot level for different lengths of time. As shown in Figs. 12, 13 and Table 4-14, there are times when the reservoir is projected to rise above 4,325 feet, but most of the time, the reservoir would be below this level. As such, implementing one or another of the alternatives through 2050 is projected to produce little, if any, differences in direct effects on flycatchers, cuckoo, or their habitat in these segments, beyond impacts associated with current operations and climate variability.

Effects on flycatcher and cuckoo habitat under all alternatives are projected to be as follows:

- Without inundation from rising pool elevations, nutrients would not be replenished and salts would not be flushed in areas of trees associated with flycatchers and cuckoos. This would reduce the vigor of vegetation, degrading its overall habitat suitability for flycatchers and cuckoos. Periods of lower water inflows and lower pool elevations in Elephant Butte Reservoir would lead to maturation of vegetation communities and changes in species composition that could eventually render flycatcher and cuckoo nesting habitat unsuitable. This would come about without other types of disturbance in the delta reach, such as fire or mechanical disturbance.
- Inundation could create short-term impacts on birds and shrubs through the physical loss of riparian vegetation (Service 2014a); however, over the long term, a rising reservoir would support riparian vegetation by increasing the water table in some areas, resulting in denser vegetation and taller trees favored by the birds. Inundation would also flush accumulated salts from the soils, replenish nutrients, and deposit new sediments.

4.14.3 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, Table 4-14 and Figs. 12-13, and show there would be periods of both increasing and decreasing reservoir levels under all climate scenarios. To assess impacts on special status species, Reclamation consulted with the Service on the effects of the wetter climate scenario, which provided a conservative worst-case, based on the potential impacts to vegetation used by listed species. Reclamation's finding is that implementation of Alternative 1 "may affect, and is likely to adversely affect" flycatcher and cuckoo that could be present in Elephant Butte Reservoir. Compared to the 2014 baseline, individual birds may be displaced and some territories/nests may be inundated by a rising reservoir. Such a rising reservoir would result in only minor adverse effects because there is more suitable habitat available that is not being used, and vegetation regrowth could occur quickly under the right conditions.

Reclamation's finding for critical habitat is that Alternative 1 "may affect, and is likely to adversely modify" flycatcher designated critical habitat and cuckoo proposed critical habitat. Modeling presented in Section 4.3 and Table 4-5 shows that reservoir rising/filling would inundate existing critical habitat. This determination is also appropriate for indirect effects related to the habitat south of River Mile 54, which is projected to be regularly inundated due to water level increases in the reservoir.

Additionally, note that willow habitat, documented to be preferred for nesting in the delta reach of the Elephant Butte Reservoir, matures with time, becoming unsuitable for flycatcher nesting (Reclamation 2013a, Service 2002). Similarly, as described in the proposed critical habitat designation (Service 2014b), cuckoos require large tracts of willow-cottonwood forest or woodland for their nesting habitat. This habitat also matures with time, becoming unsuitable for cuckoo nesting. Prolonged flooding of the overly mature habitat would likely destroy the old vegetation. Quality nesting habitat would then be regenerated after the reservoir water level recedes.

4.14.4 Alternative 2: No San Juan-Chama Project Storage

Alternative 2 tends to reduce the reservoir water surface elevation relative to Alternative 5 (No Action). Under Alternative 2, Elephant Butte Reservoir would reach a lower elevation than under the other alternatives, and there would most likely be longer periods of lower elevations.

Therefore, the impacts on flycatchers and cuckoos associated with a rising reservoir and a greater number of acres of habitat inundated would occur.

When the reservoir recedes, reservoir bottomlands or nutrient-enriched exposed soils would quickly be revegetated with both desirable species, such as willow, and undesirable species, such as nonnative or invasive plants. This recession could create habitat for the flycatcher and cuckoo. If the reservoir were to remain at low water levels, habitat upstream to River Mile 62 and next to the reservoir pool would ultimately mature through natural succession past a point of suitability for the flycatcher and cuckoo. A low reservoir level equates to lower water in the Rio Grande system overall, so under drier conditions in the future degrading riparian vegetation would eventually be replaced by more upland species until the reservoir levels increase and this older vegetation is replaced.

Alternative 2 has the greatest potential for creating habitat, if the reservoir were to fill, depending on the timing and duration of filling. Alternative 2 also has the greatest amount of habitat that could be inundated and potentially destroyed. Therefore, under Alternative 2, riparian vegetation would expand, leading to more flycatcher and cuckoo habitat. Conversely, under Alternative 2, flycatcher and cuckoo habitat has the greatest potential for maturing beyond the point of suitability. It could also lead to increased drying and expansion of upland vegetation into formerly riparian areas.

4.14.5 Alternative 3: No Carryover Provision

Under Alternative 3, Elephant Butte Reservoir water surface elevations would fluctuate over time. The birds currently are above the 4,325-foot elevation level, so some impacts are expected when the reservoir rises above that elevation.

4.14.6 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, Elephant Butte Reservoir water surface elevations would fluctuate over time. The birds are presently located above 4,325 feet, so under Alternative 4 some impacts are expected when the reservoir rises above that elevation.

4.14.7 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5, the No Action Alternative, Elephant Butte Reservoir water surface elevations would fluctuate over time. Again, the birds are presently located above the 4,325-foot elevation level, so under Alternative 5 (No Action), some impacts would be expected when the reservoir rises above that elevation.

4.15 Aquatic Resources and Special Status Fish Species

This section projects effects of the alternatives on sport fish in the reservoirs and on the endangered Rio Grande silvery minnow, which is found in the riverine portion of Elephant Butte Reservoir.

4.15.1 Analysis Methods and Assumptions

Previous studies indicate the sport fishery benefits when the reservoirs rise or with full, stable reservoirs (Ozen 2002, Sammons and Bettoli 2000). The New Mexico Department of Game and Fish (NMDGF 2011, 2015b) reported that fluctuating water levels, both annual and inter-annual, plus resulting high turbidities and a general lack of emergent vegetation produce poor habitat

conditions for centrarchid species, ⁹ white bass, gizzard shad, and channel catfish in the reservoirs. Fluctuating water levels apparently result in increased populations of other species, such as blue catfish.

The NMDGF reported that declining water levels during spawning, water turbidity, and inadequate forage seem to be the limiting factors for smallmouth bass and largemouth bass populations. Because Elephant Butte Reservoir is 100 years old, it tends to have very little aquatic emergent or sub-emergent vegetation to provide a viable seed bank in years when water levels rise. As such, the development of necessary emergent vegetation communities commonly associated with healthy bass populations is lacking. The NMDGF (2011) adds that it is important to have flooded vegetation every three to four years to produce strong year classes of largemouth bass, which is what occurs as the reservoir fills since the upper portion of the reservoir is flatter with more recurring vegetative growth.

The NMDGF (2015b) suggests that centrarchid habitat could be improved if the lake would refill to near capacity. However, multiple years of low lake levels have allowed natural revegetation in the upper lake and have depressed centrarchids and other fish populations.

The analysis method is considering the potential effects of the alternatives on water resources to determine whether these would affect aquatic wildlife and their habitats. Reclamation considered data and information related to hydrology modeling used to develop the baseline conditions for aquatic resources in the study area. It used these data to assess potential biological responses to habitat condition modifications, including reservoir inundation extremes, during the assessment period (relative to baseline conditions of 2014).

Fluctuations in reservoir water surface elevations are anticipated during the 43-year simulation period for all alternatives and climate scenarios. In general, the Rio Grande silvery minnow would be expected to benefit from lower water levels and a longer river channel into Elephant Butte Reservoir.

In addition, Elephant Butte Reservoir is projected to reach capacity or full pool during both the central tendency and wetter climate scenarios (Appendix C). In general, sport fish would benefit from an increasing reservoir shoreline and flooded vegetation; although riverine fish would have slightly less riverine habitat in the reservoir pool, they are expected to move upstream to suitable habitat as the reservoir fills.

4.15.2 Effects Common to All Alternatives

Under all alternatives, there would be cycles of rising and falling reservoirs. During wetter periods, when the RMBHM model simulates rising water levels in the reservoirs, the populations of sport fish may increase or improve, while periods of reservoir decline would benefit the endangered Rio Grande silvery minnow due to increased riverine conditions.

For sport fish, periods of low water elevations might result in the localized loss of some species and restocking would be necessary to maintain or enhance the public's recreational opportunities. Fish stocking by NMDGF is commonly practiced to augment various fish species populations in both reservoirs.

⁹ e.g., largemouth and smallmouth bass, crappie, and bluegill

4.15.3 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, Elephant Butte Reservoir is predicted to reach slightly higher maximums during modeled wet periods than predicted for the other alternatives (Fig. 13). Sport fish would benefit from an increasing reservoir shoreline and flooded vegetation; riverine fish would have slightly less habitat in the reservoir pool, but they are expected to move upstream to suitable habitat as the reservoir levels increase. Riverine fish species in Elephant Butte Reservoir headwaters would benefit from a lower reservoir and a longer river channel into the reservoir, while lake fish would have slightly less habitat in the reservoir pool.

4.15.3.1 Rio Grande Silvery Minnow

The model simulation indicates that Elephant Butte Reservoir would fill under both average and wetter climate scenarios (Fig. 13) and would displace minnows in the delta channel as the water elevation rises. The minnows would be displaced to more upstream reaches of the river in the delta reach until Elephant Butte Reservoir reaches its full storage volume. This gradual upstream movement of minnows could extend into their critical habitat reach of the Rio Grande, upstream of the full pool extent of Elephant Butte Reservoir (River Mile 62).

As the reservoir pool subsequently contracts, the minnows could and likely would again repopulate the river channel within the reservoir. Minnows could swim freely in the available delta channel habitat of the reservoir. Reclamation would continue to maintain the delta channel for efficient delivery of water to the reservoir; even without a maintained channel, a naturally formed river channel would develop as long as upstream river flows were sufficient to enter the Elephant Butte Reservoir pool. The minnow is not considered to live within the Elephant Butte Reservoir past the furthest south point of the river channel due to a lack of appropriate food and habitat. Minnows do not occur in the other downstream Rio Grande reaches of the OA study area below Elephant Butte Reservoir. The minnow has been extirpated from the river below Elephant Butte Reservoir, except for the pilot population of introduced minnows in Big Bend, Texas. Due to the absence of minnows in these reaches of the study area, continued implementation of the OA would not affect this species.

Reclamation consulted with the Service on the effects of implementing Alternative 1 on the Rio Grande silvery minnow and the Service's biological opinion is presented in Appendix F. The analysis was based on the wetter climate scenario, which constitutes a conservative, worst-case for the minnow and its habitat. Reclamation's finding was that given future fluctuations under Alternative 1, and based on the observations of biologists that in low water conditions, the minnow is able to move upstream/downstream, following the water, the action "may affect, is not likely to adversely affect" the minnow. With sufficient magnitude and duration of reservoir filling, critical habitat upstream of River Mile 62 may receive beneficial effects due to increased deposition of sediment north of the full pool of the reservoir.

4.15.4 Alternative 2: No San Juan-Chama Project Storage

The effects of Alternative 2 on the sport fish and the Rio Grande silvery minnow would be similar to those described under Alternative 1. The delta channel may extend farther into the reservoir for longer periods and would provide some additional riverine habitat due to fluctuations in reservoir levels.

4.15.5 Alternative 3: No Carryover Provision

The effects of Alternative 3 on sport fish and the Rio Grande silvery minnow would be almost identical to those described under Alternative 1 because of the fluctuations in reservoir levels over time.

4.15.6 Alternative 4: No Diversion Ratio Adjustment

The effects of Alternative 4 on sport fish and the Rio Grande silvery minnow would be almost identical to those under Alternative 1 because of the fluctuations in reservoir levels over time.

4.15.7 Alternative 5: Prior Operating Practices, No Action Alternative

Under the No Action Alternative (Alternative 5) the effects on sport fish and the Rio Grande silvery minnow are projected to be the same as those under Alternative 1.

4.16 Invasive Species

4.16.1 Analysis Methods and Assumptions

As described in Section 4.13, the assumption is that lower reservoir levels may lead to the spread of noxious weeds and invasive plants including saltcedar, which competes with native, riparian vegetation. The spread of invasive animal species, including zebra and quagga mussels, is unrelated to reservoir elevations or releases from the dams. Therefore, these species are not relevant to the alternatives.

4.16.2 Effects Common to All Alternatives

The potential for spread and continued presence of invasive species, both plant and animal, would be the same under all alternatives. Invasive zebra and quagga mussels have been detected in upstream reservoirs. Under all alternatives, there is a potential for mussels to become established in Elephant Butte and Caballo Reservoirs; however, slight alterations in reservoir operations or flows in the river reaches do not affect the potential for the reservoirs' colonization or infestation by mussels. Preventative measures to clean boats entering and leaving reservoirs would continue under all alternatives.

4.17 Cultural Resources

4.17.1 Analysis Methods and Assumptions

Reclamation evaluated the effects of the alternatives on historic properties using the criteria defined in 36 CFR 800, which define adverse effects as "direct or indirect alteration of the characteristics that qualify a property for inclusion in the NRHP in a manner that diminishes integrity of location, design, setting, materials, workmanship, feeling, or association." The integrity of historic properties is assessed by the ability of the property to convey the important traditional, scientific, and public values for which it is determined to be historically significant.

4.17.2 Effects Common to All Alternatives

Under all alternatives, the effects would be the same: "no historic properties affected," in accordance with 36 CFR 800.4(d)(1). In November 2015, the New Mexico State Historic Preservation Officer concurred with this finding. (See Chapter 6 and Appendix D).

Because RGP water would continue to flow under all alternatives and allow the growth and harvesting of plants valued by the Mescalero Apache Tribe, there should be no effects to

resources of tribal concern. No Indian sacred sites have been identified to date, and thus there would be no effect on these cultural resources.

4.18 Indian Trust Assets

4.18.1 Effects Common to All Alternatives

Government-to-government consultation to date with potentially affected tribes, including the Mescalero Apache Tribe and the Pueblo of Ysleta del Sur, has not identified any ITAs. Therefore, implementing any of the alternatives would have no impact on ITAs.

4.19 Socioeconomics

4.19.1 Impact Indicators

The socioeconomic analysis evaluated impacts of the alternatives on economic benefits and regional economic indicators, as listed below. The summary of the results is found in Section 4.19.5. Economic benefit (direct impact) indicators are:

- 1. Economic value of agricultural water use in EBID
- 2. Economic value of agricultural water use in EPCWID
- 3. Economic value of urban water use in EPCWID
- 4. Economic value of recreation at Elephant Butte Reservoir
- 5. Economic value of hydropower generation at Elephant Butte Powerplant

Regional economic indicators are:

- 1. Employment (full and part-time jobs)
- 2. Income (employee compensation and proprietors' income)
- 3. Output (sales)

4.19.2 Analysis Methods and Assumptions

The proposed alternatives are analyzed using two economic measures: 1) the economic benefits, or direct impacts; and 2) the regional economic impacts. The economic benefits or direct impacts measure the effects of each alternative from a societal standpoint (a gain or loss to society from a change in activities). The regional economic impacts measure the effects of each alternative on a region's economy (such as changes in employment and income).

For this FEIS, the net economic benefit and regional economic impact calculations rely on hydrologic outcomes of project alternatives as provided by the hydrology technical memorandum (Reclamation 2015c; Appendix C) and available economic data.

The economic benefits and regional economic impacts stemming from the use of RGP water under each alternative are calculated and presented along with the differences from Alternative 5, the No Action Alternative. The economic benefits or direct impacts and regional economic impacts are calculated for the following categories of water use or users:

- 1. EBID
- 2. EPCWID
- 3. Hydropower production at Elephant Butte Powerplant

4. Recreation benefits at Elephant Butte Reservoir

Note that the regional economic impacts are measured based on the same general water use categories except for hydropower production at Elephant Butte Powerplant.

4.19.2.1 Economic Benefits (Direct Impacts)

4.19.2.1.1 Elephant Butte Irrigation District

The estimation of net economic benefit value is limited to agricultural users and is based on the findings shown in the hydrology technical memorandum (Appendix C). The hydrologic simulation found that although depletion of shallow groundwater within the EBID service area occurs under all alternatives, the available supply to project irrigators was never exhausted, and therefore all crops received a full irrigation supply under all simulated conditions. The full impact of changes in project deliveries between alternatives is thus calculated as the differences in costs of pumping groundwater between alternatives.

The hydrologic modeling identified complete substitution of groundwater when surface water deliveries were not available. No changes in cropping or acreage resulted during the study period. Focusing solely on the Rincon and Mesilla Basins, the difference in the economic benefits between alternatives is limited to the differences in pumping costs incurred by project irrigators when surface water is not available.

Differences in costs of RGP surface water delivery between alternatives are not considered because costs are almost entirely fixed and are not volume dependent. While irrigators may experience differences in labor costs and other factors in using surface water instead of groundwater, there is no basis for quantifying these differences and so they are not considered.

Pumping costs are determined by the total volume pumped and the total head. Because both volume and head differ by alternative, each factor is used in calculating pumping costs. Capital costs are not considered, as all project irrigators are assumed by the hydrology technical memorandum (Appendix C) to have access to available supplemental groundwater as needed, and the relatively small volumes that differentiate alternatives are assumed to have no effect on pump lifetimes or maintenance costs.

Groundwater pumping cost calculation

The calculation of groundwater pumping costs was based on the energy costs of delivering the quantity of groundwater identified under each project alternative. The annual average groundwater delivery and the elevations and beginning of period well depths were taken from the hydrology technical memorandum (Appendix C), and the static head was taken from crop enterprise budgets for Sierra and Doña Ana Counties (New Mexico State University 2005). Energy (electric) costs and pump efficiency were likewise obtained from the crop enterprise budgets. The wells cover all cropping areas in EBID, and the simple average well elevation changes within each cropping area were used to calculate average pumping heads for each alternative.

Groundwater elevations for regions served by major canals were taken from the hydrology technical memorandum (Appendix C), which calculated groundwater elevations and initial groundwater depths. Groundwater elevations reported under each alternative for the 15 wells in the project area were averaged for the Rincon Valley and the Mesilla Valley Leasburg, Eastside, and Westside Canals. The total groundwater deliveries to EBID were allocated to each region based on the acreage reported in the hydrology technical memorandum (Appendix C). The

starting well depth was also taken from the hydrology technical memorandum (Appendix C). The typical head across the region and study period was 70 to 80 feet with 50 feet of static head (New Mexico State University 2005) and a calculated 20 to 30 feet well depth to water.

A pump efficiency of 0.47 for electric pumps and an electricity cost of \$0.1098/kilowatt-hour for electricity were taken from crop enterprise budgets (New Mexico State University 2005). The cost of electricity was adjusted to 2015 levels using the producer price index for North American Industry Classification System 2211, electric utilities. A resulting energy cost of \$0.152/kilowatt-hour was used (price index 2015 = 144.3; 2005 index = 104.2). The potential energy conversion is 1.024 kilowatt-hour /acre-foot/foot, meaning that at 100 percent efficiency, 1.024 kilowatt-hour of energy is required to lift one acre-foot of water to a height of 1 foot.

4.19.2.1.2 El Paso County Water Improvement District Number 1

RGP deliveries to water users from the American Diversion Dam are not treated in the hydrologic modeling and there is no specific information on the disposition of RGP waters after delivery (Appendix C). The most recent financial report from El Paso Water (2015) gives an average year surface water delivery of 60,000 acre-feet for M&I uses, with these flows providing approximately half of the El Paso Water supply. The balance of the M&I water supplies is pumped from the Hueco and Mesilla Basins. All other surface water deliveries at the American Diversion Dam are then available for diversion for agricultural uses. (Deliveries to Mexico at the International Diversion Dam are included within the hydrologic modeling [Appendix C], and do not vary by alternative; therefore, they are not further considered in the economic analysis.) The historical full EPCWID allocation of 376,842 acre-feet then gives surface diversions of 316,842 acre-feet available for agricultural uses. Acreages of 6,494 and 62,516 in the Mesilla and El Paso Valleys, respectively, are used to calculate Mesilla and El Paso Valley full allocation diversions of 29,816 and 287,026 acre-feet, respectively. Any greater levels of urban surface water use would result in proportionally lower levels of Rio Grande agricultural diversions; this possibility is not considered here.

EPCWID El Paso Valley agricultural water users

Net benefits of RGP water use reported by Ward and Pulido-Velazquez (2012) are used to estimate the economic benefits associated with RGP surface water deliveries at the American Diversion Dam to El Paso Valley agricultural users. Their base scenario reports average deliveries to agricultural users of 237,000 acre-feet, with average net benefits of \$112 per acrefoot. This is taken as the value of RGP surface water deliveries to El Paso Valley agricultural users when diversions fall below the full allocation level. According to Ward and Pulido-Velazquez (2012), agricultural users have not developed much groundwater pumping infrastructure and therefore are not reported to make significant use of groundwater to supplement their surface water use.

EPCWID El Paso Valley urban water users

El Paso urban uses rely heavily on groundwater, and sustainability of both the quantity and quality of groundwater supplies are a concern. To value the Rio Grande surface water delivered for urban use, the Ward and Pulido-Velazquez (2012) "sustaining" and "renewing" natural capital scenarios were used, which report a difference in urban water use of 6,000 acre-feet. The difference in the reported net benefits to urban water users is \$574 per acre-foot and is taken here as the value of RGP water in El Paso urban uses when supply falls below 60,000 acre-feet.

Distribution between agricultural and urban users

The hydrology technical memorandum hydrologic studies provide no guidance on the distribution of RGP water to urban versus agricultural uses (Appendix C). Because values in urban and

agricultural uses can be substantially different, economic valuation would be sensitive to this distribution. The economic analysis here assumes that RGP water is distributed proportionally to urban and agricultural uses throughout the study period, and that urban uses are held to 60/376.842 = 15.9 percent of total EPCWID diversions, and agricultural uses receive 84.1 percent of diversions.

EPCWID Mesilla Valley agricultural water users

Deliveries of RGP water to EPCWID agricultural water users in the Mesilla Valley are valued identically to EBID agricultural water users. The hydrologic studies show full availability of groundwater to substitute for surface water when diversions fall below allocations. Total benefits from the use of groundwater and RGP surface water are calculated identically to EBID project users.

4.19.2.1.3 Hydropower

The hydroelectric plant at Elephant Butte Dam generates power that is dependent on flow volume and head. Because both flows and reservoir elevation would differ between alternatives, expected power generation would also vary. There is currently no hydroelectric production at Caballo Dam, and thus no economic differences between alternatives exist, despite differing releases between alternatives.

Reservoir elevation and releases

The hydrology technical memorandum provides monthly elevations at Elephant Butte Reservoir for each alternative (Appendix C, Reclamation 2015c). Power production does not occur during winter months when RGP releases do not occur. Hydropower calculations are thus based on the calculated average elevation during the March to October period only. Annual releases from Elephant Butte Reservoir reported by the hydrology technical memorandum, reduced by the volume of spills, are used with the March to October average elevations (Appendix C) to calculate hydropower generation.

Power plant characteristics and valuation

The Elephant Butte Powerplant has a rated head of 140 feet and is assumed to operate with 90 percent efficiency. Energy generation is calculated from reservoir elevation, with the rated head achieved at the maximum elevation over the study period, and the potential energy conversion of 1.024 kilowatt-hour per acre-foot per foot of head. Calculated production based on the average March to October monthly elevation and release data for 2014 is 3 percent below the actual power plant production of 13.4 gigawatt-hours reported by Reclamation (2015d). Economic valuation of production is based on the economic opportunity cost concept and uses the same \$0.152/ kilowatt-hour value as is assigned to the cost of groundwater pumping. This neglects distribution costs and losses (which would suggest a lower figure), but also does not consider use of the power plant for short-term peaking operations (which suggest an increased valuation). Reservoir elevation for purposes of hydropower calculations use only Alternative 1 reported values.

4.19.2.1.4 Recreation

Elephant Butte Reservoir provides a variety of recreational benefits that vary based on reservoir storage. Because storage varies between project alternatives, recreational benefits are calculated for Elephant Butte Reservoir. Similarly, Caballo Reservoir provides recreational benefits. These benefits are not addressed, however, because the differences in Caballo Reservoir storage among alternatives are small and would not result in significant differences in economic benefits from recreation at Caballo Reservoir under each alternative.

Annual recreation benefits reported by Ward and Pulido-Velazquez (2012) are based on:

Value of Elephant Butte Reservoir recreation = $379.82 + 2.21 X - 0.0005030852 X^2$

where *X* equals the average annual storage in thousand acre-feet and the economic value is in thousand dollars. Management costs of \$0.31 per acre-foot of storage (due to increased visitation) are also identified (Ward 2014) and deducted from the economic benefit calculation reported here. The hydrology technical memorandum annual average reservoir storage is used with the above equation to estimate direct economic benefits of recreation (Reclamation 2015c, Appendix C).

4.19.2.2 Regional Economic Impacts

In addition to considering the net economic benefits or direct impacts of each alternative, the socioeconomic analysis estimates the potential regional economic impacts. The regional impacts may stem from changes in agricultural pumping costs, the costs of providing urban water, and recreation visitation expenditures. These direct economic impacts are input into the IMPLAN model to estimate total regional impacts. The direct economic impacts of hydropower are assumed to have no impacts on the regional economy.

IMPLAN is the modeling package used to assess the regional economic impacts stemming from the direct impacts associated with each alternative. IMPLAN is an economic input-output modeling system that estimates the effects of economic changes in a defined analysis area. IMPLAN is a static model that estimates impacts for a snapshot in time when the impacts are expected to occur, based on the makeup of the economy at the time of the underlying IMPLAN data. IMPLAN measures the initial impact on the economy but does not consider long-term adjustments as labor and capital move into alternative uses. Realistically, the structure of the economy would adapt and change; therefore, the IMPLAN results can only be used to compare relative changes between the No Action Alternative and the action alternatives and cannot be used to predict or forecast future employment, labor income, or output (sales).

Input-output models measure commodity flows from producers to intermediate and final consumers. Purchases for final use (final demand) drive the model. Industries produce goods and services for final demand and purchase goods and services from other producers. These other producers, in turn, purchase goods and services. This buying of goods and services (indirect purchases) continues until leakages from the analysis area (imports and value added) stop the cycle. These indirect and induced effects (the effects of household spending) can be mathematically derived using a set of multipliers. The multipliers describe the change in output for each regional industry caused by a \$1.00 change in final demand.

This analysis used 2013 IMPLAN data for the counties encompassing the study areas. IMPLAN data files for the analysis area are compiled from a variety of sources, including the U.S. Bureau of Economic Analysis, the U.S. Bureau of Labor, and the U.S. Census Bureau.

4.19.3 Economic Benefits (Direct Impacts)

4.19.3.1 Elephant Butte Irrigation District

The hydrologic modeling assumes there are no changes in cropping or acreage during the study period. Focusing solely on the Rincon and Mesilla Basins, the difference in the economic benefits or direct impacts between alternatives is limited to differences in pumping costs incurred by project irrigators when surface water is not available. The hydrology modeling assumes that the

cropping pattern for each service area within the model domain is based on cropping data available for the year 2000.

The average annual ground water supply available to EBID as estimated by the hydrology model (Appendix C) are shown above in Section 4.10 entitled Farm Groundwater Deliveries. These EBID deliveries are split between the Rincon (roughly 20 percent) and Mesilla (roughly 73 percent) Valleys based on the acreage distribution between the two valleys (including EPCWID land in the Mesilla Valley).

Table 4-15 EBID average annual pumping costs (millions of dollars) by alternative and climate scenario

Valley &	Alternative					
Climate	1	2	3	4	5	
Rincon						
Drier	1.3	1.3	1.3	1.1	1.1	
Central	1.1	1.1	1.1	0.9	0.9	
Wetter	1.0	1.0	1.0	0.8	0.9	
Mesilla						
Drier	4.7	4.7	4.6	4.1	4.2	
Central	4.1	4.1	3.8	3.4	3.4	
Wetter	3.6	3.6	3.7	2.9	3.1	

Table 4-16 EBID Agricultural benefit values (millions of dollars) relative to a change between No Action and action alternatives and climate scenario

Valley &			Alternative		
Climate	1	2	3	4	5
Rincon					
Drier	-0.2	-0.2	-0.2	0.0	No Action
Central	-0.2	-0.2	-0.2	0.0	No Action
Wetter	-0.1	-0.1	-0.1	0.1	No Action
Mesilla					
Drier	-0.5	-0.5	-0.4	0.1	No Action
Central	-0.7	-0.7	-0.4	0.0	No Action
Wetter	-0.5	-0.5	-0.6	0.2	No Action
Total					
Drier	-0.7	-0.7	-0.6	0.1	No Action
Central	-0.9	-0.9	-0.6	0.0	No Action
Wetter	-0.6	-0.6	-0.7	0.3	No Action

4.19.3.1.1 Alternative 1: Continued OA and San Juan-Chama Storage, Preferred Alternative

Under Alternative 1, the estimated pumping costs equal \$1.1 million in the Rincon Valley and \$4.1 million in the Mesilla Valley based on the central climate scenario as shown in Table 4-15. The impact of this alternative is measured relative to Alternative 5 (No Action) as shown in Table 4-16. Under Alternative 1, pumping costs increase relative to Alternative 5, therefore under this alternative, economic benefits decrease, based on the central climate scenario, by \$0.2 in the Rincon Valley and \$0.7 in the Mesilla Valley.

4.19.3.1.2 Alternative 2: No San Juan–Chama Project Storage

As shown in Tables 4-15 and 4-16, Alternative 2 would be the same as Alternative 1.

4.19.3.1.3 Alternative 3: No Carryover Provision

Under Alternative 3, the estimated pumping costs equal \$1.1 million in the Rincon Valley and \$3.8 million in the Mesilla Valley based on the central climate scenario as shown in Table 4-15. The impact of this alterative is measured relative to Alternative 5 (No Action) as shown in Table 4-16. Under Alternative 3, pumping costs increase relative to Alternative 5, therefore under this alternative economic benefits decrease, based on the central climate scenario, by \$0.2 and \$0.4, in the Rincon Valley and Mesilla Valley, respectively.

4.19.3.1.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the estimated pumping costs equal \$0.9 million in the Rincon Valley and \$3.4 million in the Mesilla Valley based on the central climate scenario as shown in Table 4-15. The impact of this alterative is measured relative to Alternative 5 (No Action) as shown in Table 4-16. Under Alternative 4, pumping costs do not change relative to Alternative 5, therefore under this alternative economic benefits are unchanged, based on the central climate scenario, in both the Rincon and Mesilla Valleys.

4.19.3.1.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5, the estimated pumping costs equal \$0.9 million in the Rincon Valley and \$3.4 million in the Mesilla Valley based on the central climate scenario as shown in Table 4-15. Alternative 5 is the No Action Alternative, therefore the impacts of the action alternatives are relative to this alternative.

4.19.3.2 El Paso County Water Improvement District No. 1

As discussed in Section 4.19.2, EPCWID supplies water to both agricultural water users and urban or M&I users. The economic benefits and regional economic impacts are analyzed separately for agricultural and M&I water uses. The average annual water supply available to EPCWID is estimated by the hydrology model (Appendix C). The economic analysis here assumes that RGP water is distributed proportionally to M&I (15.9 percent of diversions) and agricultural (84.1 percent of diversions) uses throughout the study period.

4.19.3.2.1 El Paso Valley agricultural use

EPCWID El Paso Valley agricultural water use value is based on the net benefits of RGP water use reported by Ward and Pulido-Velazquez (2012). Agricultural users in this area are not reported to make significant use of groundwater to supplement their surface water use. Therefore, the agricultural benefit value is based on the effects of surface water deliveries for each alternative as it relates to surface water deliveries.

Table 4-17 EPCWID El Paso Valley average annual agricultural benefits (millions of dollars) by alternative and climate scenario

Valley &	Alternative					
Climate	1	2	3	4	5	
Drier	20.6	20.6	20.5	19.2	19.5	
Central	23.4	23.4	22.8	22.0	21.7	
Wetter	26.2	26.2	26.3	25.3	25.2	

Table 4-18 EPCWID El Paso Valley average annual agricultural benefits changes (millions of dollars) between alternatives and climate scenario

Valley &	Alternative					
Climate	1	2	3	4	5	
Drier	1.1	1.1	1.0	-0.3	No Action	
Central	1.7	1.7	1.1	0.3	No Action	
Wetter	1.0	1.0	1.1	0.1	No Action	

4.19.3.2.1.1 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, the estimated value of production is \$23.4 million in the El Paso Valley based on the central climate scenario as shown in Table 4-17. The impact of this alterative is measured relative to Alternative 5 (No Action) as shown in Table 4-18. Under Alternative 1 based on the central climate scenario, the change in value of production is \$1.7 million compared to Alternative 5.

4.19.3.2.1.2 Alternative 2: No San Juan–Chama Project Storage

As shown in Tables 4-17 and 4-18, Alternative 2 would be the same as Alternative 1. Under Alternative 2 based on the central climate scenario, the change in value of production is \$1.7 million compared to Alternative 5 (No Action).

4.19.3.2.1.3 Alternative 3: No Carryover Provision

Under Alternative 3, the estimated value of production is \$22.8 million in the El Paso Valley based on the central climate scenario as shown in Table 4-17. The impact of this alterative is measured relative to Alternative 5 (No Action) as shown in Table 4-18. Under Alternative 3 based on the central climate scenario the change in value of production is \$1.1 million compared to Alternative 5.

4.19.3.2.1.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the estimated value of production is \$22.0 million in the El Paso Valley based on the central climate scenario as shown in Table 4-17. The impact of this alterative is measured relative to Alternative 5 (No Action) as shown in Table 4-18. Under Alternative 4 based on the central climate scenario the change in value of production is \$0.3 million compared to Alternative 5.

4.19.3.2.1.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5, the estimated value of production is \$21.7 million in the El Paso Valley based on the central climate scenario as shown in Table 4-17. Alternative 5 is the No Action Alternative, therefore the impacts of the action alternatives are relative to this alternative.

4.19.3.2.2 Mesilla Valley agricultural use

In the Mesilla Valley, the hydrologic studies show full availability of groundwater to substitute for surface water when diversions fall below allocations. The difference in the economic benefits or direct impacts between alternatives is limited to differences in pumping costs incurred by project irrigators when surface water is not available.

Table 4-19 EPCWID Mesilla Valley agricultural benefit values relative to a change (\$ millions) between No Action and action alternatives and climate scenario

Mesilla Valley &		A	Iternative		
Climate	1	2	3	4	5
Drier	0.3	0.3	0.4	0.4	0.4
Central	0.3	0.3	0.3	0.3	0.3
Wetter	0.2	0.2	0.2	0.2	0.3

Table 4-20 EPCWID Mesilla Valley annual agricultural benefits changes (\$ millions) between No Action and action alternatives by alternative and climate scenario

Mesilla								
Valley &		Alternative						
Climate	1	2	3	4	5			
Drier	0.1	0.1	0.0	0.0	No Action			
Central	0.0	0.0	0.0	0.0	No Action			
Wetter	0.1	0.1	0.1	0.1	No Action			

4.19.3.2.2.1 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, the estimated pumping cost is \$0.3 million in the Mesilla Valley based on the central climate scenario as shown in Table 4-19. The impact of this alterative is measured relative to the No-Action Alternative (Alternative 5) as shown in Table 4-20. There is no change in pumping costs under Alternative 1 compared to the No-Action Alternative; therefore, the economic benefit value is unchanged.

4.19.3.2.2.2 Alternative 2: No San Juan–Chama Project Storage

As shown in Tables 4-19 and 4-20, Alternative 2 would be the same as Alternative 1. There is no change in pumping costs under Alternative 2 compared to Alternative 5 (No Action); therefore, the economic benefit value is unchanged.

4.19.3.2.2.3 Alternative 3: No Carryover Provision

Under Alternative 3, the estimated pumping cost is \$0.3 million in the Mesilla Valley based on the central climate scenario as shown in Table 4-19. The impact of this alterative is measured relative to Alternative 5 (No Action) as shown in Table 4-20. There is no change in pumping

costs under Alternative 3 compared to Alternative 5; therefore, the economic benefit value is unchanged.

4.19.3.2.2.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the estimated pumping cost is \$0.3 million in the Mesilla Valley based on the central climate scenario as shown in Table 4-19. The impact of this alterative is measured relative to Alternative 5 (No Action) as shown in Table 4-20. There is no change in pumping costs under Alternative 4 compared to Alternative 5; therefore, the economic benefit value is unchanged.

4.19.3.2.2.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5, the estimated pumping cost is \$0.3 million in the Mesilla Valley based on the central climate scenario as shown in Table 4-19. The impact of this alterative is measured relative to Alternative 5 (No Action) as shown in Table 4-20. Alternative 5 is the No Action Alternative; therefore, the impacts of the action alternatives are relative to this alternative.

4.19.3.2.3 EPCWID El Paso Valley urban use

The Ward and Pulido-Velazquez (2012) values were used to estimate the economic benefit values for urban water use in EPCWID as explained in Section 4.19.2. A value of \$574 per acre-foot was applied to the estimated average annual urban deliveries to estimate the average annual benefits value for the alternative.

Table 4-21 EPCWID El Paso Valley urban use average annual economic benefits (\$ millions) by alternative and climate scenario

El Paso					
Valley &		A	Alternative		
Climate	1	2	3	4	5
Drier	19.9	19.9	19.6	18.3	18.3
Central	22.8	22.8	21.8	21.2	20.7
Wetter	25.3	25.3	25.1	23.8	23.7

Table 4-22 EPCWID El Paso Valley urban use average annual economic benefits (\$ millions) changes between No Action and action alternatives by alternative and climate scenario

El Paso								
Valley &		Alternative						
Climate	1	2	3	4	5			
Drier	1.6	1.6	1.3	0.0	No Action			
Central	2.1	2.1	1.1	0.5	No Action			
Wetter	1.6	1.6	1.4	0.1	No Action			

4.19.3.2.3.1 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, the estimated value of urban water in EPCWID is \$22.8 million based on the central climate scenario as shown in Table 4-21. The impact of this alterative is measured relative to Alternative 5 (No Action), as shown in Table 4-22. Under Alternative 1 based on the central climate scenario the change in value is \$2.1 million compared to Alternative 5.

4.19.3.2.3.2 Alternative 2: No San Juan–Chama Project

As shown in Tables 4-21 and 4-22, Alternative 2 would be the same as Alternative 1. Under Alternative 2 based on the central climate scenario, the change in value is \$2.1 million compared to Alternative 5 (No Action).

4.19.3.2.3.3 Alternative 3: No Carryover Provision

Under Alternative 3, the estimated value of urban water in EPCWID is \$21.8 million based on the central climate scenario as shown in Table 4-21. The impact of this alterative is measured relative to Alternative 5 (No Action) as shown in Table 4-22. Under Alternative 3 based on the central climate scenario, the change in value is \$1.1 million compared to Alternative 5.

4.19.3.2.3.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the estimated value of urban water in EPCWID is \$21.2 million based on the central climate scenario as shown in Table 4-21. The impact of this alterative is measured relative to Alternative 5 (No Action) as shown in Table 4-22. Under Alternative 4 based on the central climate scenario the change in value is \$0.5 million compared to Alternative 5.

4.19.3.2.3.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5, the estimated value of urban water in EPCWID is \$20.7 million based on the central climate scenario as shown in Table 4-21. Alternative 5 is the No Action Alternative; therefore, the impacts of Alternatives 1 to 4 are shown relative to this alternative.

4.19.3.3 Hydropower

Flows and reservoir elevations differ between alternatives; therefore, the expected power generation (gigawatt-hour) would also vary between alternatives. The estimated generation at Elephant Butte Dam by alternative is shown in Table 4-23. The estimated economic value of this generation is shown in Table 4-24 and the impacts by alternative are shown in Table 4-25.

Table 4-23 Elephant Butte hydropower (Gwh) average annual economic benefits by alternative and climate scenario

Benefit &	Alternative					
Climate	1	2	3	4	5	
Drier	25.2	25.2	26.2	24.8	25.0	
Central	34.8	34.8	34.3	33.5	33.7	
Wetter	39.6	39.6	36.1	34.7	35.0	

Table 4-24 Elephant Butte hydropower average annual economic benefits (\$ millions) by alternative and climate scenario

	Alternative							
Climate	1	2	3	4	5			
Drier	3.8	3.8	4.0	3.8	3.8			
Central	5.3	5.3	5.2	5.1	5.1			
Wetter	6.0	6.0	5.5	5.3	5.3			

Table 4-25 Elephant Butte hydropower average annual economic benefits (\$ millions) changes between No Action and action alternatives by alternative and climate scenario

	Alternative						
Climate	1	2	3	4	5		
Drier	0.0	0.0	0.2	0.0	No Action		
Central	0.2	0.2	0.1	0.0	No Action		
Wetter	0.7	0.7	0.2	0.0	No Action		

4.19.3.3.1 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, the estimated value of hydropower is \$5.3 million based on the central climate scenario as shown in Table 4-24. The impact of this alterative is measured relative to Alternative 5 (No Action) as shown in Table 4-25. Under Alternative 1 based on the central climate scenario the change in value is \$0.2 million compared to Alternative 5.

4.19.3.3.2 Alternative 2: No San Juan–Chama Project Storage

As shown in Tables 4-24 and 4-25, Alternative 2 would be the same as Alternative 1. Under Alternative 2 based on the central climate scenario, the change in value is \$0.2 million compared to Alternative 5 (No Action).

4.19.3.3.3 Alternative 3: No Carryover Provision

Under Alternative 3, the estimated value of hydropower is \$5.2 million based on the central climate scenario as shown in Table 4-24. The impact of this alterative is measured relative to Alternative 5 (No Action) as shown in Table 4-25. Under Alternative 3 based on the central climate scenario the change in value is \$0.1 million compared to Alternative 5.

4.19.3.3.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the estimated value of hydropower is \$5.1 million based on the central climate scenario as shown in Table 4-24. The impact of this alterative is measured relative to Alternative 5 (No Action) as shown in Table 4-25. Under Alternative 4 based on the central climate scenario there is no change in value compared to Alternative 5.

4.19.3.3.5 Alternative 5: Prior Operating Practices, No Action Alternative

Under Alternative 5, the estimated value of hydropower is \$5.1 million based on the central climate scenario as shown in Table 4-24. Alternative 5 is the No Action Alternative; therefore, the impacts of the action alternatives are relative to this alternative.

4.19.3.4 Recreation

Elephant Butte Reservoir provides a variety of recreational benefits that vary based on reservoir storage. Because storage varies between alternatives, recreational benefits are calculated for Elephant Butte Reservoir (Mesilla Valley). Recreational activities at Caballo Reservoir also provide recreational benefits. Because the differences in Caballo storage between project alternatives are small and would not result in significant differences in economic benefits from Caballo recreation, these benefits were not estimated.

Table 4-26 Elephant Butte recreation average annual economic benefits (\$ millions) by alternative and climate scenario

		A	Alternative		
Climate	1	2	3	4	5
Drier	0.9	0.9	0.9	0.8	0.9
Central	1.1	1.1	1.1	1.1	1.1
Wetter	1.1	1.1	1.2	1.1	1.1

Table 4-27 Elephant Butte recreation average annual economic benefits changes (\$ millions) between No Action and Action Alternatives by alternative and climate scenario

		Alternative						
Climate	1	2	3	4	5			
Drier	0.0	0.0	0.0	-0.1	No Action			
Central	0.0	0.0	0.0	0.0	No Action			
Wetter	0.0	0.0	0.1	0.0	No Action			

4.19.3.4.1 Alternative 1: Continued OA and San Juan-Chama Storage, Preferred Alternative

The estimated value of recreation is shown in Table 4-26. The impact of this alterative is measured relative to Alternative 5 (No Action) as shown in Table 4-27. The differences in Elephant Butte Reservoir storage compared to Alternative 5 are small and would not result in significant differences in economic benefits.

4.19.3.4.2 Alternative 2: No San Juan-Chama Project Storage

As shown in Tables 4-26 and 4-27, Alternative 2 would be the same as Alternative 1. The differences in Elephant Butte Reservoir storage compared to Alternative 5 (No Action) are small and would not result in significant differences in economic benefits.

4.19.3.4.3 Alternative 3: No Carryover Provision

The estimated value of recreation is shown in Table 4-26. The impact of this alterative is measured relative to Alternative 5 as shown in Table 4-27. The differences in Elephant Butte Reservoir storage compared to Alternative 5 (No Action) are small and would not result in significant differences in economic benefits.

4.19.3.4.4 Alternative 4: No Diversion Ratio Adjustment

The estimated value of recreation is shown in Table 4-26. The impact of this alterative is measured relative to Alternative 5 as shown in Table 4-27. The differences in Elephant Butte Reservoir storage compared to Alternative 5 are small and would not result in significant differences in economic benefits.

4.19.3.4.5 Alternative 5: Prior Operating Practices, No Action Alternative

Alternative 5 is the No Action Alternative; therefore, the impacts of the action alternatives are relative to this alternative.

4.19.4 Regional Economic Impacts

4.19.4.1 Elephant Butte Irrigation District

The regional economic impacts in EBID would result from a change in pumping costs. Pumping cost changes would result in higher or lower net farm income, which translates to farm households having more or less money to spend within the regional economy.

Table 4-28 EBID regional economic impacts by alternative under the central tendency climate change scenario (incremental to Alternative 5)

	Alternative							
EBID Ag.	1	2	3	4	5			
Employment	-5	-5	-4	0	No Action			
Labor Income	(185,947)	(185,947)	(123,965)	0	No Action			
Output	(599,166)	(599,166)	(399,444)	0	No Action			

4.19.4.1.1 Alternative 1: Continued OA and San Juan-Chama Storage, Preferred Alternative

Pumping costs in the Rincon and Mesilla Valleys are estimated to increase by \$0.9 million compared to Alternative 5 (No Action) under the central tendency climate change, as discussed in Section 4.19.3. The regional impacts of this alternative stem from a decrease (\$0.9) in farm household income, because of the pumping cost increase, relative to Alternative 5. The changes in employment, labor income, and output under Alternative 1 are shown in Table 4-28.

4.19.4.1.2 Alternative 2: No San Juan–Chama Project Storage

As shown in Table 4-28, Alternative 2 would be the same as Alternative 1. The regional impacts of this alternative stem from a decrease (\$0.9) in farm household income because of the pumping cost increase relative to Alternative 5 (No Action).

4.19.4.1.3 Alternative 3: No Carryover Provision

Pumping costs in the Rincon and Mesilla Valleys are estimated to increase by \$0.6 million compared to Alternative 5, under the central tendency climate change, as discussed in Section 4.19.3. The regional impacts of this alternative stem from a decrease (\$0.6) in farm household income, because of the pumping cost increase, relative to Alternative 5 (No Action). The changes in employment, labor income, and output under the Alternative 3 are shown in Table 4-28.

4.19.4.1.4 Alternative 4: No Diversion Ratio Adjustment

Compared to Alternative 5, under the central tendency climate scenario there is no estimated change in pumping costs in the Rincon and Mesilla Valleys under Alternative 4 as discussed in Section 4.19.3. Therefore, there is no change in the estimated regional impacts under this alternative as shown in Table 4-28.

4.19.4.1.5 Alternative 5: Prior Operating Practices, No Action Alternative

The regional economic impacts are measured based on incremental changes from Alternative 5 conditions; therefore, the total regional impacts associated with Alternative 5 (No Action) were not measured.

4.19.4.2 El Paso County Water Improvement District No. 1

4.19.4.2.1 El Paso Valley agricultural use

The regional impacts stemming from El Paso Valley agricultural use are based a change in production value as shown in Table 4-18.

Table 4-29 EPCWID, El Paso Valley agriculture regional impacts under the central tendency climate change scenario by alternative (incremental to Alternative 5)

	Alternative								
EPCWID Ag.									
El Paso	1	2	3	4	5				
Employment	45	45	29	8	No Action				
Labor Income	1,107,627	1,107,627	716,700	195,463	No Action				
Output	3,194,525	3,194,525	2,067,046	563,740	No Action				

4.19.4.2.1.1 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative

Under Alternative 1, the agricultural production value is estimated to increase by \$1.7 million (shown in Table 4-18) compared to Alternative 5 (No Action). This increase in value has a positive impact on the regional economy in terms of job, labor income, and output as shown in Table 4-29.

4.19.4.2.1.2 Alternative 2: No San Juan–Chama Project

As shown in Table 4-29, Alternative 2 would be the same as Alternative 1 in terms of job, labor income, and output as shown in Table 4-29.

4.19.4.2.1.3 Alternative 3: No Carryover Provision

Under Alternative 3, the agricultural production value is estimated to increase by \$1.1 million (shown in Table 4-18) compared to Alternative 5 (No Action). This increase in value has a positive impact on the regional economy in terms of job, labor income, and output as shown in Table 4-29.

4.19.4.2.1.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the agricultural production value is estimated to increase by \$0.3 million (shown in Table 4-18) compared to Alternative 5 (No Action). This increase in value has a positive impact on the regional economy in terms of job, labor income, and output as shown in Table 4-29.

4.19.4.2.1.5 Alternative 5: Prior Operating Practices, No Action Alternative

The regional economic impacts are measured based on incremental changes from Alternative 5 conditions; therefore, the total regional impacts associated with Alternative 5 (No Action) were not measured.

4.19.4.2.2 Mesilla Valley Agricultural Use

The estimated change in economic benefits or direct impacts are unchanged for all alternatives relative to Alternative 5 (No Action) as shown in Table 4-20.

4.19.4.2.3 EPCWID Urban Use

The regional impacts stemming from El Paso Valley urban water use are based a change in the change in economic value or direct impacts as shown in Table 4-22.

Table 4-30 EPCWID, El Paso Valley urban regional impacts under the central tendency climate change scenario by alternative (incremental to Alternative 5)

	Alternative								
EPCWID M&I,									
El Paso	1	2	3	4	5				
Employment	15	15	8	7	No Action				
Labor Income	1,041,396	1,041,396	545,493	557,497	No Action				
Output	3,603,279	3,603,279	1,887,432	857,923	No Action				

<u>4.19.4.2.3.1 Alternative 1: Continued OA and San Juan–Chama Storage, Preferred Alternative</u>

Under Alternative 1, the value of urban water use is estimated to increase by \$2.1 million (shown in Table 4-22) compared to Alternative 5 (No Action). This increase in value has a positive impact on the regional economy in terms of job, labor income, and output as shown in Table 4-30.

4.19.4.2.3.2 Alternative 2: No San Juan–Chama Project

As shown in Tables 4-22 and 4-30, Alternative 2 would be the same as Alternative 1 in terms of job, labor income, and output.

4.19.4.2.3.3 Alternative 3: No Carryover Provision

Under Alternative 3, the value of urban water use is estimated to increase by \$1.1 million (shown in Table 4-22) compared to Alternative 5 (No Action). This increase in value has a positive impact on the regional economy in terms of job, labor income, and output as shown in Table 4-30.

4.19.4.2.3.4 Alternative 4: No Diversion Ratio Adjustment

Under Alternative 4, the value of urban water use is estimated to increase by \$0.5 million (shown in Table 4-22) compared to Alternative 5 (No Action). This increase in value has a positive impact on the regional economy in terms of job, labor income, and output as shown in Table 4-30.

4.19.4.2.3.5 Alternative 5: Prior Operating Practices, No Action Alternative

The regional economic impacts are measured based on incremental changes from Alternative 5 conditions; therefore, the total regional impacts associated with Alternative 5 (No Action) were not measured.

4.19.4.3 Hydropower

The regional impacts are not affected by hydropower production at Elephant Butte.

4.19.4.4 Recreation

The differences in Elephant Butte Reservoir storage for all action alternatives compared to Alternative 5 (No Action) are small and would not result in significant differences in regional economic impacts.

4.19.5 Summary Conclusions

The average annual economic benefits under the central tendency climate scenario for each alternative and water use category are summarized in Table 4-31. Generally, Alternatives 1 to 4 would increase the total benefits compared to Alternative 5 (No Action). The economic benefits estimated for EBID would decrease compared to Alternative 5 for all of the alternatives except Alternative 4, while the benefits estimated for EPCWID would increase compared to Alternative 5.

The regional impacts under the central tendency climate scenario estimated for each alternative and water use category are summarized in Table 4-32. Generally, the regional impacts in the New Mexico study area (Doña Ana and Sierra Counties, New Mexico) where EBID is located decrease compared to Alternative 5 for all action alternatives.

The regional impacts in the Texas study area (El Paso and Hudspeth Counties) where EPCWID is located increase for all action alternatives compared to Alternative 5. Compared to the overall region, these changes (positive and negative) are small compared to the entire regional economies of the New Mexico and Texas study areas.

Table 4-31 Summary of economic benefits (millions of dollars) by alternative under the central tendency climate scenario

	Alternative					
Valley & Resource	1	2	3	4		5
Rincon Agriculture	-0.20	-0.20	-0.20	0.00	No Action	
Mesilla Agriculture	-0.70	-0.70	-0.40	0.00	No Action	
EPCWID El Paso Ag.	1.70	1.70	1.10	0.30	No Action	
EPCWID Mesilla Ag.	0.00	0.00	0.00	0.00	No Action	
EPCWID El Paso						
M&I	2.10	2.10	1.10	0.50	No Action	
Hydropower	0.20	0.20	0.10	0.00	No Action	
Recreation	0.00	0.00	0.00	0.00	No Action	
Total	3.10	3.10	1.70	0.80	No Action	

Table 4-32 Regional impacts summary (jobs, dollars) by alternative under the central tendency climate scenario

	Alternative							
Valley/Resource	1	2	3	4	5			
EBID Agriculture								
Employment	-5	-5	-4	0	No action			
Labor Income	(185,947)	(185,947)	(123,965)	0	No action			
Output	(599,166)	(599,166)	(399,444)	0	No action			
EPCWID El Paso Valley Agric	culture							
Employment	45	45	29	8	No action			
Labor Income	1,107,627	1,107,627	716,700	195,463	No action			
Output	3,194,525	3,194,525	2,067,046	563,740	No action			
EPCWID Mesilla Valley -Ag	No Change	No Change	No Change	No Change	No action			
EPCWID El Paso – M&I (Urban)								
Employment	15	15	8	7	No action			
Labor Income	1,041,396	1,041,396	545,493	557.497	No action			
Output	3,603,279	3,603,279	857,923	563,740	No action			

4.20 Environmental Justice

4.20.1 Analysis Methods and Assumptions

As informed by the Federal Interagency Working Group on Environmental Justice and NEPA Committee (2016), a disproportionately high and adverse impact on minority or low-income populations is based on a comparison of the adverse impacts on the environmental justice community relative to the impacts on the overall population of the study area, based on the particular resource analyzed in the NEPA document. As described in Section 3.15 of Chapter 3, Doña Ana, El Paso, and Hudspeth Counties are environmental justice communities, while Sierra County is not an environmental justice community. However, because the economic analysis combined Sierra County with Doña Ana County as the New Mexico study area, this combination is retained here.

4.20.2 Employment

From 1970 to 2014, employment in the four counties grew from 179,838 to 515,740 jobs, a 187 percent increase (Commerce, Bureau of Economic Analysis 2015). Tables 4-28 and 4-32 project a potential loss of 4 or 5 farm jobs in the non-environmental justice communities (Doña Ana and Sierra Counties, New Mexico study area) under the action alternatives compared to Alternative 5 (No Action). Tables 4-29 and 4-32 show that the environmental justice communities (El Paso and Hudspeth Counties, Texas study area) would experience a slight positive benefit: a potential increase of 8 to 45 farm jobs compared to Alternative 5 (No Action). Relative to 515,740 total jobs in the study area during 2014, 4 to 45 jobs is insignificant. This means there is neither a high nor disproportionate effect on environmental justice communities.

4.20.3 Income

From 1970 to 2014, personal income grew from \$8,820.3 million to \$33,568.8 million, a 281 percent increase across the four-counties (Commerce, Bureau of Economic Analysis 2015). Tables 4-28 and 4-32 project a potential maximum decrease in labor income in the non-environmental justice communities (Doña Ana and Sierra Counties, New Mexico study area) of \$185,947. Tables 4-29 and 4-32 indicate there would be a potential maximum increase of \$1,107,627 in the environmental justice communities (El Paso and Hudspeth Counties, Texas study area), an insignificant effect relative to the \$34 million incomes in the counties.

5 Cumulative Effects and Other NEPA Considerations

This chapter discusses the cumulative effects of the alternatives within the context of other past, present, and reasonably foreseeable future actions. It also presents other NEPA considerations from 40 CFR 1502.16 including adverse effects which cannot be avoided should the proposal be implemented, the relationship between short-term uses and long-term productivity, and any irreversible and irretrievable commitments of resources involved in the proposal should it be implemented.

5.1 Regulatory Framework

CEQ regulations require consideration of cumulative impacts defined as:

"...the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." [40 CFR 1508.7]

Following CEQ guidance, the cumulative impact study area for identifying these actions is expanded beyond the immediate project area to include actions that might affect the same water resources, biological, cultural and socioeconomic resources of the environment as those described in Chapters 3 and 4. Cumulative actions that could result in cumulative impacts are listed below.

5.2 Reasonably Foreseeable Future Actions

Actions which have the potential to create ongoing or additive effects to those of the alternatives are summarized in chronological order with the most recent documents first

5.2.1 Far West Texas Water Development Board Plan (2016) and El Paso Water Plan (2013)

The 2016 Far West Texas Water Plan prepared by the Texas Water Development Board (2016) recognizes that current and future water demand and supply sources are constantly changing and indicates water plans need to be updated every 5 years. The plans recognize the City of El Paso as one of the fastest growing cities in Texas and that throughout Far West Texas (a larger area than the study are for this FEIS), the largest category of water use is irrigated agriculture. The 2016 Far West Texas Water Plan states that irrigation water shortages have occurred in El Paso and Hudspeth Counties due to insufficient water in the Rio Grande during the recent drought and those farmers in these counties have generally reduced irrigated acreage, changed types of crops planted, or not planted crops.

El Paso Water is the largest supplier of municipal water in Far West Texas and the utility has implemented a water conservation program that has significantly reduced per capita water demand. The City of El Paso has historically received about 50 percent of its M&I supply from surface water and 50 percent from groundwater in the Hueco Bolson and the Mesilla Bolson.

According to Hutchison (2006), historic pumping in the Mesilla Bolson has not resulted in significant changes in groundwater levels or groundwater quality, but pumping up to 1979 in the Hueco Bolson lowered groundwater levels and led to brackish groundwater intrusion. In the 1980s, El Paso reduced its groundwater pumping in the Hueco Bolson to about 80,000 AFY by increasing surface water diversion from the Rio Grande, increasing conservation efforts, and increasing reclaimed water use. By 2002, El Paso Water pumping in the Hueco Bolson dropped below 40,000 AFY and has since remained at these levels (Hutchison 2006). Reclamation, 2014a. River Maintenance Program-Delta Channel Maintenance Project Environmental Assessment The Delta Channel Maintenance Project maintains the existing, constructed Delta Channel to facilitate efficient delivery of Rio Grande water to the Elephant Butte Reservoir pool. It involves such activities as channel sediment removals, berm repair, site access, and staging area maintenance. River maintenance is conducted along 20.8 miles of the Delta Channel. Project-related road and staging area maintenance would be conducted within an approximately 293-square mile study area boundary in Socorro and Sierra Counties, New Mexico.

5.2.2 Reclamation River Maintenance Program-Delta Channel Maintenance Project Environmental Assessment and Finding of No Significant Impact

The Delta Channel Maintenance Project maintains the existing constructed delta channel to facilitate efficient delivery of Rio Grande water to Elephant Butte Reservoir. It involves activities such as channel sediment removal, berm repair, site access, etc. River maintenance is conducted along a 20.8 miles in Socorro and Sierra Counties, New Mexico. The project includes a suite of conservation measures to minimize or avoid adverse impacts on water quality, vegetation, species habitat, and wildlife. In addition, Reclamation is implementing recovery actions identified in the flycatcher and Rio Grande silvery minnow recovery plans.

5.2.2 USIBWC River Management Alternatives for the Rio Grande Canalization Project, River Management Plan, FEIS and Record of Decision (2014, 2012, 2009)

The USIBWC completed an evaluation of river management alternatives for the Rio Grande Canalization Project. This project affects a 105.4-mile long river reach from Percha Dam to the international boundary at El Paso and Cuidad Juarez, Chihuahua. The status is that the USIBWC is in the second phase of implementation of their 2009 Record of Decision on the River Management Alternatives for the Rio Grande Canalization Project and complying with the Service's (2012) biological opinion. The project, as proposed, would include ongoing channel maintenance and floodplain management, including levee improvements, vegetation management, habitat restoration work, and conservation of endangered birds following a flycatcher management plan. The USIBWC committed to establish flycatcher habitat and no-mow zones to enhance riparian vegetation.

5.2.3 Corps FLO-2D Model Development, Caballo Reservoir Flood Release and Court Order No. CIV-90-95 HB/WWD (2013, 2005)

As part of USIBWC's Rio Grande Canalization Project, USIBWC contracted with the Corps of Engineers who subcontracted with Tetra Tech to update the calculations of design storms affecting Caballo Dam releases. While the report is not an "action" per se, in conjunction with Reclamation and USIBWC management of Caballo flood releases, the cumulative action with cumulative effects is that there is statistically almost no chance of a 5,000 cubic feet per second (cfs) release for flood control, although historically, there have been greater than 5,000 cfs flows at the USIBWC's gage below Caballo Dam. The peak discharge is approximately 2,990 cfs, which essentially precludes overbank flooding below Caballo.

5.2.4 Corps of Engineers and CH2MHill (2012) and Rio Grande Salinity Management Program (2012)

The Corps and others have formed a coalition to reduce salinity from San Acacia to Fort Quitman. The project consists of four phases: salinity assessment, salinity management alternatives analysis, feasibility and pilot control project testing, expanded scale salinity control project and evaluation of project effectiveness. Effects of this ongoing project may result in improvements (decreases) in salinity and other contaminants in the Rio Grande through the study area for this FEIS.

5.2.5 City of Las Cruces Wastewater System Master Plan Update (CDM 2008) and 40-Year Water Development Plan (2007)

The City of Las Cruces has had a water and wastewater plan in place since 1995. In 2007, it prepared a 40-year water development plan. In 2008, the City updated their water and wastewater plan which projected that by 2025, with low growth demand it would need a total of 20,549 acrefeet per year; with high growth demand it would need a total of 33,307 acre-feet per year (CDM 2008:6-4). As of 2008, the City's water supply is groundwater from wells in the Mesilla and Jornada groundwater basins. The City's plans include three elements: conjunctive use of surface and groundwater, water conservation, and reclaimed water use. The City anticipates that some but not all of any increase in groundwater pumping would require offsets. The City's director of utilities (Garcia 2008) indicated that they have been acquiring and leasing some surface water rights through EBID with verification from the NMOSE. The City's strategy is to concentrate on surface water supply. Working with EBID, they have implemented a Special Water Users Association. The City of Las Cruces has not contracted with EBID and Reclamation for conversion of irrigation water to municipal and industrial uses.

5.2.6 New Mexico State Parks, Elephant Butte Lake State Park Management Plan (2006)

This is a resource management plan guiding recreation and the management of public recreational opportunities at Elephant Butte Lake State Park. NM State Parks also manages recreational areas at Caballo, Percha, and Leasburg Diversion Dams.

5.2.7 New Mexico Lower Rio Grande Regional Water Plan (2004)

This plan, with a revision currently in progress, provides population projections through 2040 for three different rates of regional growth to provide a high estimate, a medium-range estimate, and a low range estimate. Projected public water supply requirements for the area are made through the year 2040 for the low, medium and high growth scenarios. This plan includes other public water supply systems located within the planning area with relevant estimates of the population served and the total amount of water provided by these systems.

5.2.8 NMOSE Active Water Resource Management Initiative (2004)

This project of the NMOSE, initiated in 2004, could have ongoing effects in the cumulative impact study region. Under this initiative, the NMOSE declared the Lower Rio Grande a "priority basin" (NMAC 19.25.13). The objective is to supervise the physical distribution of water to protect senior water right owners, to assure compliance with interstate stream compacts and to prevent calls by senior water rights holders for administration of water rights. In addition, these rules fulfill the mandates of Section 72-2-9.1 NMSA, requiring the state engineer to adopt rules for priority administration based on appropriate hydrological models and facilitate marketing within water master districts subject to priority administration.

5.2.9 Reclamation Elephant Butte and Caballo Reservoirs Resource Management Plan, Record of Decision and FEIS (2003, 2002)

This is Reclamation's resource management plan designed to guide Reclamation and other Federal, state, local, and participating agencies in managing, allocating, and appropriately using Elephant Butte and Caballo Reservoirs' land and water resources. The RMP was also designed to assist Reclamation in making decisions regarding the management of recreation resources.

5.3 Cumulative Impacts by Resource

This section projects cumulative impacts of the reasonably foreseeable future actions listed in Section 5.2 on resources described in Chapters 3 and 4 of the FEIS.

5.3.1 Water Resources including Reservoir Storage, Elephant Butte Reservoir Elevations, Allocations, Releases, Diversions, Farm Surface Water Deliveries

Effects of the Federal actions listed above were included in the modeling of the effects of the alternatives, so there would be no additional cumulative effects to water resources. While water management plans of the Cities of Las Cruces and El Paso and of Far West Texas (Texas Water Development Board 2016) are listed as cumulative actions above, due to uncertainties, future effects of these municipal plans have only partially been incorporated in Chapter 4 water resource analyses. The original 1920 Act contracts with the City of El Paso were done in 1940 which allowed the city to purchase 2,000 acres of irrigated farmland for conversion of the water allocated to that land to M&I supply. By the 1950s (President's Commission 1950), El Paso and Albuquerque had experienced water shortages. Back then, El Paso began buying additional lands from landowners within the RGP to obtain rights to water under arrangements with EPCWID. These effects were part of the modeling of water resources analyses in Chapter 4 (Sections 4.1 to 4.12). The City of Las Cruces, through its 40-Year Water Plan, is considering a similar strategy of acquiring or leasing surface water rights through EBID. While their plan is considered a cumulative action, there are not enough data or details to model how this might occur.

5.3.2 Groundwater

The assumption of the Chapter 4 groundwater analyses (Sections 4.9 to 4.11) is that irrigation water requirements that are not satisfied by RGP surface water deliveries are met through supplemental groundwater pumping. For groundwater elevations, the model projects that the differences that would be caused by implementing one or another of the alternatives would be less than the differences that might arise due to future climatic conditions.

Increases in future groundwater pumping by the Cities of Las Cruces or El Paso were not modeled, but could be anticipated to result in lower groundwater levels in the future unless offset by decreases in pumping in other parts of the aquifer. No data or models are presently available to Reclamation to quantify groundwater effects of the cities' future actions related to groundwater uses.

5.3.3 Water Quality

Since the 1950s, quality of surface water in the Rio Grande has been documented as degrading from the San Luis Valley to Fort Quitman (President's Commission 1950), although in the latest 303d report of New Mexico (NMED 2016: 175-178), water quality has improved in Elephant Butte Reservoir. When the effects of the alternatives are added to those ongoing effects from Reclamation's Delta Channel Maintenance Project and low flow conveyance channel, water

quality in the reservoir is expected to be within the ranges historically documented with possible impairments due to mercury, nutrients and polychlorinated biphenyls. Likewise, cumulative impacts to water quality in Caballo Reservoir are expected to fluctuate over time with the quantity of water in storage, but with ongoing impairments due to high nutrient levels.

Downstream of Caballo Reservoir in the USIBWC Rio Grande Canalization Project, water quality should improve over time when the effects of the alternatives are added to those of USIBWC's Record of Decision implementation (2012, 2009), which includes more efficient water delivery, soil erosion prevention, and habitat restoration, water quality should improve slightly over time. Also, the Corps' Salinity Management Program and work of El Paso Water should result in cumulative improvements to water quality.

5.3.4 Vegetation and Weeds

As described in Sections 3.6 and 4.13, the existence of the reservoirs, combined with USIBWC's Rio Grande Canalization Projects downstream of Caballo Reservoir has led to the present status of vegetation communities across the cumulative impact study area. At the inflow area to Elephant Butte Reservoir, ongoing effects of Reclamation's Delta Channel Maintenance Project would continue to help moderate potential impacts from inundating vegetation and vegetation loss or degradation in Elephant Butte Reservoir.

The reservoir pool elevations would continue to fluctuate under all alternatives and these fluctuations would continue to affect individual plants throughout the reservoir area. Although given the low probabilities of the reservoir surface water remaining at one elevation for a prolonged period, it is unlikely that whole patches of vegetation would be affected or that there would be a net loss of habitat for nesting birds.

Downstream of the RGP reservoirs, the Rio Grande was canalized between 1938 and 1943, and the vegetation in most areas is managed by the USIBWC and monitored as part of USIBWC's and Reclamation's ESA commitments. There are sections of the downstream environment where some native vegetation is being managed by USIBWC to improve wildlife habitat and there are ongoing beneficial effects due to their non-native plant control program (USIBWC 2012). These beneficial effects are expected to continue into the future.

While there is some potential for noxious weeds to grow or increase in the short-term, however as a cumulative impact of management by both the USIBWC and Reclamation noxious weeds are managed under an integrated pest management framework. As a result, no increase in cumulative impacts to weeds is expected.

5.3.5 Wetlands and Floodplains

No additional cumulative impacts to wetlands and floodplains would be anticipated based on the cumulative actions listed in Section 5.2. There are patches of emergent marsh plants in the sediment delta inflow area to Elephant Butte Reservoir, but these patches are not expected to become jurisdictional wetlands due to the repeated cycles of wetting and drying: the fluctuations are unlikely to support the development of hydric soils.

For floodplains in the cumulative impact study region, between the USIBWC's and Reclamation's ongoing actions of managing releases from Elephant Butte and Caballo Dams and actively managing the river segments, there would be no change in base floodplains and no construction proposed in the 100- or 500-year floodplains that has not undergone prior NEPA analysis.

As stated by the USIBWC (2007, 2009a, b), the Rio Grande floodplain was enclosed by a levee system and dredged river channel beginning in 1938 and completed in 1943. The canalization extends some 105.4 miles along the Rio Grande from below Percha Dam in Sierra County, New Mexico to American Dam in El Paso, Texas, and along the river to Fort Quitman, Texas. The USIBWC increased flood containment capacity as a result of raising levees between 4 – 12 feet in height and dredging the river channel in a series of past actions; and these effects of managing the floodplains to meet Federal Emergency Management Agency certification requirements would continue into the future (USIBWC 2007, 2009b).

5.3.6 Wildlife and Special Status Species

The potential cumulative impacts to terrestrial wildlife (defined by NEPA, not ESA) and special status wildlife species are essentially the same as the projected effects for vegetation. As described in Section 4.14, the flycatcher and the cuckoo are seasonally present in Elephant Butte Reservoir and their habitats may be degraded, expanded, or enhanced depending on the duration at which the water surface elevations remain at a particular elevation. None of the actions listed in Section 5.2 would create cumulative impacts on wildlife or special status species that have not been included in the Section 4.14 analysis or the consultation with the Service.

Along the Rio Grande below Caballo Dam, cumulative impacts to wildlife from the actions of the USIBWC have been described in a series of environmental assessments, environmental impact statements, and consultations (USIBWC 2007, 2009a, b; 2012, 2014a). The USIBWC committed to work on restoring riparian shrub communities suitable for breeding flycatchers in this reach. When Reclamation's action of releasing water from Caballo Dam is added to the actions of the USIBWC, there should be no cumulative impacts to vegetation, wildlife or special status species that have not already been consulted upon.

5.3.7 Aquatic Resources and Special Status Fish Species

The existence of the RGP dams and reservoirs led to the extirpation of native fish, as discussed in Sections 3.8 and 4.15, but dam existence is in the baseline and cumulative effects are restricted to Reclamation's Delta Channel Maintenance Project that extends the river into Elephant Butte Reservoir and provides additional occupied habitat for riverine species, including the endangered Rio Grande silvery minnow. Conservation measures included in the project provide habitat features in the channel to support the minnow's life stages and avoid harming the fish during construction and maintenance. No other cumulative effects to aquatic resources and special status fish are expected to occur through 2050.

Similar to the other biological resources, the range of releases to the Rio Grande from the alternatives is within the range of historical operations. When all the actions listed above are added to the potential effects of the alternatives, no additional cumulative effects to aquatic resources and special status fish species are expected to occur through 2050.

5.3.8 Cultural Resources

Management of historic properties within the cumulative impact study areas is being conducted by Reclamation and the USIBWC as part of their respective Section 110 compliance responsibilities. No other undertakings are reasonably foreseeable that have not undergone Section 106 or 110 compliance; thus, no cumulative effects to historic properties are expected to occur through 2050.

No adverse impacts to Indian sacred sites or resources of tribal concern would be anticipated from the alternatives (as described in Section 4.17); therefore, no cumulative effects would apply to these resources.

5.3.9 Indian Trust Assets

The Rio Grande is recognized as aboriginal territory of the Apache and the Pueblo of Ysleta del Sur has interests in the area around El Paso, but no ITAs have been identified in the cumulative impact study area. As a result, there would be no adverse impacts of the alternatives to ITAs and no cumulative effects on ITAs. The Federal agencies are committed to government-to-government consultation with these Indian tribes, going into the future.

5.3.10 Socioeconomics, Including Farmland

The primary purpose of the RGP is irrigated agriculture and maintaining the water supply for this purpose would continue into the future under all the alternatives. When the cumulative impacts of the actions of the USIBWC are added to those in this FEIS, there are no anticipated changes to farmland in production. As noted by the USIBWC (2009), measures associated with their Integrated Land Management Alternative were selected and are being implemented to minimize the conversion of farmland to non-agricultural uses. As the USIBWC found, no significant impacts on prime farmland are anticipated.

Simulation and analysis of project operations was carried out to evaluate relative changes in the storage, release, and delivery of project water to diversion points for EBID, EPCWID, and Mexico from the five alternatives under future possible climate and hydrologic conditions within the project area, but with the assumption that future M&I demands would be consistent with recent demands. This assumption allows for analysis of changes in project operations because of alternatives, without confounding effects of changes in M&I demand or uses.

The modelling for the FEIS assumes that future pumping for M&I uses would be consistent with recent pumping and there would be no reasonably foreseeable change into future. This assumption is consistent with water plans of the cities in the study area, as cited above.

5.4 Unavoidable Adverse Effects

As described in Chapters 4 and 5, implementation of any of the alternatives, combined with climate change, could result in adverse impacts to birds listed under the ESA and on designated or proposed critical habitat. However, with careful monitoring and reservoir management, and coordination with the Service, adverse effects to birds or their habitat should be avoided or reduced below the level of significance. No other significant adverse effects to resources are projected by the FEIS.

5.5 Relationship between Short-term Uses of the Environment and Maintenance and Enhancement of Long-term Productivity

To assess the relationship between short-term uses and maintenance of long-term productivity, Reclamation considers the period through 2050 to be short-term when compared with the long history of the RGP or the indefinite period beyond 2050 when the RGP continues to be operated and maintained. Within this short-term time frame, Reclamation's implementation of the OA would result in increased certainty to the RGP water users, given the increased flexibility afforded by carryover allocation and adjustments for project efficiency projected by the diversion ratio. With this FEIS, the RGP water users should have a better understanding of how the system

would operate in the future under climate change. There will be times when the districts experience a smaller allocation of surface water which would translate into a smaller surface allocation of water to farms and possible future M&I users, which would be supplemented by groundwater at the discretion of each farmer. Conversely, during wetter climatic conditions, the districts would receive larger surface water allocations resulting in more water to farms and possible future M&I users, which would translate to less groundwater use, all water use dependent on crop types and population.

5.6 Irreversible and Irretrievable Commitments of Resources

The CEQ's regulations at 40 CFR 1502.16 require consideration of irreversible and irretrievable commitments of resources. This is interpreted to mean decisions affecting non-renewable resources such as land, or causing a species to become extinct, or a resource to be destroyed or removed. The term irreversible also describes the loss of future options.

None of the alternatives has or would result in an irreversible or irretrievable commitment of resources. The proposed action would ensure that the RGP water would continue to be managed consistently and efficiently with respect to the RGP authorization, the districts' rights, the 1906 treaty, and other applicable laws, court decrees, agreements, and contracts.

6 Preparers, Consultation and Coordination

This chapter details the consultation and coordination among Reclamation and other Federal, state and local agencies, American Indian tribes, and the public in preparing this FEIS. The public scoping process was described in Section 1.9 of the FEIS. This chapter also includes the list of preparers.

6.1 Cooperating Agency Involvement

Reclamation invited nine agencies to cooperate in the NEPA process. Three agencies either declined or did not respond to the request: HCCRD, the New Mexico Interstate Stream Commission, and ABCWUA. Six agencies signed a memorandum of understanding with Reclamation to become cooperating agencies. In October 2015, the City of Santa Fe Water Division ended its role as a cooperating agency. The five agencies cooperating throughout the process are:

- Colorado Division of Water Resources
- Elephant Butte Irrigation District of New Mexico
- El Paso County Water Improvement District No. 1
- Texas Rio Grande Compact Commissioner
- U.S. Section, International Boundary and Water Commission

Reclamation hosted periodic cooperating agency meetings throughout the preparation of this FEIS to ensure that the agencies were informed of and involved in the process based on their legal jurisdiction or special expertise.

6.2 Tribal Consultation

Following Executive Order 13175, Consultation and Coordination with Indian Tribal Governments, Reclamation sent letters on June 24, 2014, asking the two tribes with potential interests in the RGP: Ysleta del Sur Pueblo of Texas and the Mescalero Apache Tribe of the Mescalero Reservation, New Mexico, if they wished to be consulted or had issues or concerns with the proposed action. In October 2015, Reclamation reached out to the tribes via phone call and follow-up e-mail. To date, no response has been received from either tribe.

During the preparation of the SEA covering the OA from 2013 to 2015, the Mescalero Apache Tribe, whose aboriginal territory lies within the project area, expressed concerns about native plants growing along the irrigation canals in the service areas of EBID and EPCWID. Tribal members collect plant material for cultural purposes. This is identified as a resource of tribal concern in the cultural resources analysis (Section 4.17.2).

6.3 Other Consultations and Coordination

6.3.1 U.S. Fish and Wildlife Service

To comply with ESA Section 7(a)(2), Reclamation submitted a biological assessment to the Service on August 20, 2015. Reclamation's finding was that Alternative 1 "may affect, but is not likely to adversely affect" the Rio Grande silvery minnow (*Hybognathus amarus*). The finding was that Alternative 1 "may affect, and is likely to adversely affect" the flycatcher, the cuckoo, and "may affect, is likely to adversely modify proposed or designated critical habitat" for the birds. The finding for the mouse was no effect, because the species is not present in the action area. On May 25, 2016, the Service issued its biological opinion.

6.3.2 Consultation with the Government of Mexico

The USIBWC served as a cooperating agency and assisted Reclamation in conforming to the requirements of Executive Order 12114 regarding effects of proposed Federal actions in other countries. This FEIS describes water deliveries to Mexico, but the modeling assumptions or descriptions in this FEIS are not intended to constitute an interpretation or application of the Treaty with Mexico or to represent current U.S. policy or a determination of future U.S. policy regarding deliveries to Mexico.

6.3.3 New Mexico State Historic Preservation Officer

To comply with the NHPA, Reclamation consulted with the New Mexico Historic Preservation Officer on October 29, 2015, requesting concurrence on the determination of "no historic properties affected." Reclamation received concurrence on November 25, 2015 (see Appendix D).

6.4 Final EIS Distribution

The notice of availability of this FEIS was sent to area libraries, other Federal, state and local agencies, American Indian tribes, and the public. All parties listed in Table 6-1 received a CD or electronic version of the FEIS. Copies may be reviewed at the locations listed below:

- Reclamation, Albuquerque Area Office, 555 Broadway NE, Albuquerque, NM 87102
- Reclamation, El Paso Office, 10737 Gateway West, Suite 350, El Paso, TX 79935
- Natural Resources Library, U.S. Department of the Interior, 1849 C Street NW, Main Interior Building, Washington D.C. 20240-0001
- Elephant Butte Irrigation District, 530 South Melendres Street, Las Cruces, NM 88005
- El Paso County Water Improvement District No. 1, 13247 Alameda Avenue, Clint, TX 79836

A copy of the FEIS is available on Reclamation's website at: http://www.usbr.gov/uc/envdocs/eis.html

Table 6-1 Distribution list

Table 6-1 Distribution list	
Affiliation	Name
Federal:	
US Environmental Protection Agency	Houston, Robert
U.S. International Boundary and Water Commission	Anaya, Gilbert
U.S. Fish and Wildlife Service	Tuggle, Benjamin
State or Quasi-state:	
Colorado Division of Water Resources	Sullivan, Mike
Colorado Attorney General	Wallace, Chad M.
Colorado Compact Commissioner	Wolfe, Dick
Colorado Department of Law	Wallace, Chad M.
Counsel for EPCWID	Speer Jr., James M.
El Paso Water Control and Improvement District, No. 1	Stubbs, Johnny
Elephant Butte Irrigation District of New Mexico	Salopek, James
New Mexico Attorney General	Balderas, Hector
New Mexico Department of Game & Fish	Wunder, Matt
New Mexico Environment Department	Flynn, Ryan
New Mexico Interstate Stream Commission	Dixon, Deborah K.
New Mexico Office of the State Engineer	Verhines, Scott
New Mexico State Historic Preservation Office	Pappas, Jeff
New Mexico State Parks	Tafoya, Christy
Texas Rio Grande Compact Commissioner	Gordon, Pat
Local Agencies:	
Albuquerque Bernalillo County Water Utility Authority	Sanchez, Mark
City of Las Cruces	Miyagishima, Ken
Stein & Brockman for the City of Las Cruces	Stein, Jay F.
American Indian/Tribal:	
Mescalero Apache	Chino, Frederick
Ysleta del Sur	Paiz, Frank
Libraries:	
New Mexico State University Library	Carter, Stephanie
University of Texas at El Paso	Gaunce, Charles
Organizations and Individuals:	
Audubon New Mexico	Bardwell, Beth
Individual	Welsh, Heidi
New Mexico B.A.S.S. Nation	Earl Conway
Paso del Norte Watershed Council	Keyes, Conrad
Southwest Environmental Center	Bixby, Kevin
Wild Earth Guardians	Pelz, Jen

6.5 List of Preparers

This FEIS was prepared by Reclamation's Upper Colorado Region, Albuquerque Area Office, with contributions from the Denver Policy Office, with assistance from Environmental Management and Planning Solutions, Inc. (EMPSi), Santa Fe, New Mexico. The names of persons who prepared various sections, provided information, or participated to a significant degree in reviewing the document are listed in Table 6-2.

Table 6-2 L	ist of	preparers
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Name and Title	EIS Responsibility
Reclamation Preparers:	
Cortez, Filiberto, special assistant Coulam, Nancy, environmental protection specialist	Technical coordination, water resources Technical coordination, environmental justice
Coykenall, Arthur, biologist	ESA policy and biology review
Cunningham, Catherine, environmental	1 2
protection specialist	NEPA policy and review
Engel, Paula, economist	Socioeconomics
T	Hydrology, climate change, water
Ferguson, Ian, civil engineer	resources
Garcia, Hector, environmental protection specialist	Technical coordination, quality control
Graham, Rhea, special project officer	Project manager
Heffernan, Beverly, division manager	NEPA policy and review
,	Hydrology, climate change, water
Llewellyn, Dagmar, hydrologist	resources
Painter, M. Jeff, resource management specialist	Technical coordination, quality control
Environmental Management and Planning Solutions, Inc. (EMPSi):	
Batts, David, principal-in-charge	Technical coordination, quality control
Cordle, Amy, administrative planner	Quality control, editing Document and administrative record
Crump, Sarah, administrative	support
Doyle, Kevin, project manager	Technical coordination, cultural resources
Estep, Melissa, engineer	Water resources
Gahli, Zoe, environmental planner	Socioeconomics, environmental justice
McCarter, Molly, environmental planner	Administrative record support
Parker, Nicholas, environmental planner	Technical coordination, quality control
Patterson, Katie, legal reviewer	Legal sufficiency
Prohaska, Holly, environmental planner	Quality control
Rice, Kevin, biologist	Biological resources
Rickey, Marcia, GIS specialist	Maps, figures
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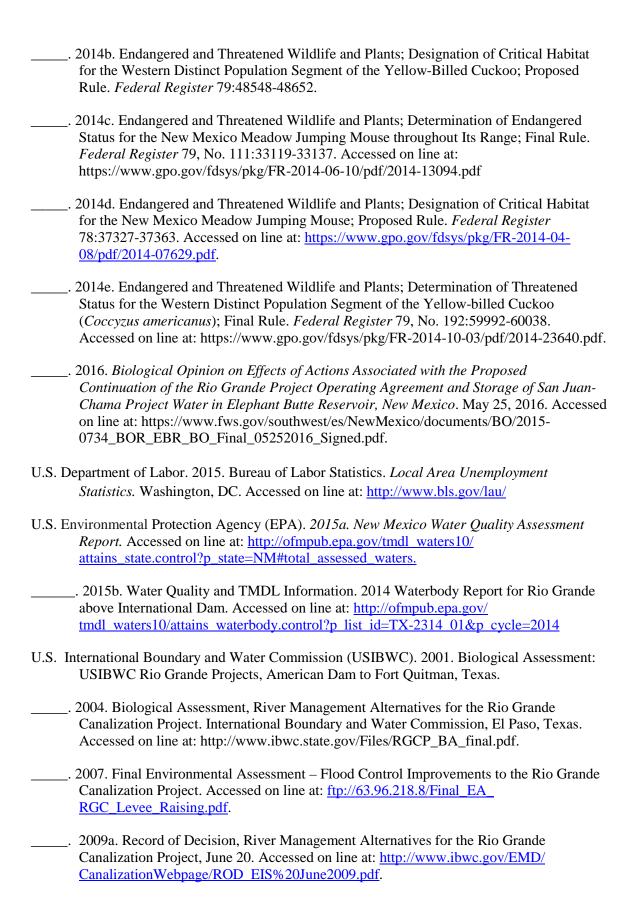
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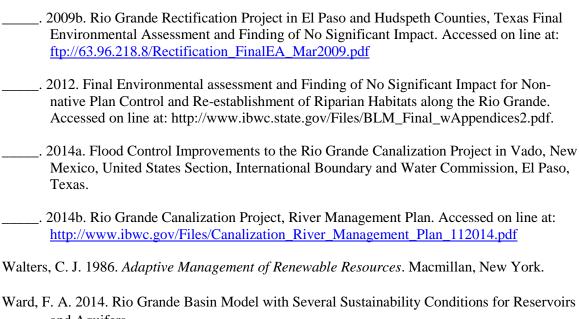
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