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SUBJECT: Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects.

CATEGORY: Guidance.

1. **References**. See Attachment D.

2. **Purpose.** This Engineering and Construction Bulletin (ECB) reissues and updates the policy in ECB 2016-25 (reference a), Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects. This ECB is effective immediately and applies to all hydrologic analyses supporting planning and engineering decisions having an extended decision time frame (i.e., not for short-term water management decisions). It provides guidance for incorporating climate change information in hydrologic analyses in accordance with the USACE overarching climate preparedness and resilience policy and ER 1105-2-101 (reference l) . This policy requires consideration of climate change in all current and future studies to reduce vulnerabilities and enhance the resilience of communities. Hence, consideration of climate change should occur early enough in the SMART planning process to inform plan formulation, evaluation, and selection of the tentatively selected plan.

3. **Objective.** The objective of this ECB is to enhance USACE climate preparedness and resilience by incorporating relevant information about observed and expected climate change impacts in hydrologic analyses for planned, new, and existing USACE projects. It does not apply to short-term water management decisions. Changes other than climate that affect inland hydrology will continue to be evaluated in the manner described in current USACE guidance (e.g., Chapter 18, Evaluating Change in EM 1110-2-1417 (reference c) and ER 1105-2-101 (reference l)).

4. **Background.** Up to this time, USACE projects, programs, missions, and operations have generally proven to be robust to climate variability over their operating life spans. However, in some geographic locations and for some impacts relevant to USACE operations, the climatological baseline and the range of natural climate variability is shifting. The range of that variability may be changing in some cases as well. More extreme seasonal conditions of rainfall and runoff (flooding or drought) and altered snow volume and melt have been observed in some regions. As a result, the assumptions of stationary climatic baselines and a fixed range of natural variability as captured in the historical hydrologic record are no longer appropriate for long-term project planning in some locations (ETL 1100-2-3 (reference j)). Projections of specific climatic changes and their associated impacts to local-scale project hydrology that may occur in the future can be highly uncertain, requiring guidance on their interpretation and use. This ECB helps

support a qualitative assessment of potential climate change threats and impacts that may be relevant to the particular USACE hydrologic analysis being performed.

5. **Incorporating Climate Change and Variability and Change in Hydrologic Analyses.**

a. Climate change information for hydrologic analyses includes direct changes to hydrology through changes in temperature, precipitation, evaporation rates and other climate variables, as well as dependent basin responses to climate drivers, such as sedimentation loadings. The qualitative analysis required by this ECB should focus on those aspects of climate and hydrology relevant to the project's problems, opportunities, and alternatives, and include consideration of both past (observed) changes as well as projected, future (modeled) changes. ***At the time of issuance of this ECB, the qualitative analysis is not expected to alter the numerical results of the calculations made for the other, non-climate aspects of the required hydrologic analyses.*** However, the qualitative analysis can inform the decision process related to future without project conditions, formulation, and evaluation of the performance of alternative plans, and other decisions related to project planning, engineering, operation, and maintenance. Some examples of how a qualitative assessment may affect a project design include considering whether the project could be modified in the future or if another strategy to address the study objectives should be considered to accommodate projected future increases in discharge. Consistent with existing guidance (e.g., references d, l, and m), decision risks associated with the project or project features that could result from climate change need to be identified, communicated, and managed.

b. The climate for which the project was designed can change over the full lifetime of that project and may affect its performance, or impact operation and maintenance activities. Given these factors, the project lifetime (not to be confused with the period of analysis) should be up to 100 years as determined using ER 1110-2-8159 (reference b) and ER 1105-2-100 (reference m) with the uncertainty of environmental factors over that horizon clearly articulated. Most current climate model datasets typically end at 2099 or 2100. Therefore, 2100 shall be considered to approximate the 100-year planning horizon until longer model datasets become available.

c. This qualitative analysis is required for all hydrologic studies for inland watersheds at the time of issuance of this ECB. The level of effort of this analysis is scalable to the project complexity, its consequences, and the sensitivity of the alternatives and/or project to climate variability and change. Attachment A provides a flow chart of the guidance provided in this ECB. This guidance does not prevent the performance of a quantitative analysis should USACE Headquarters provide updated climate data and information in the future.

d. Attachment B provides detailed guidance on how to perform the qualitative analysis. The level of detail and complexity of the analysis will depend on the uncertainty and risks associated with the impact of climate on alternatives. The first qualitative analysis in a geographical area will likely take additional time due to lack of familiarity with pertinent literature and time to learn to use the tools. However, if using the available tools and literature syntheses, the level of effort to complete a qualitative analysis should not take more than a few days, and the level of effort could decrease as projects in nearby geographic areas are completed and become examples to draw from.

(1) The Climate Preparedness and Resilience (CPR) Community of Practice (CoP) Applications Portal (https://maps.crrel.usace.army.mil/projects/rcc/portal.html) is an online repository that provides access to tools and information for use in the analyses required by this ECB. The repository includes access to:

(a) Tools that provide information on historic trends in observed data that are required to be used in the climate change analysis, including the Climate Hydrology Assessment Tool (CHAT, trends in annual maximum peak flow at USGS gages), the Nonstationarity Detection Tool (changes in annual maximum peak flow at USGS gages), and the Time Series Toolbox (trend analysis and nonstationarity detection for user-supplied datasets).

(b) Tools that provide qualitative information on projected (modeled) climate conditions at the watershed (hydrologic unit 4) scale, a spatial scale consistent with the spatial and temporal precision of downscaled modeled climate-hydrology datasets. These include portions of the CHAT (change in maximum monthly flows) and the Civil Works Vulnerability Assessment (VA) Tool (factors that contribute to changes in environmental conditions associated with USACE business lines).

(c) An Information Repository that includes links to reference literature including the US National Climate Assessment, regional climate syntheses, and USACE reports developed by the CPR CoP, along with a Library of CPR Assessments (CAL), which contains examples of assessments conducted since ECB 2016-25 took effect on 16 September 2016.

(d) For areas outside the continental United States (CONUS), data sparsity is an issue; both qualitative and quantitative analyses must be coordinated with the CPR CoP Lead.

(2) At the time of issuance of this ECB, USACE policy does not require a quantitative assessment of how climate change might impact probable maximum flood (PMF) magnitudes for a particular study area. Only after a substantial body of research has been amassed to facilitate a quantitative understanding of the relationship between climate change and the magnitudes of extreme storms can USACE begin to develop the tools and technical guidance necessary to facilitate a quantitative assessment of how to incorporate climate change impacts into applied hydrologic analyses supporting PMF magnitudes and/or the uncertainties associated with them. Attachment C provides a preview of planned future quantitative guidance, which will depend on more highly resolved climate hydrology information now in production by an interagency and expert consortium to which USACE contributes. At the time of the issuance of this ECB, there is no consensus how extreme storms will evolve in the future, and this issue is not addressed in this ECB. A preview of direction USACE intends to take in the future with respect to quantitative analysis can be found in Attachment C of this ECB.

e. At least one member of an Agency Technical Review Team for projects covered by this ECB must be certified by the CPR CoP in the Corps of Engineers Review Certification and Access Program (CERCAP). The Climate Preparedness and Resilience CoP may help identify those who can perform, assist, or review qualitative assessments.

6. **Update.** All new requirements will be included in the next appropriate policy document update prior the expiration of this ECB. A series of guidance documents will be published in the future to support quantitative analyses of climate threats and impacts to specific project types.

7. **Point of Contact.** The HQUSACE point of contact for this ECB is Dr. Kathleen White, CECW-EC, (202) 761-4163.

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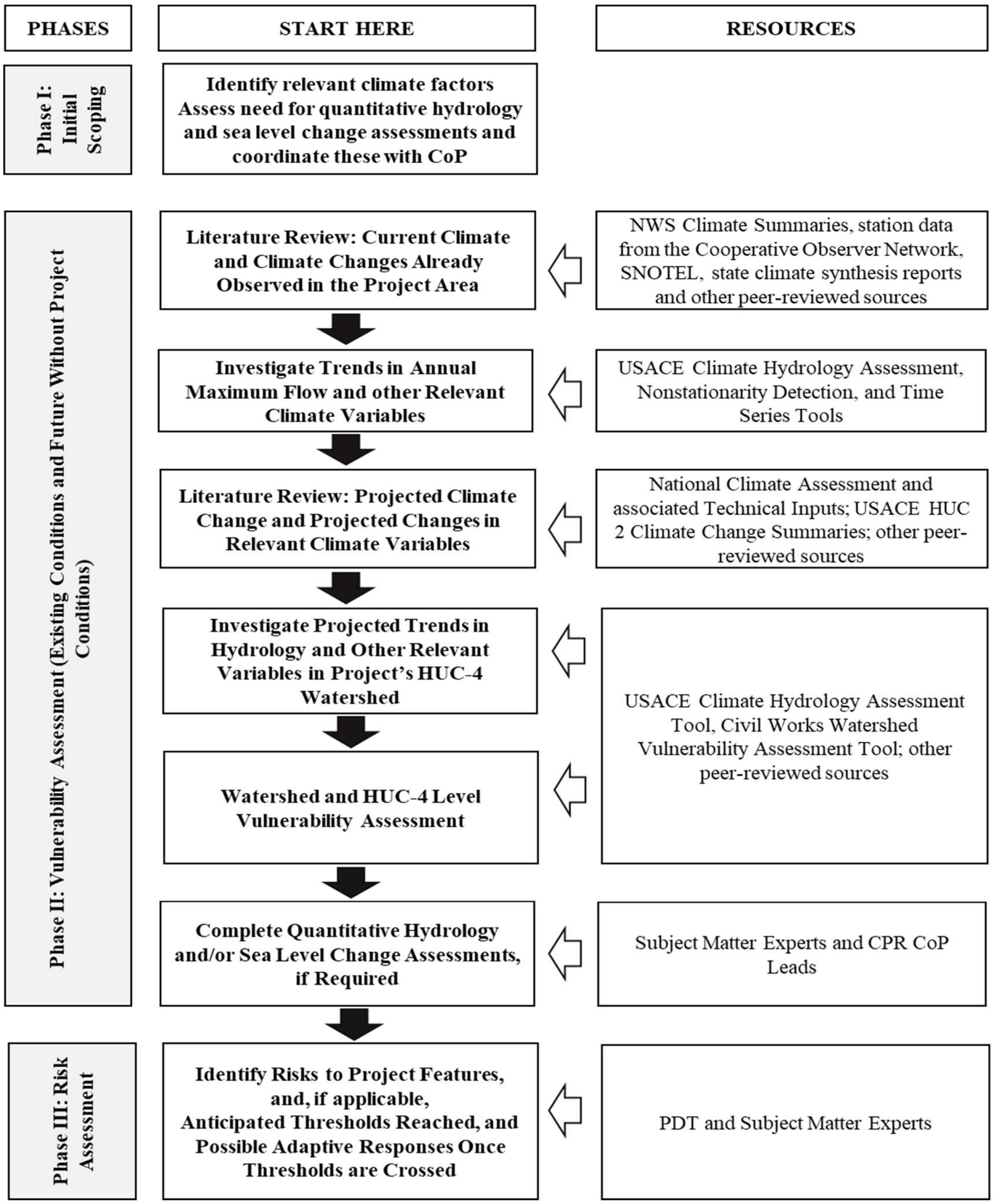
Attachment A – Flow Chart and Crosswalk Table
Attachment B – Method for Qualitative Assessment
Attachment C – Preview of Quantitative Analysis Requirements
Attachment D – References

ATTACHMENT A: Flow Chart and Crosswalk Table

The flow chart below illustrates the steps to perform a qualitative assessment of the impacts of climate change in hydrologic analyses. More quantitative guidance will be developed as actionable science evolves.



The table below provides a crosswalk between the activities mandated in this ECB and the Civil Works (CW) project milestones identified under USACE SMART Planning guidance (Walsh Memorandum (reference e), EC 1165-2-217 (reference f), and Planning Manual Part II (reference g)).

CW Milestone	Alternatives	Tentatively Selected Plan (TSP)

Tasks	**Decide which climate factors contribute to the problems, opportunities, and constraints so these can be included in the analysis**
	• Is a quantitative hydrology assessment needed?
	    • If yes, coordinate with the CPR CoP Lead before the Alternatives milestone.
	• If the elevation of the project area is ≤ 50 ft NAVD88, is sea level change likely to affect the project hydrology?
	    • If yes, plan to also conduct analysis consistent with ER 1100-2-8162 before the TSP milestone.
		Decide which of the alternatives is the tentatively selected plan (TSP)
		• Is climate change already a factor?
		    • What are the existing conditions and is there evidence that these are already changing?
		        • Data: existing climate conditions and observed trends based on a literature review, and analysis using the CHAT, Nonstationarity Tool, and/or Time Series Toolbox.
		• Will expected climate changes affect performance requirements of project alternatives?
		    • What are the future without project conditions?
		        • Data: literature review, and analysis of future conditions using the CHAT and VA Tool.
		        • Additional Data: If needed, include quantitative hydrologic analyses and sea level change analyses.
		• Will the proposed project (TSP) affect the regional climate:
		    • For most projects, the future with project conditions should be the same as the without project.
		    • For large wetland and/or new reservoir construction, discuss with CoP Lead and/or assigned ATR reviewer.
		• Is the proposed project (TSP) is resilient to expected changes in climate.
		    • What risks due to a changing climate remain?
		        • Include a description of the risk resulting from changed climate conditions, including a table, with the discussion of the TSP.

ATTACHMENT B: Method for Qualitative Assessment

1. Introduction

a. This section provides additional detail about the conduct of the analyses required under this ECB, and the relationship to planning activities under the USACE Planning process (EC 1165-2-217 (reference f)). Consistent with the SMART planning goal of concise decision documents, it is expected that the analytical detail of the analysis for this ECB will be documented in a separate climate change appendix to the main report, while summaries of the analyses and key findings, as well as the residual risk discussion, will be integrated in to the relevant sections of the main document.

b. If a quantitative hydrology analysis is conducted, that analysis is in addition to, and not in lieu of, the qualitative analysis required by this ECB (see Attachment C).

c. Climate change has been observed, and is expected to continue, to impact all USACE business lines. Consequently, for multi-purpose projects, it is recommended that project development team (PDT) members from different disciplines collaborate on this analysis.

2. Purpose

a. Climate is important for all USACE Civil Works projects because of the role it plays in modulating streamflows that underpin the flood risk management, aquatic ecosystem restoration, navigation, water supply, hydropower, and emergency management services that USACE provides to the Nation. The purpose of the analyses required under this ECB is to make these relationships explicit, and to ensure that changes in climate with the potential to significantly affect project hydrology are identified, and their potential impacts are assessed with respect to project features and feature performance over their life cycle. This analysis relies on the best available science and the use of professional judgment to address the risks associated with climate change.

b. A qualitative assessment of climate change alone is an insufficient basis for significant changes to identifying or modifying a TSP under current USACE guidance. However, identified performance and decision risks may provide the project partner with indications of actions they may choose to take to improve community resilience to climate change in the future. For example, knowing that flood magnitudes in a stream are likely to increase over 50 years, a project partner might choose to monitor changes in flood magnitudes every decade to determine whether adaptation measures are necessary, or implement zoning to manage risks outside the current project footprint. Awareness of projected changes might also inform a project partner's decision to request a Locally Preferred Plan that confers additional resilience to the changes.

3. Qualitative Analysis Framework

a. To improve climate preparedness and resilience, USACE requires climate science-informed decision-making in studies, designs, projects, and groups of projects. The certainty and applicability of the science on climate change and hydrology available at the time of issuance of this ECB varies with location and spatial scale. It is important to conduct a qualitative analysis at a scale appropriate for the study. This does not mean that broad, global or continental-scale analyses cannot be used for this analysis. Nor does it mean that observed changes in current climate and hydrologic responses measured at very fine scales cannot be used for this analysis. Rather, a successful qualitative analysis will combine the most useful information from a range of sources, noting the differences in information types, such as observed and projected data and the differences in uncertainty or confidence in the data and information deployed for the analysis.

b. The current state of actionable climate science, regardless of its scale of analysis, encompasses large uncertainties about projected future conditions relevant to USACE projects and programs. In some cases, these uncertainties may be comparable in scale to existing sources of uncertainty, such as future changes in land use and land cover. In other cases, the climate-related uncertainties may be larger or smaller than the ones more often considered in previous hydrologic analyses. Uncertainties associated with different climate variables and in different locations should be noted in the qualitative assessment and placed into context with the other uncertainties relevant to the hydrologic analysis.

c. It is important to remember that the concern of this analysis is primarily to understand and incorporate climate in the Future Without Project condition, evaluating differences, if they exist, between alternatives, and any climate-related risks to a project achieving the estimated outputs in the future with project condition. The qualitative analysis is conducted in three phases, introduced here and described in more detail below (see also Attachment A: Flow Chart and Crosswalk Table).

(1) Phase I: Initial Scoping. Initial scoping includes all the tasks needed to decide which climate factors contribute to the problems, opportunities, and constraints. Scoping includes the determination of whether quantitative hydrology or sea level change assessments are required. Initial scoping should be completed early in the planning process, prior to the Alternatives Milestone.

(2) Phase II: Vulnerability Assessment. The Vulnerability Assessment phases is the collection and analysis of information necessary for deciding which of the alternatives is the TSP. It addresses whether changes (nonstationarities) are already occurring the baseline climate and hydrologic conditions, and whether expected changes in climate and hydrologic conditions in the future will result in performance requirements significantly different from the present.

(3) Phase III: Risk Assessment. The Risk Assessment phase describes the resilience of the TSP to expected changes in climate and hydrology, and identifies risks that have not been addressed during formulation due to knowledge and data uncertainties.

4. Conduct of the Qualitative Analysis.

a. Phase I: Initial Scoping. Initial scoping right-sizes the climate analysis to the problems, opportunities and constraints of the study. Scoping consists of two activities: understanding which climate variables are relevant to the analysis and determining whether quantitative hydrology and/or sea level change assessments are needed. Scoping is completed prior to, and reported out at the Alternatives Milestone.

(1) Identifying relevant climate variables. Not all aspects of climate are relevant to all USACE projects, and professional judgment is necessary to identify which aspects affect changes in the future without project conditions and future with project conditions. During

scoping, the project delivery team (PDT) needs to identify and consider which variables, if any, are exacerbating or ameliorating the identified problems and opportunities and identified a clear and logical climate evaluation rationale. For example, a project that addresses spring flooding may be concerned about winter and spring temperature and precipitation, especially with respect to snow pack conditions, and the resulting effects these have on the magnitude and duration of spring flood flows. However, this study may not be concerned about river conditions during the late summer and would thus not consider the climate variables that influence these flows. By contrast, the climate factors that contribute to late summer low flows may be of great concern for an ecosystem restoration project, and for such a study one might additionally consider patterns of summer precipitation, temperature, and drought. The primary action at this stage is to define the "relevant climate variables" with respect to the study area and identified alternatives.

(2) Evaluating whether additional analyses are necessary.

(a) For most USACE projects and studies, a qualitative analysis will provide the necessary information to support the assessment of climate change risk and uncertainties to the constructed project or watershed (for a watershed study). Under some circumstances, a quantitative hydrology assessment may be warranted, and initial coordination with the CPR CoP Lead and scoping of the effort needs to happen as early in the study as the need is identified. Quantitative analysis must focus on differentiating between alternatives and understanding any impacts to the project outputs.

(b) For project areas at elevations less than or equal to 50 ft NAVD88, a determination should be made as to whether sea level rise will affect the river stage by increasing (or decreasing) water surface elevation downstream of the project area. If yes, policy and procedures outlined in ER 1100-2-8162 and ETL 1100-2-1 will apply. At each milestone, the climate analysis supports the relevant decision, with detail limited to answering the decision-question at hand for the identified milestone (see reference k). Some considerations for each milestone follow.

b. Between the Alternatives milestone and Tentatively Selected Plan (TSP) Milestone, the PDT focuses on evaluating and comparing the focused array of alternatives through additional iterations of the planning process in order to identify a TSP and, potentially, a locally preferred plan (LPP). The climate analysis during this period of the study focuses on differentiating between identified alternatives, including which of the relevant climate factors will influence alternatives similarly and differently in the analysis of those alternatives. Shortly after the TSP Milestone, the decision document is released to the public, so as the evaluation and comparison occurs, the documentation of the climate analysis also is necessary.

c. Additional analysis after the TSP focuses on scaling measures and features for the recommended plan. Most work at this point in the study focuses on reducing uncertainties associated with cost data, engineering effectiveness, environmental and social impacts, and economic benefits. The climate analysis supports the scaling and uncertainty reduction through the application and understanding of the relevant climate factors influencing the TSP or LPP's outputs and uncertainties in the future (i.e. future with project condition).

d. Documenting the Climate Analysis. The following activities support the documentation of the climate analysis in the feasibility study.

(1) Existing Conditions.

(a) Existing conditions documentation includes a brief overview of current regional climate conditions in the project area, followed by a more detailed overview of the relevant climate variables identified for the Alternatives Milestone, including how these variables contribute to the problems and opportunities related to your project.

(b) Source material for this write up could include station normal data from the National Weather Service Cooperative Observer network and the National Resources Conservation Service Snow Telemetry (SNOTEL) network (both available at https://www.data.gov), state climate synthesis reports, and other sources.

(c) The write-up should include a discussion of observed trends in the relevant climate variables, and how these changes have contributed to the problems and opportunities related to the project.

(d) USACE online tools must be used in this assessment, including the CHAT, and the Nonstationarity Detection Tool, and, as needed, the Time Series Toolbox. All three are available at the Climate Preparedness and Resilience Data Portal (https://maps.crrel.usace.army.mil/projects/rcc/portal.html).

(2) Future Without-Project Condition.

(a) The future without project condition includes a brief overview of how climate change is projected to impact the project area, followed by a more detailed overview of projected changes to the relevant climate variables identified in Alternatives Milestone. The overview can include ranges of change, where appropriate.

(b) Source material for this write up could include the National Climate Assessment and supporting Technical Input documents (https://www.globalchange.gov/), USACE Regional Climate Synthesis reports (https://maps.crrel.usace.army.mil/projects/rcc/portal.html), peer reviewed studies, and government documents.

(c) USACE online tools must be used in this assessment to evaluate how projected changes in relevant climate variables will impact hydrologic conditions in the study area and the functions performed under USACE business lines. These tools include the CHAT and the VA Tool, both available at the Climate Preparedness and Resilience Data Portal (https://maps.crrel.usace.army.mil/projects/rcc/portal.html).

(d) The VA Tool provides information at the Hydrologic Unit 4 Watershed scale for wet (wettest 50% of models) and dry (driest 50% of models) future scenarios. Results from both should be reported. Variables that contribute significantly to the vulnerability of a given watershed for a given business line can be found at the HUC Summary tab.

(e) If a quantitative hydrology assessment is completed (Attachment C), the data should be included in the hydrologic analysis. Both the methodology for projecting future hydrologic conditions and an overview of the results should be presented in the climate change appendix and an overview presented in the main report.

(f) If a sea level change assessment is necessary, the impacts of changing sea level should be included in this analysis. Both the methodology for projecting future hydrologic conditions under changed sea levels and an overview of the results should be presented in the climate change appendix and an overview presented in the main report.

(3) Future With-Project Conditions.

(a) The future with-project condition assessment is typically focused on the impact of the project on the resource. Most USACE projects will have no significant effect on climate change, and a single sentence to this effect could be provided in this section. Exceptions to the "no significant effect" might include construction of very large wetlands or large reservoirs. In this case, consult with the CPR CoP Lead for direction on this section.

(b) There is no policy or guidance requirement for greenhouse gas accounting on Federal projects, and therefore such activity falls to the partner to complete; if greenhouse gas emissions during construction and operation are determining factor in plan formulation and selection, the resulting plan would be considered a LPP

(4) Description of the Tentatively Selected Plan (TSP).

(a) The description of the TSP should include a brief discussion of whether and how climate change risks were included to make the project more resilient to those changes in the future. The risks identified in this step are not necessarily risks to project completion. Risks unrelated to project execution do not need to be included in the project risk register or the project cost and schedule risk assessment.

(b) In most cases, there will be risks to the project due to climate change that do not meet current evaluation criteria. The description of the TSP and ultimately recommended plan should include a brief discussion of the residual risks resulting from changed climate conditions, and should include a table with rows for each major measure or feature (including nonstructural measures) and columns that describe the trigger event (climate variable that causes the risk), the hazard (resulting dangerous environmental condition), the harms (potential damage to the project or changed project output), qualitative assessment of the likelihood and uncertainty of this harm (for more discussion of these terms, see Yoe and Harper, 2017 (reference g)).

(c) Table B-1 provides examples that might be included in a decision document or climate appendix for the measures and features of the TSP:

(d) Not all impacts of climate change will result in increased risks: projected benefits should also be briefly discussed. To continue the example from Table C-1, wetland restoration features in the proposed floodway may benefit from more frequent wetting and larger volumes of water, making these more sustainable in the future. Potential reductions in risk from climate change should also be briefly described in this section.

Table B-1. Example table identifying climate risks.

Feature or Measure	Trigger	Hazard	Harm	Qualitative Likelihood
Levee	Increased precipitation from larger, slower-moving storms	Future flood volumes may be larger than present Large flood volumes may occur more frequently	Flood waters may remain on the levee for longer durations, and more frequently, potentially damaging levee	Likely
Drought resilience measure	Decreased precipitation or increased severity of drought	Future droughts may be more severe than at present Future droughts might occur at increasing frequency	Water availability and quality may be decreased, impacting water supply storage or water quality within and downstream of reservoir	Likely
Weir at upstream end of flood bypass channel	Increased precipitation from larger, slower-moving storms	Future flood volumes may be larger than present Large flood volumes may occur more frequently	Weir may be overtopped more frequently than at present, resulting in more frequent flows in the floodway	Likely
Off-channel wetland restoration feature	Decreased winter precipitation and higher winter temperatures	Lower stream flows year round Reduced freshet volume and duration	Water may no longer inundate restoration feature during all or part of year, resulting in loss of habitat and reducing project benefits	Highly Likely

ATTACHMENT C: Preview of Quantitative Analysis Requirements.

1. Quantitative Climate Change Analysis for Hydrologic Analyses in Planning and Engineering Design Studies. Quantitative assessments can directly alter the numerical calculations and results in the hydrologic analysis and thus are necessarily project-specific. These changes to numerical results can alter calculations of project benefits and costs, thus directly informing the decision process. A quantitative assessment will be described in future additions to this guidance along with new information for considering those climate-related uncertainties in the context of other uncertainties associated with hydrologic estimates under future conditions.

a. Specific guidance for implementing quantitative analyses will be provided as suitable climate hydrology information and methods are developed.

(1) Studies involving the Probable Maximum Flood (PMF) determination. At the time of the issuance of this ECB, there is no compelling evidence that would support climate-related changes in PMFs. Only after a substantial body of research has been amassed to facilitate a quantitative understanding of the relationship between climate change and the magnitudes of extreme storms, can USACE begin to develop the tools necessary to facilitate a quantitative assessment of how to incorporate climate change impacts into applied hydrologic analyses supporting PMF magnitudes and/or the uncertainties associated with them.

(2) Exemptions may be considered on a case-by-case basis.

b. The three primary components of any future quantitative guidance are detection of trends, attribution of these trends to climate change, and projection of future trends.

(1) Detection. The first step in a quantitative analysis is to detect changes in the observed hydrologic record for the metric relevant to the study, such as increases or decreases in variability or magnitude (ETL 1100-2-3 (reference j)). If no change is detected, no further quantitative analysis of historic time series will be necessary. The USACE Nonstationarity Detection Tool and the Time Series Toolbox use a wide range of statistical techniques to identify changes in the mean, variance, and trend of hydrologic time series data, but are not designed to attribute a cause to detected nonstationarities.

(2) Attribution. If a statistically significant change is detected, the next step is to attempt to attribute the change to one or more causes, primarily by evaluating additional information about changes in the watershed, searching the supporting literature, and in some cases using results from experiments with numerical climate simulation models already performed – no new numerical climate simulations will be required. Professional judgment is needed to identify the cause(s) for each nonstationarity detected, and to determine whether and how to correct the data to create a homogeneous time series for subsequent analysis. USACE is developing information to support the use of climate attribution in the quantitative analyses to be required in future. This information will be distributed together with the future guidance requirements as described above.

(3) Projection. Finally, projected hydrologic changes can be analyzed using climatological and hydrological model data sets, such as those available at http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/. This information can be used in concert with hydrologic, hydraulic, or reservoir simulation tools to produce a range of possible watershed

responses. Until future guidance is released in the use of projections, the following points are made for consideration:

(a) It is USACE policy to use the hydrologic projections from the full ensemble CMIP5 model outputs to capture the range of potential future hydrologic conditions within a basin, as at this time there is no justification for selecting only a subset of models.

(b) Projected national climatological and hydrological data sets do not include flow regulation, which can have a significant effect on watershed response to climate change. The results of unregulated flow models can provide a comparison to the unregulated projections. Or, regulation may be incorporated by routing unregulated flows through a reservoir simulation model, such as HEC-ResSim or more simplified methods within the hydrologic model, HEC-HMS.

(c) National climatological and hydrological data sets often require bias correction to account for systematic model errors due to inherently imperfect conceptualization for nation-wide models and spatial averaging from relatively coarse grids used to apply the global climate projection inputs.

(d) Study teams must investigate the limitations of the models being used in a study along with the magnitude of the bias corrections and the reasonableness of the model outputs for their particular region in the United States.

(e) At the time of issuance of this ECB, climate hydrology projections are not available for Hawaii and the Pacific Islands, the Caribbean and Alaska, but are being developed with an anticipated release in 2019 or 2020.

(f) USACE is developing information to support the use of projected climate hydrology in the quantitative analyses to be required in future. This information will be distributed together with the future guidance requirements as described above.

ATTACHMENT D: References

a. Engineering and Construction Bulletin (ECB) 2016-25, Subject: Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects, 2 May 2014.

b. Engineer Regulation (ER) 1110-2-8159, Life Cycle Design and Performance, 31 October 1997.

c. Engineer Manual (EM) 1110-2-1417, Flood Runoff Analysis, 31 August 1994.

d. Director's Policy Memorandum Civil Works Programs (DPM CW) 2018-05, Improving Efficiency and Effectiveness in USACE Civil Works Project Delivery (Planning Phase and Planning Activities), 03 May 2018.

e. Walsh, Memorandum for Major Subordinate Commands, Subject: U.S. Army Corps of Engineers Civil Works Feasibility Study Program Execution and Delivery, 08 Feb 2012.

f. Engineer Circular (EC) 1165-2-217, Review Policy for Civil Works, 20 Feb 2018.

g. Yoe, C. and B. Harper, 2017, Planning Manual Part II: Risk-Informed Planning, U.S. Army Corps of Engineers Institute for Water Resources publication 2017-R-03, July 2017.

h. ER 1100-2-8162, Incorporating Sea Level Change in Civil Works Programs, 31 Dec 2013.

i. Engineer Technical Letter (ETL) 1100-2-1, Procedures to Evaluate Sea Level Change Impacts, Responses, and Adaptation, 30 June 2014.

j. ETL 1100-2-3, Guidance for Detection of Nonstationarities in Annual Maximum Discharges, 28 April 2017.

k. Planning Bulletin (PB) 2017-01, Subject: Feasibility Study Milestones, 10 January 2017.

l. ER 1105-2-101, Risk Assessment for Flood Risk Management Studies, 17 July 2017.

m. ER 1105-2-100, Planning Guidance Notebook, 22 April 2000.