Climate Resilience Evaluation and Awareness Tool Exercise with North Hudson Sewerage Authority and New York-New Jersey Harbor Estuary Program

Office of Water (4608T) EPA 817-K-12-002 April 2012 www.epa.gov/watersecurity

Disclaimer

Executive Summary

Current watershed management practices may not be sufficient to cope with potential effects of climate change on aquatic ecosystems, water supply reliability, water quality, and coastal flood risk. As a result, there is a need to identify regional consequences from climate change and to develop adaptation strategies that are integrated at a watershed scale. EPA's Climate Ready Water Utilities (CRWU) and Climate Ready Estuaries (CRE) initiatives are working to coordinate their efforts and support climate change risk assessment and adaptation planning. Both EPA initiatives have a focus on addressing climate change and water resource issues with stakeholders that share common interests regarding watershed management. This report details a recent exercise that provided an opportunity for these parties to collaborate on assessment and planning with respect to potential climate change impacts on utility infrastructure and natural resources.

The Climate Resilience Evaluation and Awareness Tool (CREAT) was used to support the collaborative process of identifying climate change threats, assessing potential consequences, and evaluating adaptation options for both a utility and for the overall watershed. CREAT guides users through an evaluation of potential climate-related impacts, including impacts to source water, receiving waters, and other natural resources that may be a priority concern to other stakeholders. Within the tool, users can assess adaptation options to address these impacts using both traditional risk assessment and scenario-based decision making. The entire process is designed to be iterative, with opportunities to revise assumptions, add new information, and revisit analyses at a later date.

The New York/New Jersey (NY/NJ) Harbor Estuary Program was the lead National Estuary Program (NEP) for this exercise and North Hudson Sewerage Authority (NHSA) was chosen as a local utility to host this exercise. Both NHSA and the NEP quickly identified common interests with respect to current challenges and how their efforts related to climate change may complement each other. The receiving waters for the NHSA system are part of the NY/NJ Harbor Estuary ecosystem which provides critical habitat and serves the surrounding communities by providing recreation and transportation services. Participants were introduced to CREAT through a series of webinars that culminated at NHSA with an in-person meeting. This final meeting provided a venue for participants to meet, discuss the results of the analysis, and consider lessons learned and next steps.

The value of collaboration between the participants was noted during all stages of the CREAT process, especially in the definition of consequence categories, the assessment of consequences to natural resources, and the selection of adaptive measures requiring coordination as part of implementation. Both the utility and its watershed partners gained perspectives on the value of information used in assessments and the interpretation of results for their use in future planning efforts. Feedback on the exercise process and on CREAT itself will be used in the design of future joint exercises as well as in development of the second version of the tool. Participants recommended sharing results with a larger audience to solicit additional input and continue the dialogue between NHSA and its watershed partners. For any subsequent exercises, there may be a need to select a location with a different level of urbanization so that the analysis will support a more thorough exploration of the overlap between NEP and utility planning efforts related to climate change.

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Purpose of Exercise

EPA's Climate Ready Water Utilities (CRWU) and Climate Ready Estuaries (CRE) initiatives are working to coordinate their efforts and support climate change risk assessment and adaptation planning. The impacts of climate change can extend beyond the traditional assets of a utility (i.e., infrastructure). Furthermore, current watershed management practices may not be sufficient to cope with potential effects on aquatic ecosystems, water supply reliability, water quality, and coastal flood risk. As a result, there is a need to identify regional consequences from climate change and to develop adaptation strategies that are integrated at a watershed scale. During this exercise, the Climate Resilience Evaluation and Awareness Tool (CREAT) was used as a framework to bring together a larger group of watershed or community stakeholders to explore an expanded scope of risk management and planning activities at drinking water and wastewater utilities.

The objectives of this exercise were to:

- Bring together the North Hudson Sewerage Authority (NHSA) and the New York-New Jersey (NY/NJ) Harbor Estuary Program for climate change risk assessment activities that foster opportunities for collaborative adaptation planning;
- Assess the usefulness and applicability of CREAT software for identifying watershed-scale climate change consequences and developing adaptation strategies;
- Identify ways to enhance the water resources and ecosystem sections of CREAT as part of improvement for Version 2.0; and
- Identify gaps in the current CREAT approach and areas for further refinement.

The major steps used to develop and conduct this exercise were the following:

- Scoping meeting and report;
- Site selection;
- Webinars (three conducted);
- In-person exercise; and
- Post-exercise report.

Project Background

During this exercise, representatives from the NHSA and the NY/NJ Harbor Estuary Program worked together to use CREAT software to conduct a risk assessment analysis of climate impacts on shared assets. The NY/NJ Harbor Estuary Program is one of 28 National Estuary Programs (NEPs) established under the Clean Water Act and is managed under a Comprehensive Conservation and Management Plan. EPA's Climate Ready Estuaries (CRE) initiative works with the NEPs and other coastal managers to:

- Assess climate change vulnerabilities;
- Develop and implement adaptation strategies;
- Engage and educate stakeholders; and
- Share lessons learned about climate change adaptation.

The EPA CRWU initiative plays a similar role for utilities in the water sector. More specifically, CRWU provides resources for the water sector to adapt to climate change by promoting a clear understanding of climate science and adaptation options and by promoting consideration of integrated water resources management (IWRM) planning in the water sector. Both the CRWU and CRE initiatives have a focus on addressing climate change and water resource issues and this exercise provided a first opportunity to collaborate.

Throughout this exercise, CREAT provided a platform for discussion of climate change impacts on shared water resources. CREAT is designed to assist drinking water and wastewater utilities in understanding potential climate change threats and in assessing the related risks. Using the most current scientific understanding of climate change, CREAT allows users to evaluate potential impacts of climate change on their utilities and to assess adaptation options to address these impacts using both traditional risk assessment and scenario-based decision making. CREAT also has the capability to consider impacts on source water, receiving waters, and other natural resources that may be a priority concern to other stakeholders (e.g., NEPs).

Scoping Meeting

The scoping meeting for this exercise produced a vision for the collaborative process: participants conduct climate change risk evaluations using CREAT to determine the resilience of the local water/wastewater utilities and their surrounding watershed. Participants used known information about their utility and the watershed to identify climate change threats, assess potential consequences, and evaluate adaptation options in CREAT. During scoping discussions, the NY/NJ Harbor Estuary Program was identified as the lead NEP for this exercise. Based on location and interest, NHSA was chosen as a local utility to host this exercise. Both NHSA and the NEP quickly identified common interests with respect to current challenges and how their efforts related to climate change could impact each other.

Site Description

The NHSA system includes approximately 107 miles of combined sewers, 17 combined sewer overflow (CSO) regulators, 11 CSO outfalls, and 6 pump stations. This system serves the New Jersey communities of Hoboken, Union City, Weehawken, and West New York. The receiving waters for the NHSA system are part of the NY/NJ Harbor Estuary ecosystem. The estuary is fed by a system of rivers draining from five states, mainly off the Catskill Mountains, and flowing through several major metropolitan areas. An important natural resource in the region, the estuary provides habitat for over 300 species of migratory birds, spawning ground for several species of fish, and also serves the surrounding communities by providing recreation and transportation services.

CREAT Exercise Methodology

General Approach

Prior to the in-person meeting at the NHSA facilities, participants engaged in three webinars. These webinars served several functions including introducing participants and providing a familiarity with CREAT. Originally, EPA planned to use webinars as working sessions with all parties. However, following the first webinar, the process was refined. Instead, utility representatives worked with contractors and EPA to enter their data prior to the webinar session. NHSA staff called to discuss any questions about the data entry and then provided their data file in advance of each webinar. The data file was edited in preparation for the webinar. Between webinars, participants communicated with regard to individual priorities and goals as well as data-related questions.

Webinar 1 – June 3, 2011

The objective of this webinar was to review the Setup and Assets portions of CREAT and begin preparing for the joint exercise. Using an initial set of information prepared by NHSA and entered into CREAT, the group reviewed the Setup portion of the tool.

CREAT captures a variety of information about the utility being assessed, including aspects such as size and ownership structure. This information is important, but is neither fundamental nor a prerequisite to establishing an inventory or assessing resilience. Some of the data specified are used when generating the final results and reports. These reports provide documentation of the analyses and may facilitate feedback from report recipients. For example, wastewater utilities may use the Wastewater tab to specify the National Pollutant Discharge Elimination System (NPDES) or State Permit Number, Design Capacity, and other flow and system details.

Scenario Planning

CREAT provides two options for assessing the likelihood for specific climate events. One approach is to assume that threats will occur in the time periods considered, allowing users to explore a range of potential conditions as future climate scenarios for risk assessment. If a user is not comfortable assessing likelihood for threats due to uncertainty in climate projections or anticipation of future conditions, this approach is preferable. With this approach, the threat likelihood will indicate that the threat simply *occurs* instead of having a likelihood of occurrence on a qualitative scale.

If a user elects to assess the likelihood of threats, a second approach allows users to qualitatively assess the likelihood of occurrence as low, moderate, high, and very high based on best professional judgment, past experience and observations of historical conditions, and research using resources linked from CREAT. Definitions for these are as follows:

- Very High – Occurrence within the time frame is probable: not certain, but far more likely to occur than not. Recurrence is also likely within the time frame.
- High – Occurrence within the time frame is likely. Recurrence within the time frame is also possible.
- Medium – Occurrence within the time frame is less likely. Recurrence within the time frame is unlikely.
- Low – Occurrence is possible, but unlikely within the time frame.

Following a discussion of the merits of each method, NHSA chose to use the second method and assess the likelihood of threats during the exercise. The specific assessments were deferred until a later webinar, but participants anticipated that the assessment of likelihood would be a valuable component of the overall risk assessment and could foster discussion on how to plan for uncertain threats.

Time Periods

CREAT allows the user to select up to a total of five time periods in an analysis. Selection of time periods can be based on budget or planning cycles, infrastructure needs, or anticipated timing of climate change impacts. These time periods are then applied directly to threats being considered in assessments.

NHSA expressed interest in time periods that overlap with planned infrastructure upgrades (2015, 2020, 2030, 2040 and 2050). However, the current harbor restoration plan has target goals going out as far as 2050 and 2100. Further discussion of time periods was deferred until assets and threats could be considered.

Consequence Weighting

Next, the group moved on to the consequence weighting portion of setup. Within CREAT, the user can assess consequences across five selected categories. These attributes are provided to ensure that assessments consider a range of potential losses due to climate change impacts:

- Business Impacts
- Equipment / Facility Impacts
- Water Resource Impacts
- Environmental Impacts
- Community Impacts

Users can choose one of two methods for combining the consequence assessments across attributes:

- Select the HIGHEST LEVEL method if the user would prefer to use the highest level of consequence for any attribute to be the overall consequence value.
- Select the WEIGHTED SUM method if the user would prefer to aggregate the attributes based on relative weights. This second method would be appropriate if the user's utility would prefer to weigh some attributes more heavily than others in order to reflect overall priorities.

NHSA had initially selected the default (Weighted Sum) method and assigned equal weights to all five consequence categories. However, following discussion on the webinar, the group agreed that NHSA and NY/NJ Harbor Estuary Program would consult further with colleagues regarding organizational priorities and any potential modifications to the category definitions.

Historical Climate Data

Historical Climate Data should reflect the conditions already being experienced for comparison with projections of future climate conditions. Within CREAT, the data are organized with respect to highest and lowest observations for average temperature and precipitation at a specified location.

After a brief demonstration of how to load and display the historical temperature and precipitation data for New York City, NHSA was encouraged to explore other potential datasets for its location. As part of this discussion, NHSA indicated that the potential threats of greatest interest for the analysis were storm surge (and associated coastal flooding), volume and temperature changes (e.g., earlier spring runoff), and high flow events (e.g., increased heavy precipitation).

Assets

The final process step reviewed during this webinar was how to select and edit assets within the tool. CREAT provides two asset categories that are analyzed and maintained separately: Infrastructure and Natural Resources. Each category contains a distinct structure and levels of assets. After developing the initial My Assets list, a user may employ the Edit Assets tab to customize the assets to match the user's facility. The user can specify asset properties, such as the description and other physical details (e.g., longitude, latitude, and elevation). Additionally, the user can add custom assets not provided in the asset template.

NHSA suggested that the exercise should focus on the Adams wastewater treatment plant and associated critical infrastructure. This facility, located in Hoboken, New Jersey, includes four pump stations, several CSO facilities, and discharge locations at the Hudson River.

Webinar 2 – June 24, 2011

The objective of the second webinar was to review the Threats and Adaptive Measures portions of CREAT in preparation for the in-person meeting at NHSA.

Threats

CREAT provides users with the ability to review regional climate projections, links to quantitative information on global sea level rise, and qualitative information organized by threat type. This information is predominantly drawn from the Global Climate Change Impacts in the United States report published by the U.S. Global Change Research Program (USGCRP 2009) and peer-reviewed literature cited therein. CREAT also provides a list of threat types associated with widely recognized climate change drivers.

To begin their selection of threats, the group reviewed the qualitative climate change information for the Northeast region, including the description of how sea-level rise could change. For threats, NHSA had initially identified the following:

- *Coastal storm surge* – Gradual sea-level rise will be exacerbated by more sudden coastal storm surges during severe storms. In New York City, the 1-in-100 year coastal flood event is expected to occur once in every 15 to 35 years by the end of the century (Horton et al. 2010). Increased coastal storm surge may damage facilities and critical infrastructure.
- *High flow events* – Climate model projections, particularly for the Northeast, show that precipitation will occur in more concentrated extreme events (e.g., intense precipitation events). NHSA, like many wastewater facilities, is located at low elevation in the watershed, leaving its infrastructure at risk to flooding related to extreme events and increasing the chance of combined sewer overflows.
- *Altered surface water quality* – Climate models project increases in average temperatures and the number of extreme hot days in the United States. Algal blooms resulting from higher temperatures may impact receiving water quality, possibly leading to more stringent discharge requirements and the need for more advanced treatment by wastewater facilities. For NHSA, the threat would be related to changes in the receiving water quality and the subsequent need to adjust to ensure standards are met.
- *Volume and temperature challenges* – Climate models project that in the future, many areas are likely to receive less annual precipitation, and when precipitation does fall, it will be in fewer, more extreme rainfall events. These storm events wash sediment downstream and degrade water quality. Diminished receiving water quality from increased sediment and/or algal blooms may lead to more stringent requirements for wastewater discharges, higher treatment costs, and needs for capital improvements.
- *Loss of coastal landforms* – Climate models project increases in the frequency and intensity of storm systems. Damaging storms can lead to loss of coastal and stream ecosystems. The loss of coastal wetlands can reduce the buffer for critical infrastructure against coastal storms, leading to damage of treatments plants and potential disruption of services.

The group briefly reviewed how to select and customize threats within the tool by editing the coastal storm surge threat screen. Customization includes specifying individual threat properties (e.g., name, description) and defining any time-dependent characteristics (e.g., magnitude, frequency) of the threat. Users can also input threshold values for specific threats which can be helpful in assessing consequences to assets during the baseline and resilience analysis steps.

Participants discussed each of these threats and agreed that the last threat (loss of coastal landforms) may not be relevant for NHSA given the lack of significant natural habitat in the highly urban area surrounding the utility. The group decided to maintain the first four threats for use during the analysis and planning portions of the tool.

Adaptive Measures

During this webinar, participants also reviewed how to select and edit adaptive measures. CREAT provides an inventory of adaptive measures that can be classified as:

- Existing – part of an organization's current capabilities
- Potential – part of any plans or capabilities being considered
- Not Used – included in the Adaptive Measure Library but not applied to an analysis

The current template of available adaptive measures is based upon previous discussions with utilities and literature review. A measure is designated by the user as *Existing* or *Potential* based on their intended use. If an adaptive measure is used in the Baseline Analysis it becomes *Existing*; if a measure is used in Resilience Analysis it becomes *Potential*.

NHSA provided a spreadsheet indicating existing and potential adaptive measures that could be used for the baseline and resilience analyses. One of these measures, *Sewer/collection models*, was designated as both an existing and potential measure. This designation can be made in CREAT using one of two approaches:

- The measure is defined as existing for the Baseline Analysis and then revisited during the Resilience Analysis by choosing to *Improve an Existing Measure*.
- Alternatively, the measure can be defined twice prior to any analyses, where the potential *Sewer/collection model* measure has an updated description explaining how it differs from the similar existing measure.

NHSA agreed to continue entering adaptive measure information into CREAT and revisit this topic during the next webinar.

Webinar 3 – July 19, 2011

The objective of this webinar was to discuss logistics for the in-person exercise at NHSA in Hoboken, New Jersey, review all information previously entered into CREAT, and demonstrate the baseline and resilience analysis portions of CREAT in preparation for the exercise. During the logistics discussion, the group agreed that participation at the exercise would include the core working group and representatives from the New Jersey Dischargers Group. Other key details were also finalized such as start and end times, roles and responsibilities and final steps prior to the in-person exercise.

Revisit Assets and Threats

To evaluate the data for analysis during the in-person meeting, the group reviewed the assets, threats, and adaptive measures as entered into CREAT. The asset list for NHSA remained unchanged following review and included the Hudson River as a natural resource (the receiving water) and several elements under infrastructure (Adams Street treatment plant, Hoboken mains, Hoboken storm water sewers and four separate pump stations). Participants also discussed the idea of further grouping the existing assets so as to reduce the complexity of the baseline and resilience analyses.

A key lesson learned from this webinar was that many utilities and stakeholders would prefer to conduct an assessment on just a few priority assets or threats before conducting a more complete assessment for the watershed or system. This priority assessment would provide a way for utilities to assess conditions they are most concerned about in relation to climate change and related impacts. The main reason for conducting a priority assessment first is that utility representatives may not have time to do a comprehensive assessment of all assets and threats over each time period selected. But if initial assessments of assets or threats prove to be valuable, users may be encouraged to spend additional time on more thorough assessments.

In CREAT, threats are assigned to specific time periods by selecting whether or not they are applicable to each period and the likelihood of occurrence is assessed for each threat-time period combination. The group assigned threats to the defined time periods with likelihood of occurrence ranging from low to very high. Likelihood assessments (**Table 1**) were made based on NHSA's best professional judgment and interest in providing diverse conditions for the exercise.

Table 1. NHSA priority threats and their assessed likelihood of occurrence in identified time periods (2015, 2020, 2030, 2040 and 2050).

Threat	Likelihood of Occurrence by Time Period				
	2015	2020	2030	2040	2050
High flow events	Low	Low	Medium	High	Very High
Coastal storm surges	Medium	Medium	Medium	High	Very High
Altered surface water	n/a	n/a	Low	Medium	Low

Asset/Threat Pair Assignment

Identified threats need to be associated with assets for use in the analysis steps in CREAT: the asset/threat pair is the starting point for each detailed analysis. Threats can be paired to either single assets or groups of assets. When paired to groups, the assessment needs to consider all assets within the group together with respect to the consequences of a threat occurring.

NHSA proposed using the higher level of *PUMP Stations* to consider all stations together with respect to both flood threats (high flow events and coastal storm surges). With respect to the Hudson River as the receiving water, both flood and water quality threats were assigned to this natural resource asset.

Revisit Adaptive Measures

NHSA reviewed its initial list of existing and potential adaptive measures. Participants agreed that the list should be revised to reduce the number of adaptive measures. NHSA, EPA, and the contractor team planned to discuss this issue further and make a decision prior to the in-person exercise. The list of adaptive measures used in this exercise can be found in Appendix A.

Preview Baseline and Resilience Analyses

Finally, the group reviewed the baseline and resilience analysis steps within CREAT. The results from this Baseline Analysis establish a benchmark for the level of risk that threats associated with climate change may pose to utility assets. Comparison of these results to assessments following implementation of new adaptive measures (Resilience Analysis) provides a measure of the risk reduction possible through adaptation. CREAT guides the assessment of any asset/threat pair on any time period where the threat is applicable. An analysis considering all time periods can also be pursued where the consequences of threat occurrence may not change over time.

EPA recommended that NHSA prepare initial baseline and resilience analyses as part of a priority assessment in preparation for the in-person meeting.

In-person Meeting at NHSA – August 15, 2011

This meeting was the culmination of the exercise and brought together a diverse group of stakeholders, including representatives from the EPA, local and regional water and wastewater utilities, and consultants. During the in-person exercise, participants worked collaboratively to:

- Review the Asset, Threat, and Adaptive Measures information entered by NHSA;
- Demonstrate the baseline and resilience analyses;
- Develop implementation packages;
- Review example summary reports;
- Discuss analysis results and overall user-interface experience; and
- Provide constructive criticism on the process and lessons learned.

NHSA and the contractor team prepared example baseline and resilience analyses steps in advance of the meeting to demonstrate the process and promote discussion during the meeting. These examples included assessments of flood threats to the pump stations and degraded water quality in the Hudson River.

Baseline Analysis Discussion

Within CREAT, the Baseline Analysis is the starting point for performing assessments. The Baseline Analysis involves a specific series of steps including: 1) defining adaptive measures for this asset-threat pair; 2) assessing consequences of the threat on the asset; and 3) reviewing results of the analysis. The results of the Baseline Analysis describe the current risks to assets due to the occurrence of future, climate-related threats. More importantly, the results of the baseline analysis also serve as a frame of reference for the results from the next step in the CREAT process, the Resilience Analysis.

For the NHSA exercise, the presentation of the example analysis file started with examples of flood consequences for the pump stations. With respect to both types of floods, *High flow events* and *Coastal storm surges*, the consequences of these events in all time periods were assessed as Very High. These examples were illustrative of how utilities could consider Baseline analyses.

For the second step of baseline analysis, NHSA had assessed the consequences of defined threats on select assets given existing protective measures. A majority of the discussion during the demonstration of Baseline Analysis focused on the consequences of *Altered surface water quality* (threat) on the *Hudson River* (asset). Participants noted that this was an area for collaboration between the utility and other stakeholders, such as the NY/NJ Harbor Estuary Program. At a minimum, watershed stakeholders could provide information and resources to support assessment of threat-related consequences on natural resources.

From the perspective of a utility, climate change impacts (e.g., changes in the amount and timing of water runoff) will have multiple, interrelated effects on plant operations. Both direct loss of assets from flooding and the potential for degrading receiving water quality during storm events were central to discussions. Some additional questions NHSA and similar utilities should consider include:

- How does climate change affect our ability to treat to the level required to meet regulations? For example, do we need to adapt to changes in influent volumes and quality?
- How does climate change affect our ability to meet NPDES permit requirements? Do projected changes require responses in treatment, collection capacity, additional storage, or all of the above?

Resilience Analysis Discussion

After performing a Baseline Analysis, users define and select *Potential Adaptive Measures* to lower the risk posed to assets. Similar to the Baseline Analysis, the Resilience Analysis involves a specific series of steps including: 1) select adaptive measures; 2) re-assess consequences; 3) assign contribution from different adaptive measures; and 4) review analysis results.

The example Resilience Analysis demonstrated the risk reduction due to implementing adaptive measures. Resilience analyses were conducted for the first three time periods (2015, 2020, and 2030) for both flood and water quality threats. For each of these threats, potential adaptive measures were selected and applied within the analysis. In general, the overall risk reduction through adaptation was gauged to be greater as more time passed. In other words, even though threats and their related impacts or consequences were assessed to be more severe in later time periods, the capacity and time to implement additional adaptive measures was also anticipated to improve response and further reduce the consequences of these threats.

A key feature of CREAT is to provide a way to compare current and future risk levels as related to threats posed by a changing climate. Building resilience to climate-related threats by considering and deciding to implement adaptive measures facilitates the decision making process. In CREAT, the reduction of risk can be visualized in a risk matrix, where each analysis falls into a specific combination of likelihood of threat occurrence and level of consequence to the asset. Viewing the set of risk matrices from the exercise (**Figure 1**), it is evident that for each successive time period, the shift of numbers towards lower consequences in Resilience (bottom row of matrices) relative to Baseline (top row of matrices) is more pronounced in 2030 than in 2015. In effect, this shows that adaptive measures selected for the 2030 time period are more effective than those selected for the 2015 time period.

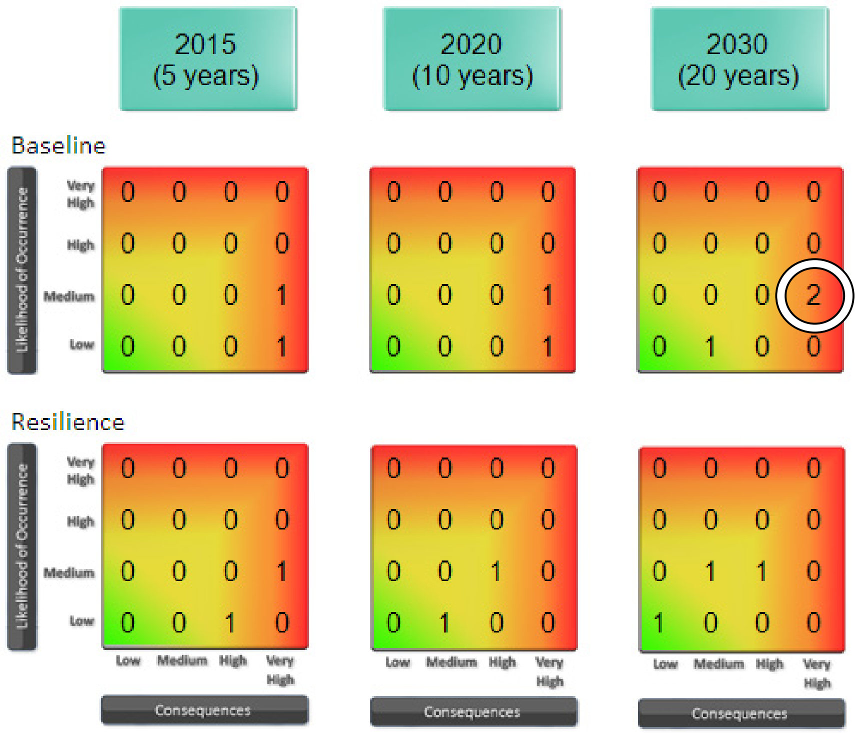

Figure 1. Example of risk matrices as displayed in CREAT for three identified time periods (2015, 2020, and 2030). Risk is assessed based on the likelihood of occurrence and the overall consequences. Risk matrices show the number of asset-threat pairs for each likelihood-consequence combination for all Baseline (top row) and Resilience (bottom row) assessments. For example, within the Baseline Analysis for the 2030 time period, two asset-threat pairs (circled number) have a medium likelihood of occurrence and a very high consequence.

More detailed discussions among participants centered on how adaptive measure contributions are calculated in the third step of Resilience Analysis. Specifically, the group recognized the difficulty in assessing these contributions and tracking the contributions made in other assessments for the same adaptive measures.

Implementation Packages

During the meeting, the group reviewed three examples of implementation packages: Phase I, Phase II and Phase I+II. These packages were designed to illustrate different priorities (e.g., timing of implementation, resources needed) that would result in different combinations of measures within packages. Each package included measures to address consequences from the water quality degradation and flood threats considered in the example analyses. Phase I provided a group of measures that could be pursued before 2020 that would provide benefits beyond mitigating consequences associated with climate change. In contrast, implementing Phase II would require more significant investment. The combined package (i.e., Phase I+II) includes all measures as the most comprehensive package.

Throughout the discussion related to implementation of adaptation packages, participants recognized the need for more guidance, specifically, on how to build these packages. The measure of risk reduction within CREAT (risk reduction units or RRUs) provides a metric for users to compare packages (**Figure 2**). Comparison of the different packages in terms of risk reduction units reveals that the implementation of more comprehensive packages results in greater risk reduction (**Table 2**). Each package that the group reviewed provided additional risk reduction with the consideration of more significant or comprehensive efforts. Consideration of the costs of the adaptive measures used in this exercise was deferred until additional staff at NHSA could be consulted. Optimally, CREAT users would use the ratio of cost to risk reduction (i.e., $/RRU) to look for cost effective options and optimize benefits from adaptation.

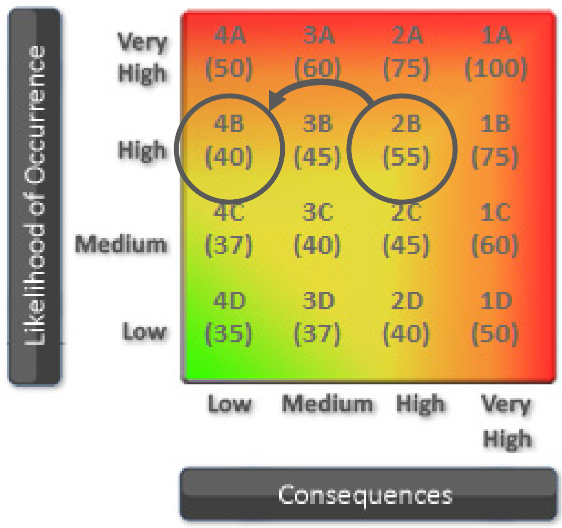

Figure 2. Matrix used in CREAT to compute risk reduction units (RRUs). Numbers within this matrix are the RRU values associated with each combination of likelihood and consequence. The difference between the Baseline and Resilience assessments is used to calculate RRUs for each asset-threat-time period combination. For example, if the consequences for an asset paired with a high likelihood threat changes from high (Baseline) to Low (Resilience), then the RRUs are calculated as 55 – 40 = 15 RRUs (circled locations).

Results and Reports

CREAT was recognized by the group as being a tool that supports awareness of climate change implications for water utilities, helps utilities to catalog actions, and promotes adaptation planning. The discussion of analysis results focused on the report generating aspects of the tool. Discussion led to several suggestions to improve and expand the reports currently available in the tool (see Appendix B).

Several participants expressed interest in additional reports targeting other goals for applying CREAT data and results. For example, the climate information provided for a specific location would be helpful for some users in communicating how climate change may generate particular threats. Another example described by NHSA staff was the need to support communication with management or customers that focuses on three questions: (1) What is the utility doing to respond to climate change? (2) Why are these actions being pursued? and (3) How much does this plan cost?

Table 2. Adaptation packages for different phases show the list of adaptive measures included in each package and the risk reduction units obtained from each (indicate those measures used in all three packages). See Appendix A for details regarding definitions for these adaptive measures*

Adaptation Packages	Phase I	Phase II	Phase I+II
Risk Reduction Units	50 RRUs	56.5 RRUs	74.5 RRUs
Adaptive Measures Included	Climate training for personnel Flood models* Community outreach Flood risk management* Communicate plans with public Infrastructure inspection* Optimized pumping* Emergency response plan – flooding Facility safety plan	Alternate wastewater / storm water capabilities Flood models* Grey water system On-site treatment / re-use Flood risk management* Effluent re-use studies Increased capacity – wastewater / storm water Infrastructure inspection* Optimized pumping* Green infrastructure at facility	Alternate wastewater / storm water capabilities Climate training for personnel Flood models* Grey water system Community outreach On-site treatment / re-use Flood risk management* Effluent re-use studies Communicate plans with public Increased capacity – wastewater / storm water Infrastructure inspection* Optimized pumping* Green infrastructure at facility Emergency response plan – flooding Facility safety plan

CREAT Exercise Summary and Lessons

The CREAT Exercise fostered an important dialogue between stakeholders that share an interest in the present and future conditions of natural and water resources, in this case, the Hudson River Harbor and Estuary. Several key lessons were learned both during and at the conclusion of the exercise. In particular, there is a need to support a process within CREAT for prioritized assets, allowing users to run preliminary analyses on these select assets prior to conducting a comprehensive risk assessment. For subsequent exercises, there may be a need to select a location with a different level of urbanization so that the analysis will support a more thorough exploration of the overlap between NEP and utility assessment and planning efforts related to climate change. However, the overall exercise process proved to be valuable for the parties involved, and both the watershed stakeholder and utility communities were receptive to further collaboration.

More specific feedback was received in response to several questions posed to participants at the conclusion of the in-person exercise. The first question asked about the usefulness and applicability of CREAT software for identifying watershed-scale climate change consequences and developing adaptation strategies for joint planning efforts. In general, participants commented that the process was helpful and recommended sharing the results with a broader, Harbor-wide audience to solicit additional input. Participants also suggested conducting additional exercises in areas affected by drought. There was some concern among participants that a balance be achieved in planning for both high flow events and droughts, even in areas that historically have experienced only one or the other but not both of these challenges. CREAT could support consideration of both of these potential climate change impacts.

A second question solicited feedback on any observed gaps or needed refinements to the current CREAT approach. Exercise participants had several recommendations that would make the tool process more user-friendly and results more applicable to real-world decisions. First, they recommended that the tool generate a map of results within the final report to help visualize impacts and adaptation options.

Participants also requested an explicit link to asset management software from within CREAT, so that existing files and work might be leveraged to support the CREAT process. Another key recommendation was the ability to generate a report containing climate information to help communicate with decision makers. Within this report, participants cited several features that would be helpful to include (e.g., the ability to add images, link to a map and export latitude and longitude information for use in the future).

The final question posed to participants during the in-person exercise targeted potential enhancements to the water resources and ecosystem sections of CREAT. While it was clear that participants valued the exercise process, EPA wanted feedback on how to make the tool itself more applicable to a broader audience of stakeholders that held a common interest in protecting shared water resources. An important area of the tool identified by participants for potential revision was the consequence section, in particular, the language used for source/receiving water impacts. Participants discussed this topic at several points during the exercise process, and it was clear that, depending on one's perspective, the language could be interpreted differently. In addition, participants suggested that the total maximum daily load process should be informed by reports. Another recommendation to enhance the water resource and ecosystem sections within CREAT was to use reports to document climate resiliency benefits of projects as part of participation in the State Revolving Fund programs. A final recommendation was the need to acknowledge the challenge of comparing spending on climate change adaptation to other budgetary and infrastructure needs. A complete list of comments provided by participants regarding potential changes to CREAT is presented in Appendix C.

Conclusions & Next Steps

The CRWU-CRE Joint CREAT Exercise at NHSA was an important step in ensuring that CREAT provides the awareness building, risk assessment framework, and planning support needed by the water sector and their watershed partners. The value of collaboration between the participants was noted during all stages of the CREAT process, especially in the definition of consequence categories, the assessment of consequences to natural resources, and the selection of adaptive measures requiring coordination as part of implementation. Both the utility and its watershed partners gained perspectives on the value of information used in assessments and the interpretation of results for their use in future planning efforts.

Feedback on the exercise process and on CREAT itself will be used in the design of future joint exercises as well as in development of the second version of the tool. The locations and priorities for these exercises should differ from those explored with NHSA to ensure a diverse set of utilities, regions, and threats are discussed. The scope and duration of follow-up activities related to NHSA's climate change assessment and planning are still being determined.

References

Horton, R., Gornitz, V., Bowman, M., Blake, R. Climate observations and projections. *Annals of the New York Academy of Sciences*, **2010.** 1196, 41-62.

U.S. Global Change Research Program (USGCRP). Global Climate Change Impacts in the United States. Karl, T.R., Melillo. J.M., Peterson, T.C. (eds.). Cambridge University Press. **2009**.

Appendix A: Adaptive Measure Inventory from Exercise

These ***Existing Adaptive Measures*** were selected from the library within CREAT as those measures currently in place at NHSA. Participants cataloged important remarks related to some of these measures in the tool for reference in reports and in current and future analyses.

Effluent re-use

Class: Alternative Strategies **Type:** Sustainable Strategies
Description: Implement sewage effluent re-use at your utility. This action should be conducted following assessment and modeling of the impacts of re-use on operations. Potential costs include the need for infrastructure and the ability to generate and meet demand for the effluent.
Remarks: Effluent is used for on-site non-potable use. More potential is available with investigation.

Back-up power

Class: Expanded Capacity **Type:** Construct
Description: Establish alternate or on-site backup power supply or electrical switching equipment.

CSO strategies

Class: Expanded Capacity **Type:** Repair / Retrofit
Description: Implement combined sewer overflow storage and design standards. For systems going through repairs and upgrades, some designs are suited to being retrofit for CSO prevention at the same time. In addition to storage options, flow diversions and isolation of storm water in areas vulnerable to high peak runoff volumes can be deployed to limit influent volumes to treatment plant.

Infiltration reduction

Class: Expanded Capacity **Type:** Repair / Retrofit
Description: Reduce infiltration into collection system to reduce excess influent volumes during times where soil is saturated from storms or floods. Effective strategies include replacing laterals, inspection, and monitoring.

Wet repair

Class: Expanded Capacity **Type:** Repair / Retrofit
Description: Develop procedures and policies for post-flood repairs when inundation persists and repairs are needed to assets in flooded areas.
Remarks: Repairs are done routinely following any damage from major events.

Performance models

Class: Expanded Operating Flexibility **Type:** Model
Description: Build flow and treatment models that accommodate climate change impacts. These models could predict changes in performance or service interruptions and assess responses to damage or changing water quality.
Remarks: Most likely to be used. Model will soon be incorporated in operations management plan and updated every 5 years.

Sewer / collection models

Class: Expanded Operating Flexibility **Type:** Model
Description: Build and use models for sewage flow, quality, and combined sewer overflow frequency. These models could be directed at the assessment of current capabilities of your utility to handle influent scenarios or as a means to evaluate infrastructure improvements and climate-related changes. These models, linked to hydrologic models, can provide information on storage needs and the potential for flood events.
Remarks: These will be used more often. GIS maps exist now that will help to monitor and plan for the future once asset management system is up and condition assessments completed.

Monitor structures

Class: Expanded Operating Flexibility **Type:** Monitor / Inspect
Description: Deploy monitoring on structures to complement inspections and inform assessments. Additional data from monitoring should improve analyses of climate change impacts on asset life and performance.

Monitor treatment

Class: Expanded Operating Flexibility **Type:** Monitor / Inspect
Description: Monitor treatment efficiency including sludge characteristics to inform treatment models and assess the impacts of changes in temperature and influent quality on performance. Monitoring in addition to that required for regulatory compliance may benefit diagnosis of new or improved treatment needs.

Monitor weather

Class: Expanded Operating Flexibility **Type:** Monitor / Inspect
Description: Integrate weather forecast monitoring into operations. Experience with responding to current weather conditions and extreme events can be applicable to plans for projected climate conditions. Discerning the limits of your system resiliency will reveal areas to address when preparing for climate change.
Remarks: Level of sophistication can be improved to enhance our ability to manage events-can tie into more sophisticated climate change information.

Emergency response plan – community

Class: Expanded Operating Flexibility **Type:** Plan
Description: Develop emergency response and recovery plans in coordination with local hospitals and first responders. These plans should focus on events that may become more frequent under projected future climate conditions, especially those that the community has limited experience dealing with. Plans should be coupled with other measures to limit consequences when possible.
Remarks: Need to update ERPs to address this.

Regulatory flexibility

Class: Expanded Operating Flexibility **Type:** Plan
Description: Consider regulatory options for compliance in areas where meeting current regulations will be difficult in responding to climate change. Plans should document the projected challenges to meeting regulations due to changing ambient conditions, water quality and availability, and other impacts on the ability of the utility to meet its mission goals. Regulatory compliance being met while enacting adaptive measures should also be considered in any plans.

These ***Potential Adaptive Measures*** were selected from the library within CREAT as those measures that may help reduce the risks of threats (e.g., floods, etc.) to assets. Participants cataloged important remarks (e.g., assumptions, potential barriers to implementation) related to some of these measures for reference in reports and in current and future analyses.

Building code changes

Class: Alternative Strategies **Type:** Green Infrastructure

Description: Partner with government to alter building codes to manage waste and storm water flows and water demand. These partnerships are an opportunity for sharing knowledge and demonstrating community leadership through pilot projects.

Green infrastructure at facility

Class: Alternative Strategies **Type:** Green Infrastructure

Description: Employ green infrastructure at facilities. Green infrastructure is a sustainable approach to wet weather management. Green Infrastructure approaches maintain or restore natural hydrologies by improving storm water infiltration or capturing water for reuse. Partner with community to employ green infrastructure to manage storm water flows and water demand. Green Infrastructure approaches maintain or restore natural hydrologies by improving storm water infiltration or capturing water for reuse.

Remarks: Combined description from second “green infrastructure” description into this first one for efficiency in analysis.

Grey water system

Class: Alternative Strategies **Type:** Sustainable Strategies

Description: Implement domestic and commercial grey-water or sewage recycling system. Scale of system deployed can vary from isolated portions of service array (e.g., identify large irrigation arrays for consumers) or gradually be deployed system-wide. This type of program should be coupled with models to assess the impact of reduced demand to ensure system performance is not detrimentally impacted by program.

Remarks: May be counter to NHSA ability to generate revenue to support other programs.

On-site treatment / re-use

Class: Alternative Strategies **Type:** Sustainable Strategies

Description: Implement on-site treatment and re-use for the utility. For any and all facilities, where appropriate, identify opportunities to treat and re-use effluent. Practices developed could have efficiency gains and serve as a model for other large facilities in the region to pursue similar practices.

Rainwater collection / use

Class: Alternative Strategies **Type:** Sustainable Strategies

Description: Implement local rainwater harvesting program. Program scale can vary from domestic incentives for homes to community-scale programs. This type of program should be coupled with models to assess the impact of reduced influent volumes from different precipitation events to ensure performance is not detrimentally impacted by program.

Alternate wastewater / storm water capabilities

Class: Expanded Capacity **Type:** Construct

Description: Develop redundant capabilities and options for storm and wastewater: treatment, discharge, collection, distribution, and receiving water (total, partial, critical portions).

Increased capacity – wastewater / storm water

Class: Expanded Capacity **Type:** Construct

Description: Increase system capacity for increased influent volumes, particularly for combined sewer systems. Constructing storage for diversion of peaks flows is one strategy to increase effective capacity by decreasing peak loads during storms.

Effluent re-use studies

Class: Expanded Operating Flexibility **Type:** Efficiency

Description: Study the ability to employ and resulting benefits of effluent re-use at your utility. Studies could include research on methods and state-of-the-art practices, regulatory implications of re-use, operational capabilities, user acceptance, simulations of supply and demand changes, and projections of benefits.

Remarks: Potential as time goes on to reduce water usage and impact on sewers/system and treatment plant process.

Optimized pumping

Class: Expanded Operating Flexibility **Type:** Efficiency
Description: Review facilities to optimize power requirements for pumping. As an overall energy efficiency goal, the optimization of power use for pumping requires careful consideration of current practices, simulation of impacts of changes in practices, and assessment of capability to refine networks to reduce power needs.

Flood models

Class: Expanded Operating Flexibility **Type:** Model
Description: Build integrated flood models for catchments, shorelines (with sea level rise), and urban drainage. Beyond many current hydrologic and flood models, these new models should ensure that perturbations due to climate change can be accommodated in models and that these models include topographic information (GIS) and risk assessment components.

Nutrient / contaminant models

Class: Expanded Operating Flexibility **Type:** Model
Description: Build and use catchment-based models for nutrients, sediment, and pesticides to predict changes attributable to projected climate conditions and design schemes for mitigation of impacts. Beyond many current hydrologic and sediment-transport models, these models should ensure that perturbations in transport and nutrient transformations associated with climate change are accommodated in models.

Infrastructure inspection

Class: Expanded Operating Flexibility **Type:** Monitor / Inspect
Description: Conduct inspections of structures throughout your system that may be compromised due to climate-related changes in event frequency, duration, or magnitude. Inspections should be part of any assessment of failure risk under projected climate conditions.

Monitor temperature

Class: Expanded Operating Flexibility **Type:** Monitor / Inspect
Description: Monitor temperature trends in water and region and incorporate results into overall performance monitoring and assessment. This information may be applicable to performance projections under projected climate conditions.
Remarks: Not sure this will be applicable or help mitigation.

Emergency response plan – flooding

Class: Expanded Operating Flexibility **Type:** Plan
Description: Develop emergency response and recovery plans as part of overall flooding strategy. These plans should focus on flood frequencies and magnitudes that may become more frequent under projected future climate conditions, especially those that the community has limited experience dealing with. Plans should be coupled with other measures to limit consequences when possible.

Facility safety plan

Class: Expanded Operating Flexibility **Type:** Plan
Description: Revisit health and safety plans in the light of climate-related impacts on operations and possible new hazards. Updates to plans may also encompass new environmental and personnel monitoring, performance models, and projections of changing hazard conditions (e.g., floods occurring at site with historical experience dealing with frequent floods).

Flood risk management

Class: Expanded Operating Flexibility **Type:** Plan
Description: Develop phased, adaptive risk management plan for urban flood risks and treatment requirements. These plans should prioritize the ability to limit or prevent damage to facilities and water resources during floods. Integrating observations, process models, and decision frameworks provides a powerful suite of tools to anticipate potential flood scenarios and deal with flood damage.

Climate training for personnel

Class: Expanded Operating Flexibility **Type:** R&D / Training
Description: Conduct climate-related training (e.g., tabletop exercises, knowledge building) for utility personnel and emergency response community. Draw from resources provided by associations and government agencies to provide information regarding the potential impacts of climate change and effectiveness of response actions.

Treatment alternatives

Class: Expanded Operating Flexibility **Type:** R&D / Training
Description: Research alternative treatment technologies for projected climate conditions. These technologies should be tested for the ability to integrate into current operations and their suitability for performance under current conditions. Possible future conditions for these processes to address include higher ambient temperatures, changing influent flows or particulate loading, and higher dissolved solids.

Communicate plans with public

Class: Expanded Operating Flexibility **Type:** Users / Demand
Description: Raise public awareness of what your utility is planning and the potential for changes in levels of service during events. These notifications should balance information on hazards with details of prepared response strategies, including opportunities for the public to assist in preparing and responding to contamination, or other events related to climate change. Develop stakeholder dialogues, relationships, trust and shared decision-making tools to improve responses to events. Stakeholders should include other water-dependent sectors, communities, and government agencies. Develop stakeholder dialogues, relationships, trust and shared decision-making tools to improve responses to events. Stakeholders should include other water-dependent sectors, communities, and government agencies. Establish public advisory communication system to alert consumers of events when they occur. This system can also disseminate information during periods of normal information. Media outlets, mobile devices, internet services, and social media can all be utilized to reach the broadest audience.
Remarks: Combined descriptions in the "User/demand" adaptive measures and then applied "not used".

Community outreach

Class: Expanded Operating Flexibility **Type:** Users / Demand
Description: Use outreach (e.g., town halls, sponsored events) to engage customers in decision making and build dialog regarding collaborations necessary to adjust demand for service in response to other priorities. Raise public awareness of what your utility is planning and the potential for changes in levels of service during events. These notifications should balance information on hazards with details of prepared response strategies, including opportunities for the public to assist in preparing and responding to water shortages, contamination, or other events related to climate change. Script public relations documents for potential service changes associated with climate change. Proactive actions to prepare for climate change are opportunities to engage the public in climate change awareness and education regarding their water resources. Material should emphasize benefits of actions beyond climate resilience.

Appendix B: Comments and Feedback from Participants

The following comments were provided during the exercise as suggestions for improving the CREAT interface, process, or content to support the collaboration between utilities and other watershed stakeholders.

Comment	Step/Screen
There is only one permit field in Setup, some utilities may have multiple permits	Setup
Timelines – may be helpful to provide default timelines that are every 10 years (or 15 years)	Time Periods
Historical data should be easier to load	Historical Data
Add guidance specific to dischargers to the source/receiving water impacts category, including recommendation to partner with other organizations	Consequence
Language is mostly drinking water focused and should be made more applicable to wastewater	Consequence
Distinguish Natural Resources from consequences (loss value) to other assets where they could overlap	Assets & Consequence
Use/mark priority assets for initial assessment	Assets
Tool should provide explicit link to asset management software	Assets
May be helpful to set up as more of a spreadsheet format	Assets
Threats interface is complex and could be simplified	Threats
Need to define competing use	Threats
Revise layout for editing measure descriptions to enable better user review	Adaptive Measures
Items needing clarification: ID #, Year in service, user defined, definition (refine based on CRWU report, EPA Office of Policy work or EPA OWM efforts	Adaptive Measures
Build cost model for inclusion in CREAT or cost guidelines	Adaptive Measures & Implementation Planning
Simplify the tool: provide output after Baseline directed at cost and prioritization of potential planning steps	Baseline
Improve indicators of progress in analysis steps	Baseline & Resilience
Reduce complexity of Resilience analysis (graphics are confusing)	Resilience
Improve interface for entering adaptive measure contributions	Resilience
Provide guidance on structuring adaptation packages (e.g., act now or later, minimize cost or $/RRU, phased approach, or green approach)	Implementation Planning
Remove Time Period Drill Down from the Summary Report; add as Attachment option	Reports
Provide graphics and data in PowerPoint Report	Reports
Provide additional reports (e.g., scoping report, planning report, implementation report, summary report versus detailed report)	Reports
Revise footer on Summary Report – make level of confidentiality custom	Reports
Add map of the results to report(s)	Reports
Report containing climate information should also be provided (e.g., user can add images, link to map, or export lat/long information)	Reports
Include a spreadsheet or worksheet to use	General