Alignment of Ocean Tipping Points Science with Environmental and Cumulative Impact Analyses under the National Environmental Policy Act

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Purpose Statement

This document briefly summarizes key statutory and regulatory requirements for conducting environmental and cumulative impact analyses under the National Environmental Policy Act and identifies points in the regulatory process where tipping points science may be most useful to managers and improving existing practice. The "Summary for Managers" introduces these high level insertion points for tipping points science. A more comprehensive analysis of integration of tipping points science and the National Environmental Policy Act's required procedures follows.

This document is designed for use primarily by agency practitioners and scientists interested in using tipping points science in their work. However, we have attempted to make this document accessible to a broader audience by including background information on the statutory and associated regulatory requirements of the National Environmental Policy Act.

This document regularly refers to tipping points scientific strategies, which are not explained in detail in this document. For information on these strategies, please refer to the Ocean Tipping Points Guide.

Summary for Managers

The Ocean Tipping Points strategies are designed to facilitate the identification and consideration of ecological thresholds, leading to informed management actions. Thus, they can help identify ecological thresholds of concern under the National Environmental Policy Act, explore social preferences and acceptable levels of risk, and enable well-informed decisions. Ocean Tipping Points strategies can also expand the integration of social and cultural concerns and impacts into management decisions. While the essential considerations outlined in this project are not new to agency practitioners, the systematic process and guidance for identifying and managing ecological thresholds of concern provided by the Ocean Tipping Points Guide can improve the use of ecological thresholds in planning and project-level decisions.

The Ocean Tipping Points project team has identified that tipping points science is well-suited to assist agency practitioners to:

- Incorporate broader ecosystem concerns and thresholds into scoping and impact analysis – The tipping points strategy for characterizing tipping points and their drivers can assist NEPA practitioners in identifying thresholds of concern that may result from the proposed project.
- Identify "significant" impacts via the use of thresholds and targets – The tipping points strategies for identifying thresholds and targets can provide practitioners with easily identifiable examples of significant effects, a crucial regulatory threshold under NEPA.
- Incorporate social and cultural preferences and risk tolerance into impact analysis – The tipping points strategy for characterizing social preferences and risk tolerance can assist decisionmakers choose alternatives that are broadly aligned with public opinion and priorities.
- Conduct quantitative watershed- or airshed-level cumulative impact analyses – The tipping points strategy for characterizing drivers and responses in an ecosystem can assist practitioners in creating conceptual models of an ecosystem to evaluate different project alternatives based on ecosystem level and cumulative effects.

- Identify leading indicators that can be used to describe the current environment and determine project consequences – The tipping points strategy for identifying leading indicators can assist practitioners in determining the current and projected future risk of crossing thresholds.

While the science and application of tipping points are still evolving, a growing number of examples reveal successful application of tipping points science in action. For real-world examples, see our case study write-ups:

- Coral Reefs in Discovery Bay, Jamaica
- Sea Urchins in the Gulf of Maine
- Kruger National Park, South Africa

For more detail, continue to the full analysis on page 4.

Environmental law is often about drawing lines to protect human and environmental health. For example, management schemes in the U.S. and abroad help define and implement acceptable levels of pollution, fishing, harm to individual species, and combined levels of stress on ecosystems. These "regulatory thresholds"—and the processes for developing them—are common components of management; however, they are often based on a linear worldview and we are learning that human activities result in dynamic, and often non-linear change in natural ecosystems. This emerging science on ecological thresholds (or tipping points) reveals a new opportunity to better align these regulatory pillars with ecological realities.

The following sub-pages explore how existing environmental laws allow for threshold-based management and highlight three key findings:

1. Best available science, cumulative impact, and cost-benefit analysis requirements, among others, are all mechanisms by which agencies may be required to incorporate new scientific information about looming tipping points into their decision-making processes.
2. In some management contexts, incorporation of ecological thresholds is more familiar (e.g., fisheries and water quality), while in others such practices are not common despite the available resources (e.g., place-based).
3. While tipping points concepts are not new to natural resource management, the systematic process and extensive guidance found in our guide can improve the identification and incorporation of ecological thresholds into management decisions.

Aligning ecological and human health thresholds with regulatory targets provides three primary benefits:

1. Obvious targets for purposes of management – Thresholds illustrate points of no return (or points of greatly increased effect) and thus can simplify the task of identifying "acceptable" levels.
2. Opportunities for large returns on policy investments – Thresholds where the ratios between cost and benefit change dramatically may help decisionmakers identify management actions that are both economically and ecologically rational.
3. Improved outcomes – Regulatory targets based explicitly on ecological thresholds appear to yield better outcomes.

Introduction

When a major federal action is proposed that may significantly affect the quality of the human environment, the National Environmental Policy Act (NEPA) requires an environmental review.[1] The Council on Environmental Quality (CEQ) has defined the particulars of environmental review, requiring among other things the consideration of cumulative effects[2] during several stages of the environmental review process. The following document explores the applicability of Ocean Tipping Points (OTP) concepts (*See Table 1*) to both the broader NEPA environmental impact analysis process and the more specific cumulative impact analysis process.

Table 1: OTP Concepts
Characterize thresholds in the system a. Define thresholds of concern b. Identify drivers of thresholds and characterize the shapes of relationships between drivers and ecosystem components
Define objectives – where do you want to be relative to thresholds? a. Characterize social preferences with respect to ecosystem regimes b. Analyze risk of crossing a threshold and characterize risk tolerance to the changes that could result
Design indicators and targets a. Identify leading indicators that signal the approach of a threshold b. Set targets and limits based on known thresholds, social preferences, and risk analysis
Evaluate scenarios and select a course of action a. Develop future management scenarios b. Evaluate management alternatives using appropriate tools and take action
Monitor the ecosystem state and response to management intervention a. Adaptively manage – evaluate results of management action and assessment of ecosystem state from monitoring data and decide whether to adjust course b. Refine models and assumptions based on new knowledge

When is NEPA Triggered?

Prior to undertaking an in-depth review of the current policy and practice of cumulative effect analyses, it is essential to understand the breadth of NEPA applicability. Two conditions precede the requirement to engage in an environmental analysis under NEPA.[3] First, a federal agency must undertake an "action." The term action includes any activity that is funded, permitted, or undertaken by a federal agency, or an activity for which the federal agency has oversight authority. Further explained, each of the following is an action:

[1] 42 U.S.C. § 4331(C). The comprehensive and detailed environmental review process that is now required—including environmental assessments, environmental impact reports, categorical exclusions, etc.—is not a part of NEPA's requirements, but is a product of regulations implemented by the Council on Environmental Quality.
[2] The terms effect and impact are used synonymously throughout CEQ NEPA regulations. 40 C.F.R. § 1508.8(b).
[3] However, some federal activity is expressly exempted from NEPA requirements. Activities undertaken pursuant to the Clean Air Act are always exempt from NEPA review. Additionally, under the Clean Water Act, EPA must comply with NEPA only when issuing new source discharge permits or providing grants for publicly-owned treatment works.

- Adopting official policy, such as rules, regulations, and interpretations
- Adopting formal plans, such as those that guide or prescribe uses of federal resources upon which future agency actions will be based
- Adopting programs
- Approving specific projects
- Approving permits for private or other agency actions on federal land or involving federal resources
- Approving grants or other funding that involves a large federal presence (i.e., much of the funding for the proposal is from federal sources)
- Conducting ongoing or continuing federal actions

The second condition necessary to trigger NEPA review is the potential to cause an environmental impact. The following visuals provide a number of ocean-specific examples that frequently meet both conditions.

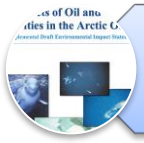
Programmatic, planning, or regulatory actions

Protected Site Designation, Management Plans, Amendments, and Regulatory Changes (National Seashores, Marine Sanctuaries)

Management Plans and Regulatory Measures for Fisheries, Bycatch, and Fishery Habitat

Programmatic Analyses of Restoration Activities (Seagrass, Dune, Coral Barrier Island Restoration)

Marine Mammal Protection Measures and Take Reduction Plans



Programmatic Analysis of Extractive Activities

Programmatic Analysis of Development Activities

Project-specific actions

NEPA Environmental Impact Analysis Process and Content Requirements

CEQ regulations require two public engagement components and two substantive components in all environmental impact assessments. The action agency must engage the public during both scoping and review stages of the draft assessment. Additionally, every environmental impact statement must include a description of the affected environment and a discussion of the environmental consequences of all project alternatives. Methods of analyzing environmental impacts and social preferences developed by the Ocean Tipping Points team can inform each of these components.

Scoping

The action agency must conduct a public scoping process to receive input from the public and other agencies on issues of concern.[4] Scoping is basically the brainstorming session that precedes the creation of an environmental impact assessment. While most ocean tipping points concepts are too complex to be fully undertaken during the scoping process, the scoping process is the ideal time to identify possible thresholds of concern

[4] 40 C.F.R. § 1501.7 ("There shall be an early and open process for determining the scope of issues to be addressed and for identifying the significant issues related to a proposed action.").

and begin to define objectives. Agencies also generally develop or refine project alternatives based on the findings of the scoping process.[5]

- During scoping, CEQ requires that action agencies identify significant issues deserving of study.[6] At this stage, agencies should **recognize thresholds of concern** as significant issues deserving of study. Identifying thresholds of concern at this early stage is necessary to guide an analysis of indicators and drivers—and the proposed projects potential influence as a driver—when conducting the environmental assessment.
- The action agency must "[i]nvite the participation of affected Federal, State, and local agencies, any affected Indian tribe, the proponent of the action, and other interested persons" in scoping.[7] Comments, questions, and concerns from the public and cooperating agencies can hint at **social preferences with respect to different ecosystem regimes**.
- The scoping process can also influence the **range of project/management alternatives and scenarios** that will be considered in the assessment.

Describe the affected environment

Every environmental assessment must describe the affected environment.[8] This requirement is limited in depth to a discussion that is "necessary to understand the effects of the [project] alternatives." In other words, the description of the affected environment need only address ecosystem components that will be impacted by the proposed project.

- By **characterizing thresholds in the system and their drivers**, agencies can readily identify components of the environment that will be impacted by the proposed project. An analysis of drivers can also enable agencies to fully explore how other past, present, and reasonably foreseeable future projects have/will contribute to the risk of crossing a threshold. This is essential for a thorough consideration of cumulative effects.
- By analyzing monitoring data on **leading indicators that signal the approach of a threshold**, agencies can determine affected ecosystem components and describe how they have been impacted over time. This can help establish a baseline, whether historic or current.
- By **setting targets and limits based on known thresholds** for the affected environment, agencies can clearly establish boundaries of significant impacts.
- By **analyzing the risk of crossing a threshold**, the action agency can inform the possible environmental consequences of the proposed action.

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[5] 40 C.F.R. § 1501.2.

[6] 40 C.F.R. § 1500.4(g). *See also* §§ 1501.1(d) & 1501.7(a)(2–3).

[7] 40 C.F.R. § 1501.7(a)(1).

[8] 40 C.F.R. § 1502.15 ("The environmental impact statement shall succinctly describe the environment of the area(s) to be affected or created by the alternatives under consideration. The descriptions shall be no longer than is necessary to understand the effects of the alternatives. Data and analyses in a statement shall be commensurate with the importance of the impact, with less important material summarized, consolidated, or simply referenced. Agencies shall avoid useless bulk in statements and shall concentrate effort and attention on important issues. Verbose descriptions of the affected environment are themselves no measure of the adequacy of an environmental impact statement.").

Discuss environmental consequences

Agencies must analyze the environmental impacts/effects[9] of all project alternatives, including the proposed action.[10] Agencies also must include and consider appropriate mitigation measures when discussing environmental consequences. Effects to be analyzed include "ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social, or health, whether direct, indirect, or cumulative."[11]

- By **evaluating project alternatives using appropriate tools**, the agency determines whether an alternative will measurably increase the risk of crossing a threshold.

Public notice and comment

Agencies must release draft environmental impact statements for public comment and review.[12] During public comment and review, the public will analyze both the validity of the assessment as conducted and the desirability of the project taking into account the benefits and negative impacts of the project for society and the environment.

- During public review and comment, true insight into **public risk tolerance** can be determined. Additionally, agencies can glean **social preferences** with respect to the impacts of the proposed project.

After taking into consideration all received public comments, the action agency must release a final environmental impact statement and determine whether to go forward with the proposed project or one of its alternatives (**take action**). Post-decision, the action agency may also provide for **monitoring** to ensure that decisions are carried out and to monitor the efficacy of mitigation measures. CEQ regulations do not require monitoring to revise impact assessments or change course. However, it is possible that ocean tipping point tools can enable monitoring programs that **inform revised models and assumptions**. In some circumstances, monitoring the outcome of decisions may lead to **adaptive management** and a change in course.[13]

[9] These terms are used interchangeably in CEQ regulations. 40 C.F.R. § 1508.8.

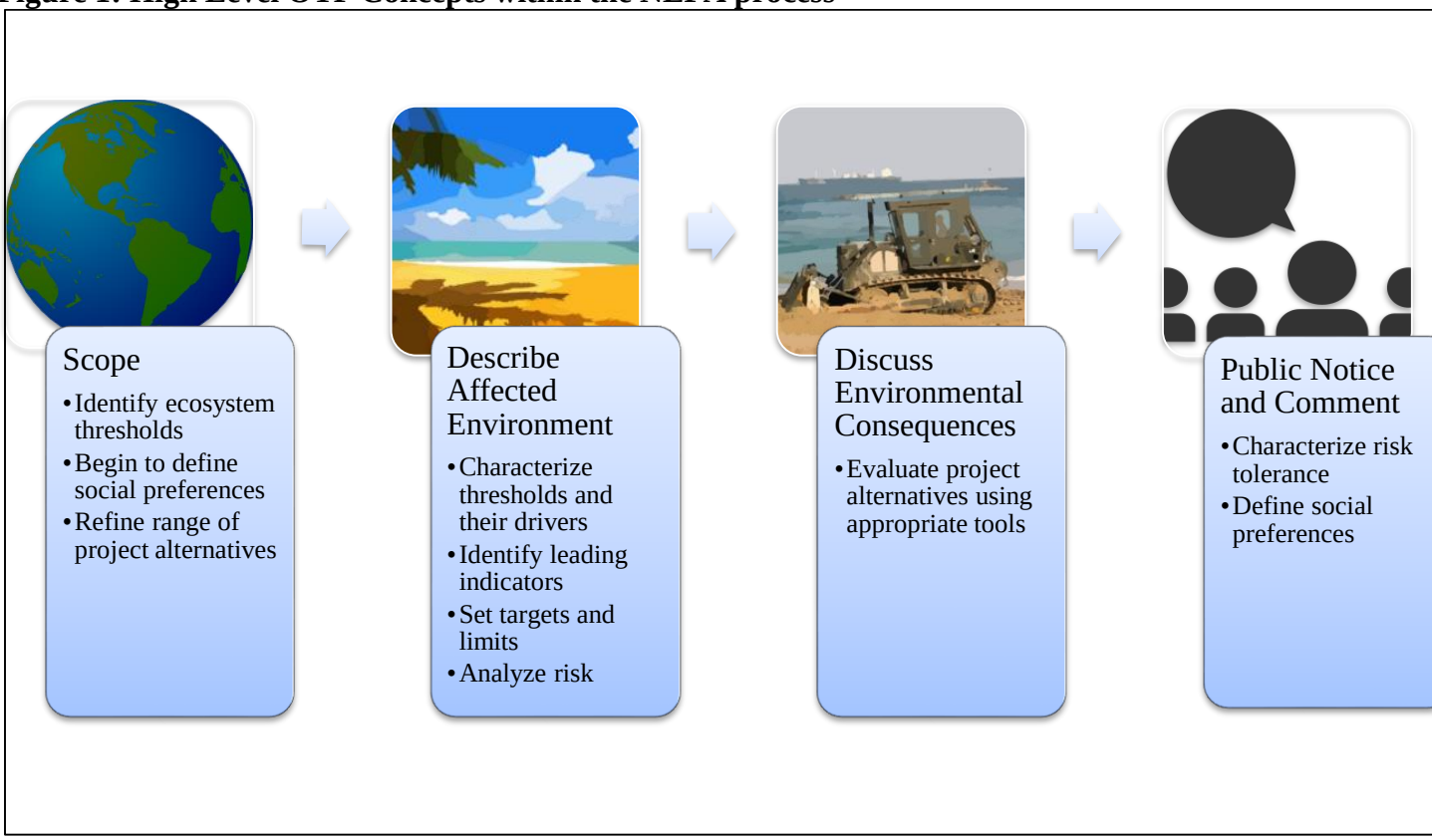
[10] 40 C.F.R. § 1502.16 (This discussion must include "the environmental impacts of the alternatives including the proposed action, any adverse environmental effects which cannot be avoided should the proposal be implemented, the relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and any irreversible or irretrievable commitments of resources which would be involved in the proposal should it be implemented.").

[11] 40 C.F.R. § 1508.8.

[12] 40 C.F.R. § 1503.1(a).

[13] Obviously some agency decisions are not reversible or adaptable, such as the decision to move forward with a construction project. However, agency decisions about pollutant discharge limitations or fisheries management measures can easily be revised based on new information. These latter management regimes have their own monitoring structure s

Figure 1: High Level OTP Concepts within the NEPA process



NEPA Cumulative Effects Analysis (CEA) Process

NEPA regulations define cumulative impact as the "impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (Federal or non-Federal) or person undertakes such other actions."[14] Cumulative impacts can result from projects that have already been completed (past projects) and present projects, in addition to proposed future projects. The NEPA regulations further recognize that cumulative impacts can result from "individually minor but collectively significant actions taking place over a period of time."[15]

NEPA regulations require that agencies consider cumulative impacts in (1) Environmental Assessments (EAs),[16] (2) Environmental Impact Statements (EISs),[17] and (3) the determination of significance.[18] These NEPA regulations are legally enforceable and every agency NEPA analysis must comply.

In 1997, CEQ released comprehensive non-binding guidance on the consideration of cumulative impacts in analyses prepared under NEPA.[19] The guidance document was intended to provide consistent best practices for federal agencies, replacing the independently developed and scattered procedures that had led to mixed results in the preceding decades. CEQ included an 11-step process for considering cumulative impacts, while recognizing that the analysis should be an iterative process. The 11-step process was built around the pre-existing EIS process of (1) scoping, (2) describing the affected environment, and (3) determining the environmental consequences of the project.

> *Scoping*
> Scoping provides the opportunity to identify important cumulative effects issues, setting the spatial and temporal boundaries for analysis, and identifying relevant past, present, and future actions.[20] Scoping should identify all past, present, and future actions conducted by any federal, nonfederal, or private entity within the designated spatial and temporal boundaries and the effects they may have on every resource, ecosystem, and human community.

[14] 40 C.F.R. § 1508.7.
[15] *Id.*
[16] 40 C.F.R. § 1508.9(b). *See also* Council on Environmental Quality, Considering Cumulative Effects Under the National Environmental Policy Act, 4 (1997) [hereinafter CEQ Guidance] *available at* https://ceq.doe.gov/nepa/ccenepa/exec.pdf.
[17] 40 C.F.R. §§ 1502.16 & 1508.8.
[18] NEPA regulations mention cumulative impacts within the listed criteria for evaluating intensity to determine significance. Id. § 1508.27(b)(7). One of the factors of intensity is whether the action is "related to other actions with individually insignificant but cumulatively significant impacts." *Id.*
[19] *See generally* CEQ Guidance.
[20] CEQ Guidance, at v.

Step 1 – Identify the significant, or potentially significant, cumulative impacts issues associated with the proposed action and define the assessment goals.

This step involves defining the direct and indirect effects of the proposed action; the resources, ecosystems, and human communities that are affected; and which effects on these resources are important from a cumulative impacts perspective. This step narrows the focus of the cumulative impact analysis to important issues of national, regional, or local significance.

When identifying cumulative effects issues, any alternatives to the proposed action that are being considered should also be included in the scoping process.

A critical principal of cumulative effects analysis outlined in the CEQ Handbook is the need to focus on "what is needed to ensure long-term productivity or sustainability of the resource," as opposed to how the resource will be modified.[21] To this end, **defining thresholds of concern** in the ecosystem can be used to identify focal areas and narrow the consideration of cumulative impacts to issues of significance. For example, if algal blooms that present human health and environmental issues are known to occur in the project area due to nitrogen loading and/or increased temperatures and the project will cause increased nitrogen levels and/or water temperatures, the scoping process should identify cumulative effects of nitrogen loading and/or thermal pollution from other past, present, and future actions as an important consideration and a threshold of concern.

Step 2 – Establish the geographic scope for the analysis.

When analyzing the contribution of a proposed project to cumulative effects, the geographic boundaries of the analysis should expand beyond the immediate area of the proposed action. Specifically, cumulative effects analysis should be conducted on the scale of human communities, landscapes, watersheds, or airsheds. Choosing the appropriate scale depends on the system, accumulation characteristics of the effects being assessed, and the regulatory entities involved.

Establishing the geographic scope for the analysis fits within the OTP concept of **characterizing the system**. CEQ guidance to use ecosystem boundaries that align with water- or air-sheds, as opposed to political boundaries or the boundary of the project area, is essential to considering ecosystem thresholds of concern.

[21] CEQ Guidance at 8.

Step 3 – Establish the time frame for the analysis.

CEQ regulations define cumulative effects as the "incremental effect of the action when added to other past, present, and reasonably foreseeable future actions."[22] Generally, the consideration of foreseeable future actions is bounded by the timeframe of the effects of the proposed action. For example, if the effects of the proposed action are expected to last for five years, the cumulative effects analysis should consider other actions that could reasonably be expected to occur within those five years. The same principle applies to how the effects of past actions will interact with the effects of the proposed action.

Step 4 – Identify other past, present, and reasonably foreseeable actions affecting the resources, ecosystems, and human communities of concern.

Past, present, and reasonably foreseeable future actions that may have similar impacts, or impact similar resources, to the proposed action must be identified. GIS or manual map overlay systems can be used to depict this information. Proximity of other actions to the proposed action is not the decisive factor for inclusion; rather the actions must have some influence on the resources affected by the proposed action. Identifying all relevant past, present, and future actions requires close coordination among agencies.

During this step, managers must **identify drivers of thresholds**. In the algal bloom example, any past, present, or future action that impacts the nitrogen levels or temperature of the receiving water body would be a potential driver of algal blooms and essential to include in the cumulative effects analysis.

Describing the Affected Environment

Steps 5–7 are designed to explore in more detail the thresholds and drivers identified in steps 1–4 and establish the current status of the environment. The description of the affected environment should include data on the status of important natural, cultural, social, or economic resources, data that characterize environmental or social stress factors, a description of regulations and other government standards, and data on environmental and socio economic trends. Importantly, steps 5 and 6 are highly intertwined and iterative, ultimately feeding into step 7. Describing the affected environment, as it exists prior to the proposed action, defines the "environmental baseline and thresholds of environmental change."[23] Baseline conditions provide the context for evaluating environmental consequences in steps 8–9.

[22] 40 C.F.R. § 1508.7.
[23] CEQ Guidance, at vi.

Step 5 – Characterize the resources, ecosystems, and human communities identified in scoping in terms of their response to change and capacity to withstand adverse impacts.

The first step in describing the affected environment is to characterize the components of the affected environment (e.g., the resources, ecosystems, and human communities) that are likely to be cumulatively affected and how these components have been altered in the past by human activities.

This step also includes determining how responsive the components of the affected environment are to change and their capacity to withstand adverse impacts. NEPA guidance explicitly contemplates the use of indicators of ecological integrity (e.g., index of biotic integrity for fish), landscape condition (e.g., fragmentation of habitat), and well-being of human communities (e.g., social service provision) to characterize accumulated change over time.

Characterizing the relationships between drivers, environmental change, and ecosystem response and **analyzing the risk of crossing thresholds** can significantly advance the process of characterizing environmental components in terms of their response to change and capacity to withstand adverse impacts. Specifically, the ability to tie the resilience of ecosystem components directly to the thresholds of concern enables a clearer picture of how much additional impact will cause the crossing of a threshold and how resources, ecosystems, and communities will respond.

Similarly, the use of **leading indicators** that signal the approach of a threshold of concern can enable the public to identify harmful shifts in environmental health and call for their mitigation prior to project approval. Increasing the use of ecosystem indicators in this step will facilitate the linking of single-species thresholds and ecosystem-thresholds.

Step 6 – Characterize the natural and human factors that adversely affect these resources, ecosystems, and human communities and their relation to safety or security thresholds established through regulations.

When describing the affected environment, the analysis should identify and characterize the human activities that have and will impact the natural and social resources characterized in step 5. CEQ guidance encourages the use of two types of information to describe all stress factors for each resource, ecosystem, and human community.[24] First, the analysis should identify the types, distribution, and intensity of social and economic activities within the region. Second, the analysis should look for individual indicators of stress on specific resources, ecosystems, and human

[24] CEQ Guidance at 27–29.

communities (e.g., canary in the coal mine). This information is then used to summarize historical environment change.

The analysis should also discuss government regulations and administrative standards that establish thresholds of resource degradation (e.g., air and water quality criteria) or manage land use (e.g., local zoning regulations).[25] These government regulations often influence development activity or shape the manner in which a project may be operated (e.g., limits on air emissions), thereby playing an important role in characterizing the regional landscape. For example, local development plans may indicate reasonably foreseeable future actions.

Similar to step 5, this step in the cumulative effects analysis process includes the **identification of leading indicators** of environmental stress and an analysis of the risk of crossing thresholds. In practice, these two steps are undertaken concurrently and include an analysis of the status of resources and stress factors acting upon them. The goal of analyzing current status and stress is to determine whether the resources, ecosystems, and human communities of concern are approaching conditions where additional stresses will have an important cumulative effect, i.e., where adding a driver of a threshold will increase the risk of crossing a threshold.

In many ways, regulatory and administrative standards reflect **social preferences and risk tolerance** to various environmental impacts. However, some social preferences may be unaccounted for by government standards. As a result, expanding the process of characterizing risk tolerance and social preferences with respect to ecological regimes would supplement the cumulative effects analysis and further NEPA's intent to encourage community-influenced decisionmaking. In the current NEPA process, the truest consideration of social preferences is most likely to arise during public comment periods that occur during scoping and post-publication of an EA or EIS.

Step 7 – Define a baseline condition for the resources, ecosystems, and human communities.

The information characterized in steps 5 and 6 must be combined in order to develop a baseline environmental condition against which to measure additional effects. Geographic information system (GIS) technologies are identified as an important means to analyze historical change in indicators of the condition of resources, ecosystems, and human communities, as well as the relevant stress factors.[26] Gathering information on trends in conditions of resources or in human activities is considered critical to assessing the cumulative effects of proposed actions.

[25] CEQ Guidance at 29.
[26] CEQ Guidance, at vi.

The analysis of cumulative effects should utilize appropriate conceptual models such as system diagrams, modeling, trends analysis, and or overlay mapping and GIS. Other special methods to address unique aspects of cumulative effects include carrying capacity analysis, ecosystem analysis, economic impact analysis, and social impact analysis.[27]

At its core, the baseline environmental condition is an analysis of all **thresholds and drivers** in the system that may be influenced by the cumulative effects of past, present, and future actions. However, the extent to which NEPA analyses utilize true ecosystem thresholds or tipping points in practice, as contemplated by the OTP process, is unknown.

Arguably, the environmental baseline also represents the socially preferred state for the resources, ecosystems, and human communities. While chances are low that any environmental baseline equates to a pristine or perfect ecosystem or human community, the basic idea behind NEPA is that project proponents should be aware of, and avoid to the extent possible, significant adverse effects as compared to the baseline condition.

Determining the Environmental Consequences

Determining environmental consequences of cumulative effects requires delineating cause and effect relationships between drivers and ecosystem state and identifying the interactions likely to result in "significant" impacts. "Significance of cumulative effects depends on how they compare with the environmental baseline and relevant resource thresholds (such as regulatory standards)."[28]

Step 8 – Identify the important cause-and-effect relationships between human activities and resources, ecosystems, and human communities.

In this step, the analysis must consider what cumulative environmental changes are likely to occur and how resources, ecosystems, and communities respond to the change. CEQ guidance stresses the usefulness of conceptual models such as networks and system diagrams for visualizing cause-and-effect relationships.[29] The relationships for each resource are then used to determine the magnitude and significance of the cumulative effects. The CEQ guidance explicitly recognizes the importance and difficulties in examining synergistic or non-linear cause-and-effect relationships.[30]

[27] CEQ Guidance at vi.
[28] CEQ Guidance, at vi.
[29] CEQ Guidance at 38.
[30] CEQ Guidance, at 40.

When identifying cause-and-effect relationships, managers should **characterize the shapes of relationships between drivers and ecosystem components**. Historically, most environmental changes were assumed to be linear. However, non-linear relationships are continuously being discovered and comprehensively studied. Non-linear changes are more difficult to predict, manage, and reverse making them potentially more dangerous or impactful. Ensuring that non-linear cause-and-effect relationships are considered—and understood to the extent possible—is essential to the determination of significance in step 9.

Step 9 – Determine the magnitude and significance of cumulative effects.

The magnitude of cumulative effects refers objectively to the size or amount of the effects. A critical element in modeling the magnitude of cumulative effects is defining an appropriate baseline or threshold condition of the resource, ecosystem, and human community beyond which adverse change would cause significant degradation of the resource. CEQ guidance recognizes that resources, ecosystems, and human communities have "maximum levels of cumulative effects that they can withstand before the desired conditions of ecological functioning and human quality of life deteriorate."[31] The cumulative effects analysis should be conducted within the context of these thresholds. Ideally, the analysis can identify the range of natural variability for resources and a quantitative threshold beyond which rapid degradation will occur. When these thresholds cannot be identified with certainty, historical degradation is analyzed to predict whether a resource is approaching a threshold.

The crux of every NEPA analysis is the identification of impacts that are "significant." The agency's goal when determining significance is to determine the severity of the impact of the action based on its context and intensity.[32] The determination of significance considers the magnitude of the impact, outlined above, as it relates to the context of the action, its geographic extent, and other factors. The magnitude must be considered in "several contexts such as society as a whole, the affected region, the affected interests, and the locality."[33] The context varies with the setting of the action.

The determination of significance must consider each alternative to the proposed action.

Setting targets and limits based on known thresholds, social preferences, and risk analysis can facilitate the determination of significance. A project that measurably increases the risk of crossing an

[31] CEQ Guidance, at 7.
[32] 40 C.F.R. § 1508.27.
[33] 40 C.F.R. § 1508.27.

ecosystem-level threshold is "the quintessential example of a 'significant' impact."[34]

The NEPA analysis may use quantitative, qualitative, or narrative information to determine whether cumulative effects are significant. Thresholds and criteria (i.e., levels of acceptable change) used to determine the significance of effects will vary depending on the type of resource being analyzed, the condition of the resource, and the importance of the resource as an issue (as identified through scoping).[35] CEQ guidance states that specific quantitative criteria for significance should be explicitly identified and described when possible. Quantitative targets that are directly tied to thresholds of concern increase the defensibility and scientific reasoning that support the significance determination.

The current use of thresholds in the NEPA decision-making process focuses in large part on individual resources (e.g., species-specific thresholds or pollutant-specific thresholds), as opposed to ecosystems. Increasing the use of ecosystem thresholds when considering the cumulative effects of human activities will provide a more complete picture of significance.

Step 10 – Modify or add alternatives to avoid, minimize, or mitigate adverse significant cumulative impacts arising from Federal activities, and identify opportunities to work with others to avoid, minimize, or mitigate adverse effects caused by non-Federal activities.

If the initial determination of significance indicates a meaningful risk of a threshold being crossed, additional alternatives or mitigation measures should be considered. Developing mitigation measures may entail revisiting the cause-and-effect relationships and identifying the pathways with the highest effect on a threshold of concern. Mitigation strategies that focus on the pathways of greatest effect will be the most useful in reducing cumulative impacts.

Ultimately a decision is made to move forward with one of the project alternatives, including the no-action alternative.

Evaluate project alternatives using appropriate tools to determine whether any project alternatives will measurably increase the risk of crossing a threshold. The project proponents may add other alternatives of mitigation measures based on the initial findings of significance. Paying careful attention of ecosystem tipping points will enable an exploration of the most effective mitigation strategies. Additionally, identifying

[34] Ryan P. Kelly et al., How Not to Fall Off a Cliff, or, Using Tipping Points to Improve Environmental Management, 41 Ecology L. Q. 843 (2014).
[35] CEQ Guidance, at 45.

hysteresis[36] in environmental responses to drivers will greatly facilitate a cost-benefit analysis when considering alternatives.

Step 11 – Monitor cumulative impacts of the selected alternative and apply adaptive management.

Any uncertainty that remains is addressed through monitoring and adaptive management. "[U]ndoubtedly, the consequences of human activities will vary from those that were predicted . . . ; therefore, monitoring the accuracy of predictions and the success of mitigation measures is critical. Adaptive management provides the opportunity to combine monitoring and decision making in a way that will better ensure protection of the environment and attainment of societal goals."[37]

Monitoring the ecosystem state provides the means to identify necessary modifications, and **adaptive management** provides the flexible program for achieving these modifications.

CEQ's cumulative effects guidance does not provide any distinct guidance for public notice and comment.

Conclusion

NEPA requires an environmental and cumulative impact analysis for all federal agency actions that may have a significant impact on the environment. the designation of water quality thresholds and provides for the use of pollution budgeting and control to remain within those limits. Water quality thresholds must be rooted in acceptable levels of pollutants that ensure publically valued uses of waterbodies are not impaired. The OTP process is designed to facilitate the establishment of this type of threshold and complementary management actions. Thus, the OTP process provides a useful lens for identifying water quality thresholds of concern under the Clean Water Act, exploring social preferences and acceptable levels of risk, and designating regulatory limits and management approaches to meet those limits. The systematic OTP process can help tighten the current practice of considering tipping points in the managed system. While the essential considerations outlined by the OTP project are nothing new to water quality managers, the systematic process and extensive guidance provided for identifying and managing thresholds of concern can improve the incorporation of thresholds into water quality management decisions.

[36] Hysteresis refers to scenarios where the transition from one state to another may differ from the path back to the first. *See, e.g.*, Beatrix E. Beisner, Alternative Stable States, NATURE EDUC. KNOWLEDGE PROJECT (2012), http://www.nature.com/scitable/knowledge/library/alternative-stable-states-78274277.
[37] CEQ Guidance, at vi.