BOSC EXECUTIVE COMMITTEE REPORT

Review of US EPA ORD
Strategic Research Action Plans (StRAPs)

and the

Roadmaps for Environmental Justice and
Global Climate Change Cross-Cutting Programs

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I. Introduction

The U.S. Environmental Protection Agency (EPA) Board of Scientific Counselors (BOSC) provides advice and recommendations to EPA's Office of Research and Development (ORD) on technical and management issues related to its research programs. It is one of several Federal Advisory Committees that provide advice to EPA, and it specifically focuses on the evaluation of the science conducted internally by ORD to support their mission.

In January 2015 the BOSC and the EPA Science Advisory Board (SAB) presented the EPA Administrator with a joint assessment of the strategic directions of the agency's research and preliminary reviews of the Strategic Research Action Plans (StRAPs) of the national research programs. The research programs then revised their StRAPs in response to this joint report.

The BOSC was rechartered in 2014 to consist of an Executive Committee that oversees five subcommittees devoted to each of the national research programs (part of the Human Health Risk Assessment program is reviewed in conjunction with the Chemical Safety for Sustainability program). Over the last six months, each of the subcommittees met with ORD senior staff, and the respective National Program Director and scientists for the relevant research area. They reviewed the revised StRAPs and responded to a series of Charge Questions provided by ORD. The Charge Questions were high-level questions to elicit feedback on the program's research direction and focus, and on the effectiveness of the programs in engaging partners and stakeholders at the appropriate time in the research cycle. There were five Charge Questions in common across the subcommittees, and several program-specific Charge Questions unique to each subcommittee.

The Executive Committee met in Washington, DC on December 8-10, 2015 to review, summarize and synthesize the five subcommittee draft reports. Certain "common threads" emerged from the subcommittee reports, and they are presented here along with the summaries of the subcommittee reports. The full subcommittee reports are attached to this report as appendices. In addition, the BOSC Executive Committee reviewed the draft Roadmaps for two of the cross-cutting ORD programs, Climate Change Research and Environmental Justice Research. (The other two crosscutting programs, Integrated Nitrogen and Children's Health, were reviewed in a previous BOSC report.) The assessments of these programs, and answers to Charge Questions from ORD, are provided in this report.

This report represents the final stage of BOSC review of the planning process that ORD has undergone since its reorganization of its science enterprise into a matrix of six national programs that are implemented by ORD scientific staff across its laboratories. BOSC will turn its attention to reviewing and evaluating the implementation of its StRAPs and Roadmaps in the future.

II. Review of National Research Program StRAPS

A. Introduction

The BOSC subcommittees were constituted to provide targeted review and assessment of ORD's national research programs. The subcommittees correspond to the research programs, and

include subcommittees on Homeland Security (HSRP); Air, Climate and Energy (ACE), Chemical Safety for Sustainability (CSS), Sustainable and Healthy Communities (SHC), and Safe and Sustainable Water Resources (SSWR). The research, non-service aspects of Human Health Risk Assessment are also reviewed by the CSS subcommittee. Because they are a small piece of the overall HRRA program, it was decided that their review could be done more efficiently in conjunction with CSS. Each subcommittee was populated with 7-12 professionals with a range of expertise and backgrounds.

Each subcommittee met with senior ORD staff, the National Program Director, and scientific staff from their corresponding national program. They responded to a series of Charge Questions provided by ORD, based on their meeting and supporting documentation including the revised StRAP. The final subcommittee reports in full form are in the Appendices of this report. Summaries of the important points and key recommendations from these reports are provided below.

The BOSC Executive Committee, in reviewing the subcommittee reports, found that observations or recommendations emerged that were common to most or all of the subcommittee reports. These have been provided below, prior to the summary recommendations of each subcommittee report.

The subcommittee summaries highlight recommendations specific to their corresponding research programs. The subcommittee recommendations that were common across programs are not repeated, but are found in "Common Threads", below.

B. Common Threads Across Research Programs: Observations and Recommendations

The recommendations below were common across several or all of the research programs, indicating that they may of particular interest to ORD to address as a whole. The BOSC recommends that ORD should:

1. Clearly define what is meant by "partners", "stakeholders", and "(end-) users". These definitions (but not the actual entities) should be consistent across the research programs and used consistently in all written documents, including the StRAPs.

2. Identify the specific partners and others (see above), and clearly document the process used to engage them in each part of the research process, for each of the research programs. For instance, certain partners should be engaged in problem formulation, and others may more appropriately be engaged in research planning or implementation. A table that has partners, stakeholders, etc. and their roles at each of the stages of the research cycle would be instructive and assist in planning. Finally, ORD should develop measures to evaluate the effectiveness of these engagements. The BOSC offers its participation and assistance in developing such measures for ORD.

3. Develop measures of success for outputs and outcomes for each program area. This includes both quantitative indicators and qualitative information. These indicators should be easily measurable, track progress closely, and widely accepted by EPA, partners,

stakeholders, and the decision makers. Collectively, the indicators should be comprehensive; that is, all important outputs should be captured by an indicator.

4. Develop a consistent, multidirectional communication strategy across ORD to inform, educate, and demonstrate partners, stakeholders, users, end-users, and clients. These parties should be engaged at the various stages of the research cycle, including problem formulation, research planning, implementation, and work product development. Different stakeholders and partners may be involved at different points in the research cycle where their engagement would have the most impact - not to direct the research agenda but to provide their perspective on what research products are most needed and how they will be used. Research translation needs to be a critical part of this strategy (see next bullet).

5. Further develop and enhance efforts in research synthesis and translation. The need for synthesis and translation of the results of program research is critical in order to support policy decisions, particularly as the programs participate in more public engagement. The BOSC applauded program involvement in translational efforts and urged continued investment in these efforts. They recognize that part of the current culture change in the Agency is to enhance the ability of researchers to understand their work in a larger context and learn how to communicate research results to non-specialists. While some project investigators might have expertise in translating and/or synthesizing research results, it is not necessarily desirable to require all investigators to engage in translation and/or synthesis efforts. The programs might benefit from identifying and/or training the appropriate people (scientific FTEs) best suited to synthesis and/or translation of research work. Rewards and incentives should be in place, because synthesis and translation work does not necessarily result in peer-reviewed publications, yet the impact on policymakers and the public can be substantial.

6. Maintain alignment between research that is focused on short-term goals and long-term objectives, as both are relevant in different contexts ranging from remediation and containment to improving human health outcomes and achieving long-term well-being. In addition, ORD should maintain the alignment between research that is responsive to partner needs and research that is proactive and motivated by forward-thinking research questions that may anticipate future partner needs. Despite their different motivations and temporal horizons, these various research threads should be mutually informative.

7. Identify specific needs and research questions within and across programs that can be addressed by social scientists, and identify the specific disciplines within the social sciences that would best fill these needs. Across the EPA ORD Programs and Cross-cutting Roadmaps reviewed by the BOSC, there are repeated calls for "more social science" or increasing research capacity in the social sciences. While the programs recognize this overall need, in most cases "social science" is not further defined. Greater specificity is needed to articulate the questions that are emerging that require input from particular social science disciplines or research that would benefit from social science methodologies. Once these needs are identified by ORD, the BOSC is willing to assist programs in moving forward in how to operationalize these needs.

8. Strengthen, enhance, and invest in more effective inter-agency interactions. The success of ORD is highly dependent on conducting good science *and* on how well their research meets the needs of their Program Office and Regional Office partners. The BOSC recognizes that there are processes in place to provide interactions between ORD and its partners, such as Regional Liaisons, webinars, etc., but these efforts are inconsistent in the degree to which they are effective. ORD is encouraged to build these efforts into a more robust and integrated program, one that is institutionalized and not dependent on the enthusiasm of key individuals. It is important for all partners to contribute to and have ownership of the ORD research process. Dedicated staff and budgeting for collaboration will enhance the participation of EPA partners in problem formulation, the design of research and the successful use of research results at the regional and program levels.

9. Continue to nurture and expand cross-program and transdisciplinary integration. Efficiencies and synergies appear possible beyond current interactions among the programs. For example, data collected by CSS may be useful for the tools developed by SHC. The focus on addressing emerging issues in HSRP may provide insights to the other programs in how to balance long-term research with more emergent issues that arise. The expertise developed in SHC in community engagement could be useful to the HSRP program in transferring their tools to the local level.

10. Make necessary investments to increase IT capacity. Keeping abreast of advances in calculation capabilities, hardware and software advances, and highly-skilled IT staff (such as informatics specialists) are essential to the successes of ORD. Each of the programs, to more or less of a degree, are impeded by IT deficiencies. The leadership of CSS requires bioinformatics experts and computing capacity for the vast "big data" generated by screening and evaluation; SSWR, and ACE are hampered by the inability to link models and tools; and HS has cyber security concerns. Such investments are an integral component to the continued success of each program, and if not made, can be a barrier to future successes.

11. Continue to develop innovative decision support tools by drawing on partner and stakeholder engagement to improve dissemination, utility, evaluation, and adaptive improvements of tools. Decision support tools are important in many program areas. Each research program should consult with the specific stakeholder(s) to ensure that the tools will address their needs, as well as be usable, helpful and effective.

12. Increase efforts to integrate tools with attention to interoperability and the ability for tools to inform each other and to answer research questions. A common theme voiced across the research programs was the need for interoperability among the various databases and analytical tools. Many of the tools use different platforms that limit interoperability. This can increase the costs of adding capabilities to the tools through extensions and/or integration. This also increases long-term maintenance and support costs; and raise the tools' collective complexity and training requirements.

C. Summary and Synthesis of Key Recommendations

1. Air, Climate and Energy (ACE)

Overall, the ACE Subcommittee found that the vision and objectives in the ACE StRAP are clearly articulated and the research topics and project areas are planned and organized appropriately. As a general conclusion, the Subcommittee agreed that the ACE plan provides a structured vision and actionable design to guide an ambitious research portfolio that delivers the science and engineering solutions the Agency needs to meet its priorities and fulfill its legislative mandates, with a specific focus on three stated objectives: 1) Assess impacts; 2) Prevent and reduce emissions; and 3) Prepare for and respond to changes in climate and air quality. The results of ACE program research support policies that have far-reaching positive impacts across the nation, including reducing health risks from air pollution, preparing for the impacts of climate change, and advancing more resilient and sustainable communities.

In view of the increasing need to prioritize the allocation of resources, the Subcommittee endorses maintaining high priority on core areas of research that ACE partners, the states, and other users rely heavily on, for example, emissions characterization, monitoring methodologies, and atmospheric/climate science. In this vein, the Subcommittee noted the need for developing new or replacing outdated federal reference methods for ambient pollutants; continuing the development of small, inexpensive sensors suitable for criteria pollutants as well as emerging air pollutants such as ammonia; and continuing support of air dispersion model development in the areas of source attribution, dry deposition, and speciation profiles.

The Subcommittee applauds the ACE focus on building on core strengths to support the evaluation of climate change impacts. The Subcommittee highlighted the increasing importance of understanding and predicting climate change-related human health effects, such as those associated with wildfires. This particular example illustrates the opportunity to leverage core ACE strengths in air emissions and modeling and to integrate with ongoing and planned research on climate change-related human health and environmental effects performed by ORD, other Federal agencies, and non-governmental organizations. As heat exposure and humidity play key roles in climate change-related health effects, the Subcommittee also noted the importance of including temperature and humidity in air quality modeling used to evaluate climate change impacts at all scales, from local to national and larger. Finally, the Subcommittee identified the need for measuring and/or modeling the changing patterns of pollen exposure as a research area that aligns well with ACE's strengths and the program's stated objective to prepare for and respond to changes in climate and air quality.

On the topic of research planning and problem formulation, the Subcommittee applauds the ACE program for the breadth and diversity of approaches used for engaging partners. The Subcommittee suggests that program planning and implementation might also benefit from more direct involvement by one or more states at the problem formulation stage. The states serve a key role in both providing and using information generated by the ACE program, yet their interests and points of view are not always fully represented by EPA's Regional Office partners. Direct involvement by one or more states should help ensure an on-the-ground perspective on

needed tools and the ultimate implementation of research accomplishments into use and operations.

The Subcommittee is sensitive to the tension between the increasing needs of ACE's partners and constrained resources. In this environment, it is important to ensure the continuation of sufficient funding for program reviews by external experts, peer review, and other quality assurance activities to maintain a high quality product. The Subcommittee believes that the ACE program is highly focused on quality assurance; however, the Subcommittee would benefit from greater knowledge of quality assurance procedures in place for different types of ORD projects. In conclusion, the Subcommittee believes that the ACE StRAP articulates and organizes an ambitious but achievable research program that aligns with EPA's objectives and mandates to protect air quality and take action on climate change. The Subcommittee looks forward to continuing to serve as a resource to the ACE program on technical and management issues related to its research programs.

2. Safe and Healthy Communities (SHC)

The Subcommittee generally found the vision and objectives in the StRAP to be clearly conveyed and the topics and project areas to be planned and organized appropriately. As a general conclusion, the Subcommittee acknowledges the consistent focus on sustainability across SHC activities, and commends the systems orientation of the programs within the SHC. The Subcommittee also recognizes the challenges of the integration across environmental science and social science disciplines, and the application across multiple spatial and temporal scales that sustainability science requires.

The Subcommittee recommends SHC continue to develop its conceptualization of sustainable and healthy communities. EPA in general, and SHC specifically, have an opportunity to be global leaders in sustainability, and in defining core principles of wellbeing, community, and resilience. The development and dissemination of an integrated framework for how to think about sustainable and healthy communities could be nationally and globally transformative.

Furthermore, the Subcommittee recommends expanding SHC's conceptualization of relationships between ecological and human health and wellbeing away from unidirectional articulations toward non-linear, multi-directional relationships. This shift in conceptualization requires the integration of systems thinking into the development of projects and tools, and may involve the integration of causal and feedback loops, scenario building, and system dynamics models. Furthermore, the Subcommittee recommends that SHC expand the time horizon for investigating the interactions of ecological and human health and community wellbeing.

The Subcommittee recommends greater integration across projects, topics, and scales in the outputs, products, and tools produced by SHC. Integration is critical for understanding sustainable and healthy communities, particularly given the scope of SHC. Greater attention could be given to considering the needs, skills, and capacity of the range of users of products and tools produced by SHC, and to ensuring that these products and tools can be customized and scaled to capture key interactions influencing community experiences and decision making.

However, this level of integration represents a kind of paradigm shift in focus from traditional, linear models of community and environmental health. To that end, the Subcommittee recommends that SHC continue to build capacity for greater integration that this paradigm shift requires. In particular, the Subcommittee recommends hiring additional staff with expertise in the social and economic sciences, and in complex socio-ecological systems. SHC could also consider expanding the use of shared staff appointments across research topics and the other research programs.

In order for the Subcommittee to more fully understand the effectiveness of partner engagement and the implementation of decision-support tools in diverse situations, we recommend future meetings of SHC and the Subcommittee provide opportunities for greater interaction with staff from centers and labs, as well as stakeholders in partnering regions and communities.

The Subcommittee recommends further that SHC compile a catalogue of tools that would include information on each tool such as the topic that the tool supports, the geographic scale of the tool, and a projection of the period of time the tool will be supported. It is further recommended that SHC increase its effort to integrate tools with attention to interoperability and ability for tools to inform each other and to answer research questions. The Subcommittee further recommends continued development of innovative decision-support tools by drawing on partner and stakeholder engagement to improve dissemination, utility, evaluation, and adaptive improvements of tools.

Another important recommendation from the Subcommittee is to systematically and comprehensively evaluate and document feedback from partners and other users of SHC tools in order to examine the effectiveness of decision-support tools. Meta-analytical work to assess efficacy of tools across diverse community types, along with qualitative narrative development of experiences, would be highly useful. Community typological work may be useful in informing selection of cases, rather than *ad hoc* application of tools for communities most able to engage. It appeared to the Subcommittee in the September 2015 meeting that more has been done in terms of evaluation and adaptive development than was apparent in the documentation provided. It may be that engaging a contractor for this systematic evaluation would be useful.

In conclusion, the Subcommittee believes that the activities of SHC are well aligned with the mission of the Program, and that SHC staff members have demonstrated considerable progress toward the objectives of conducting research and delivering products that improve the capability of EPA to carry out its responsibilities.

3. Safe and Sustainable Water Resources (SSWR)

EPA has done an admirable job of aggregating and developing the 2016-2019 StRAP that addresses some of the greatest challenges facing the nation's water resources. SSWR is to be commended for its efforts to build partnerships with the Regions and address needs the Regions are experiencing. Based on the SSWR StRAP, the SSWR is expected to make good progress toward the research objectives in the 2016-2019 time frame.

The SSWR Subcommittee is of the opinion that for internal ORD's coordination apparently is better defined and well documented while that is not the case for outside partners and stakeholders. Based on the available information, the Subcommittee feels that some important stakeholders are missing from consultations. The Subcommittee strongly suggests that a detailed mechanism should be in place for coordinating with external stakeholders and should include database of STAR grantees along with research areas and topics, topics and projects selection process and criteria, progress measurement and intermediate metrics.

It was difficult for the Subcommittee to gauge the research needs prioritization process. For example, the draft StRAP lacks discussion on relevant large-scale EPA and other federal programs (e.g. endocrine disruptor screening program, silico and high-throughput in vitro toxicology); there was no mention of consultation with National Institutes of Health, and EPA's own ToxCast Program. Consultations might have occurred but they were not included in the StRAP. So ORD should explicitly discuss how interactions took place on these large efforts within EPA and beyond.

On nonpoint source pollution, apparently there is a weak linkage between the 319 Grants Program and ORD, so a research-level analysis of 319 projects reveals mixed success; hence, there is a need to strengthen this relationship either by ORD conducting hands-on research or by ORD providing coordination and planning support to assist 319 staff in improving research elements of their projects. Further, rigorous analysis of project performance is recommended.

The prioritization of some key issues like decaying infrastructure, DBPs, and potable water reuse is not entirely transparent. Similarly, salt management, distribution system corrosion, green infrastructure, resource recovery, etc. seem tangentially related to research priorities. Therefore, it is highly recommended that SSWR finds more tangible and transparent mechanisms to engage all partners and stakeholders to identify and prioritize research areas and projects.

The development of water simulation models has been a strength of EPA; indeed most of the water quality simulation models in use today are models that have developed through EPA. These models generally have been constructed with a focus on process description, but unfortunately there has been little consideration of uncertainty analysis as a standard component of these simulation models. The Subcommittee is of the view that model utility can be improved by routine assessment of prediction uncertainty. One approach to interoperability of models and tools is to build a comprehensive model that includes and links water and socioeconomic simulations. An alternative approach is to build an uncertainty model with consideration of seamless integration with other models. Similarly, measures of success can be identified at several levels, such as number of downloads and /or number of cited applications of each model, number of attendees at modeling short courses, and number of approved Total Maximum Daily Loads based on EPA-supported models.

Concerning resource recovery and water reuse, SSWR plays a vital role in assessing cumulative human health and environmental impacts in contaminants in treated resource water and bio solids. Further, SSWR can help change the current mindset through adopting the new term

"Resource Water[1]" instead of "Wastewater". The Subcommittee strongly recommends that SSWR should continue to play a central role in assessing cumulative human health and environmental impacts of contaminants in reclaimed water and biosolids. SSWR, however, should consider whether a specific technology is best developed within EPA or within the private sector. In general, government research is best focused on emerging technologies that can require considerable study before moving into private research and development.

The subcommittee found that the various efforts undertaken by SSWR to convey to stakeholders the results and utility of its research programs can be generally categorized as efforts in communication about risk and risk management. The risks of interest pertain to human and ecological health and to the viability and sustainability of water systems and watersheds. SSWR is encouraged to consult several reports on this topic that are detailed in Appendix 1.c to improve these efforts.

4. Chemical Safety for Sustainability and Human Health Risk Assessment (CSS/HHRA)

CSS. The CSS research program is a showcase of EPA innovation; it has the potential to be truly transformative of the work of EPA and make valuable contributions to diverse fields of science. The program's research has been responsive to the recommendations of the National Research Council on toxicity testing (2007). The research objectives are ambitious, and will be challenging to accomplish in the 2016-2019 timeframe, however the program is currently on track to substantially meet their objectives.

The ToxCast project is a central effort within the CSS research program and it has provided a plethora of informative data. However the assays were originally designed for the evaluation of pharmaceuticals rather than for chemical risk assessment. The program recognizes this weakness and is developing assays to improve the biological comprehensiveness for high throughput and medium throughput evaluation of chemicals. The Committee was encouraged to learn about new assays recently developed for thyroid dysregulation and for neurotoxicity. New assay development needs to continue in order to address gaps in the chemical evaluation effort.

CSS faces significant challenges as it expands its research efforts. Examples of these challenges include: (1) Transitioning from qualitative modeling to quantitative modeling of adverse outcome pathways could provide more effective integration of high-throughput testing data with quantitative risk assessment, but it will require development and testing of novel approaches and significantly more data, including dynamic data with respect to concentration, time and change in environmental conditions. (2) Extrapolating across species will be necessary for ecological risk assessment, but it will also require extensive additional data, such as experimental data, molecular target assays across species and genomic data on a variety of representative organisms. (3) Determining the combined effects of chemicals in mixed systems is also important but it will require a major focus on interactions among multiple chemicals and emerging substances such as nanomaterials.

[1] Resource water (wastewater or sewage in old terminology) is a complex mixture of water and inorganic and organic solids in the form of inert material, ammonium, nitrate, phosphorus, etc. Reclaimed water, on the otherhand, is a just one of the components of the resource water; other extractables may include biogas, biosolids, nutrients, and heavy metals. Resource water is a more appropriate terminology to reflect economic benefits.

Virtual tissue models have the potential to be important for predicting biological responses in relevant species, but in the absence of any contribution to the evaluation of chemicals or adverse outcome pathways they could be perceived as an academic exercise. For these reasons, case studies could be helpful in demonstrating that biological activity in ToxCast translates to biological properties in virtual tissue models, and in turn to apical endpoints *in vivo*. Selection of new ToxCast compounds should consider real-world data on chemical exposures as well as the requirements of modeling, including tissue and QSAR models. It will be important to have data on a wide array of chemical structures to appropriately build and test the models. The Committee also supports the use of program resources to develop and improve exposure models.

The CSS lifecycle analytics effort is extremely ambitious; the effort has many strengths and has the potential to be successful. Success will depend, in part, on having toxicity screening data on a large pool of substances, and having a strong program in computational chemistry and biology that can help develop capability to predict adverse outcomes for new or emerging chemical systems. Another area of active research that requires attention in the screening programs is the incorporation of metabolic capacity, or testing of metabolites, as metabolites may be the toxic entity for many chemicals. Different EPA communications should be tailored to the needs of different key communities, including the public, with interest in the CSS products.

As CSS research projects are updated and refined, CSS should implement a system to clearly communicate to users when changes are made to databases and tools, and to describe the nature of such changes. Successful knowledge transfer, development and evaluation of fit-for-purpose tools will benefit from engagement with key partners including the broader scientific research community. An ongoing investment in training and educating the user community on CSS data and tools will remain critically important in order to assure that the research will be used appropriately to help protect human health and the environment.

HHRA. The Committee was favorably impressed by the breadth and depth of the HHRA Research Program. The program provides a service that is cross-cutting and fundamental to informing decisions both within and outside the Agency. HHRA is moving forward to implement important recommendations of the National Research Council on risk assessment (2008), and is propagating an open and transparent approach to efficient use of technological tools for risk assessment. The Committee especially commends the HHRA program for its work on understanding susceptibility and vulnerability, including through the application of genetic and epigenetic data, as well as its work to incorporate non-chemical stressors into cumulative risk assessment. EPA partners highlighted the key role of HHRA in emergency response, with several recent examples demonstrating substantial support to EPA regional offices.

Key recommendations for the HHRA research program include a need to develop acute or non-lifetime reference doses/reference concentrations for some chemicals, as feasible and warranted by the decision context. HHRA should also explore using CSS tools to develop preliminary risk-based screening levels for data-poor chemicals that have been detected in communities (e.g. in drinking water or indoor air), or in soil or water at contaminated sites. The HHRA online tools could benefit from a guidance document or navigation guide that is designed for effective use by intended users possessing variable levels of expertise. HHRA outreach efforts should also include the NIEHS Superfund Research Centers as a way of propagating risk assessment research into the regions.

5. Homeland Security Research Program (HSRP)

The Subcommittee found that the HSRP StRAP clearly defines strategic goals and objectives over the next few years. The topics and project areas are well planned and organized. However, HSRP is often is called to respond in a timely and efficient manner to unforeseen hazards and disasters, such as the Ebola outbreak, cyberattacks on water utilities, and the Elk River chemical spill. It is difficult to plan for resource use during these emergencies, however without doing so, the ability to make progress on all objectives is threatened. The Subcommittee recommends that the Program develop a process and strategy that allows responses to, and prioritization of, unforeseen and emerging needs while ensuring that good progress can be made on StRAP research objectives.

In addition, because of the severity of the threat of cyber-attacks, the Subcommittee recommends that the Program's research schedule should be modified to prioritize cyber security research ahead of other areas to counter the continuous and ever-increasingly sophistication of cyber-attacks that plague utilities. As utilities interconnect formally disconnected systems to increase efficiencies, they create an ever expanding attack surface – often without understanding the impact and risks. As very few utilities have staff prepared to deal single-handedly with chemical or biological attack remediation, knowledge of cyber security is limited in the utility space; consequently research and guidance is needed from HSRP.

HSRP has done a good job transitioning research to the end user, particularly through the development of validation tiers for chemical sampling and chemical analytical processes, tracking visits to tool websites to assess popularity, and the collection of Selected Analytical Methods which appears to be widely used. The Subcommittee recommends that the Program develop tools for end users that can be routinely operated and maintained, and have 'multi-use' or 'all hazards emergency response' capabilities where appropriate. For example, with regard to Water Quality Surveillance & Response Systems, develop a plan for supporting deployed tools with future updates, and minimize the number of development platforms to improve interoperability and functionality. In addition, the Subcommittee recommends that HSRP develop validation and/or readiness measures to establish awareness and manage expectations among end users of the expected performance of the analytical tools, decontamination response methods, and software tools produced by HSRP.

In conclusion, the Subcommittee recognizes that the activities of the HSRP are well aligned with the mission of the Program and that HSRP staff members have shown considerable progress toward the objectives of conducting research and delivering products that improve the capability of EPA to carry out its homeland security responsibilities.

III. Review of Crosscutting Roadmaps

A. Introduction

In addition to its six national research program areas, ORD has established four crosscutting programs. The goal of these crosscutting programs is to improve effectiveness and efficiency by integrating research that is found in several of the research programs, i.e. integrate across the

"stove-pipes" of the research programs. These four crosscutting programs are Integrated Nitrogen, Children's Health, Climate Change, and Environmental Justice. Each program prepared a Roadmap planning document. The BOSC reviewed the former two Roadmaps previously (provide reference), and provides a review of the latter two below.

B. Environmental Justice

Charge Question:
How effective is the draft Environmental Justice Research Roadmap in presenting a problem statement, elucidating key research topics and important scientific gaps appropriate to the mission of the EPA, capturing relevant research in each of the six programs, and identifying areas of integration across the six programs?

General Comments:
The BOSC was impressed overall with the Environmental Justice Research Roadmap and finds that it presents an ambitious and relevant cross-cutting research agenda. In general, the BOSC cautions that use of the term "minority" as used in the Roadmap is often not appropriate, especially when it is used to describe communities or regions where the relevant population actually represents a majority. It is more accurate to refer to "disadvantaged" communities or to be specific about issues relevant to race or ethnicity. Members of the BOSC also noted that the references include only two academic peer-reviewed papers, and no references to the extensive literature, from both social science and biological science perspectives, on the topics of environmental justice and wellbeing. Including a few selected influential publications would signal EPA's awareness of the breadth and depth of scholarly literature in the environmental justice arena.

In addressing the charge, the Committee divided the charge question into five sub-questions, which are addressed individually below.

1. How effective is the draft Environmental Justice Research Roadmap in presenting a problem statement?

The problem statement is presented in two places in the report and the two statements do not appear to be well aligned with each other. The "problem formulation statement" (p.4) is a broad statement of the goal of ORD research addressing environmental justice (EJ); the goal should be preceded by a statement that identifies and articulates the existence of EJ problems, such as the presence of environmental health disparities, greater risks facing particular populations, and/or greater exposure to the potential impacts of climate change, none of which are presented in the "Background" section of the Roadmap. The "expanded problem statement" (p.8) includes a recognition that "environmental risks are often greater for low-income and minority communities" due to proximity to chemical toxicants and non-chemical stressors, and the statement offers suggestions for the causes of these stressors, such as inadequate housing, transportation, and resource access. This latter broad problem statement, however, does not easily translate into a clear and concise justification for the science challenges agenda that is presented immediately below. The two problem statements could be harmonized to better articulate a single, concise problem statement that motivates the research roadmap. In addition to

the above discrepancies, the issues discussed in the expanded problem statement relate to research in many other agencies and academic institutions. Hence, it would be helpful to more clearly articulate ORD's unique role and contribution to the EJ research agenda.

Recommendation:

1.1 The BOSC recommends revising the problem statement by putting all relevant discussion in one place, and including three key components: (1) a clear articulation of the threats posed by the problem(s) similar to that in the 'expanded problem statement'; (2) a strong justification for a cross-cutting research roadmap within the areas of expertise represented at ORD related to environmental justice; and (3) a purpose statement that is similar to the statement on p.4 but more focused.

2. How effective is the draft Environmental Justice Research Roadmap in elucidating key research topics appropriate to the mission of the EPA?

The EJ Roadmap identifies four science challenges that form the basis for the key research topics. The research topics fit appropriately in an EJ Research Roadmap, as they are clearly within ORD's expertise, they are related to the interface between environmental justice and scientific research, and they address priority issues for many EJ communities. However, the research topics may not reflect the full breadth of environmental justice issues and their drivers, and it is not immediately clear to the BOSC how these four issues were selected and prioritized. For example, research related to tribal sustainability and wellbeing is given particular emphasis as a scientific challenge and research topic, but issues of sustainability and well-being in other under-resourced and challenged communities (such as those with significant incidences of poverty, racial and ethnic minorities, political disenfranchisement, and other marginalized communities) are not called out in the same way. The BOSC recognizes that other communities will be included in research programs, particularly as they relate to research topics such as decision-support tools for identifying concerns, understanding environmental health disparities, and community-scale vulnerability to climate change. But the articulation of the key research topics does not include this level of specificity, nor does it address the scope of potentially targeted communities or the process for identifying these communities. There may be reasons for devoting an entire area of focus to the Tribes, but the reason for this is not immediately clear on reading the Roadmap. Neither is it clear why the EJ Roadmap excludes specific areas of research targeting other EJ communities, or the issue of contaminated sites, which is of ongoing central importance and is discussed further below.

The second research topic ("Improving our understanding of environmental health disparities and developing methods and data for assessing cumulative risks") includes a brief discussion of some of the social and environmental determinants of health, including chemical exposure, but the characterization of the drivers of environmental injustice appears to be oversimplified and incomplete. Figure 2 ignores other drivers that are likely to impact EJ outcomes, such as poverty, income inequality, political marginalization, linguistic isolation, lack of awareness, and poor infrastructure. Although it is clear that the EPA has little purview over many of these drivers, they should be included in the discussion as relevant to the research program, along with a recognition by ORD that the EPA cannot possibly tackle many of these other drivers that are

clearly outside the EPA's mandate and purview. The narrow emphasis on the built environment, social environment, and biological factors does not appear to fully address the causes of exposure to risk that affect health and wellbeing in a comprehensive way. Further, we suggest consideration of the contested nature of environmental justice issues, particularly health impacts of environmental contamination and toxic exposure. While illuminating the multiplicity of factors driving disadvantaged conditions, the power dynamics often leave the burden of proof on overburdened communities.

Recommendations:

2.1 Describe in the Roadmap how the four priority research areas were selected.

2.2 Expand Figure 2 and the text to incorporate a description of the broader array of social and economic drivers of environmental injustice.

3. How effective is the draft Environmental Justice Research Roadmap in elucidating important scientific gaps appropriate to the mission of the EPA?

Key scientific gaps have been identified in the EJ Roadmap. The activities in the table provided by the National Environmental Justice Advisory Council (NEJAC) as well as the three gaps highlighted in the report (Community Engagement, Outcome Assessment, and Training the Next Generation) are indeed gaps deserving of attention, and these have been well articulated in the EJ roadmap.

Community engagement in the formulation of scientific research agendas is definitely needed. However, we caution against over-promising in this arena. Long-term engagement is the most effective way to involve communities, yet engaging long-term with multiple communities in formulation of a research agenda is a highly resource-intensive endeavor. Developing a systematic process for such engagement (and benefitting from SHC's experience and existing relationships in this regard) will help ORD to focus and prioritize. The development of a clear way to identify overburdened communities leading to an environmental justice community typology to differentiate the highly varied circumstances along different timelines of experience might be helpful for targeting representative EJ communities for engagement.

Outcome assessment is also a key gap as indicated. Mapping scientific gaps and assessing efforts to address them over time will help articulate alignment with EPA goals as well as to measure success. Metrics and measures for tracking community improvements as well as declines are essential elements of this gap. Many indicators and tools exist within EPA and the wider research and academic community, such as the Human Wellbeing Index and Environmental Quality Index in SHC, as well as the EJ Screen, the Environmental Justice Screening Methodology (EJSM) and the California Communities Environmental Screening Tool (CalEnviroScreen), and these methods could be incorporated into assessments of environmental justice efforts over time. Training the next generation is a clear part of improving sustainability and the environmental justice outlook for communities. This involves providing training opportunities in communities, but also systematically training new scientists to be mindful of the complexities of environmental justice. Social science is clearly articulated as a scientific need throughout ORD programs and this will be systematically improved by a long-term focus on interdisciplinary learning and inclusion of social science principles and methods throughout ORD programs, and particularly

throughout Environmental Justice endeavors. Finally, as EPA develops and trains scientists and communities in tools and resources related to EJ, it will be important to plan for the long-term sustainability of the effort, either through the agency, or more appropriately via knowledge transfer and ownership to other entities perhaps at the local level.

One important area that is omitted from the Roadmap is research related to contaminated sites. The Roadmap explicitly excludes this topic (p. 10) and instead refers to the SHC StRAP for more on this. This is unfortunate, as the issue of contaminated sites is of central importance to EJ research, there is much that ORD has to offer on this topic, and there is a great need for more research in this area. As one example, EPA partners often struggle to identify responsible parties (RPs) to clean up contaminated groundwater or sites. There is a need for better forensic chemistry to trace contaminants to their sources and thereby help to reduce protracted litigation, expedite cleanup, and increase cost recovery. As another example, there are often chemicals identified (or tentatively identified) at cleanup sites that are of unknown toxicity. Such chemicals may be in soil or water in communities, and in some cases remediation plans leave these chemicals in place due to the lack of regulatory cleanup numbers. Improvements in toxicity screening in the CSS program, and the incorporation of such screens into preliminary risk assessments in the HHRA program, have enormous potential to address this potential threat to communities that live near cleanup sites. For these reasons, the BOSC recommends including some additional discussion of contaminated sites in this document. Recommendations from the BOSC to the SHC program on expanding conceptualization and research on contaminated sites to broader community wellbeing issues may be helpful in this regard.

We note a few additional science gaps deserving of attention within the EJ Roadmap. It might be tempting to avoid focusing on issues that fall beyond the regulatory mandate of the EPA, such as food scarcity or quality issues or problems of poverty and poor housing, but we suggest that a full array of complex drivers and processes are important for systems understanding and research within EPA's EJ efforts. One such issue that strikes us as a gap is the need to describe and acknowledge multi-scalar, social structural factors, such as economics, income inequality and political and power dynamics (we note that the figures in the Roadmap are largely devoid of economic considerations). To be clear, the BOSC recognizes that integration of social science into development of research action plans and programs, while critical and necessary to enhancing the likelihood of positive and effective outcomes, does not imply that EPA can address all drivers of EJ and impact outcomes across the board.

We suggest that more science could be helpful in differentiating between mitigating problems in existing environmentally overburdened communities and preventing such situations in the future. Preventing future environmental justice problems in communities requires a systems understanding of the underlying driving forces so that they can be monitored and avoided. Mitigation of current issues requires a different set of tools and resources. However, both are likely dependent upon community engagement.

Recommendations:

3.1 Develop methods to more systematically assess gaps and measure outcomes over time to evaluate progress.

3.2 Incorporate social science principles and methodologies throughout EJ endeavors across ORD.
3.3 Plan for long-term sustainability of ORD EJ efforts, including in plans for knowledge transfer and maintenance of tools and databases.
3.4 Include discussion of contaminated sites and connections to broader community wellbeing as part of the EJ Roadmap.

4. How effective is the draft Environmental Justice Research Roadmap in capturing relevant research in each of the six programs?

The BOSC is not exhaustively familiar with the research going on throughout the six programs, and is therefore not necessarily best equipped to answer this question with confidence. It is possible that there is research going on in one or more of the programs that may be relevant and of which the BOSC is not aware. However, it appears that the relevant research at ORD is captured effectively in Appendix A, Table A1 of the Roadmap. This table is an extremely useful compilation of the EJ-related research at ORD, and is a valuable addition to the Roadmap. Table A2, which summarizes STAR extramural research in Environmental Justice is also useful, as is Appendix B. Taken together, the Appendices demonstrate an impressive array of research and partnerships.

The report quite effectively notes important and relevant research in SHC related to Environmental Justice and engaging communities. The relevance of the CSS research is possibly under-stated in the Roadmap. The statement on p. 23 on CSS refers generically to the program's role in 'assessing new products' and 'prioritizing chemicals for IRIS assessments', but these are not the most relevant or important uses of the CSS data. In fact, 'assessing new products' does not have obvious direct EJ relevance, and CSS data are not currently being used in IRIS assessments. More directly relevant to EJ is the role for CSS in screening data-poor chemicals and thereby providing data to potentially inform provisional risk assessments. This role includes toxicity screening of chemicals detected at contaminated sites, in groundwater or in surface water in communities. CSS also has the ability to test mixtures, which is an important way of beginning to evaluate cumulative impacts.

The role of the Human Health Risk Assessment (HHRA) research program is not properly characterized on p. 23. The Roadmap refers to the IRIS program and the ISAs, but fails to mention the Provisional Peer-Reviewed Toxicity Values (PPRTVs), and the role of the Superfund technical support centers within the HHRA program. In addition to the important work the HHRA program is doing on cumulative risk assessment (which is mentioned in the Roadmap), it is also working to generate preliminary risk assessments for data-poor chemicals, including through use of CSS work products. This work has direct relevance to communities facing exposures to multiple contaminants.

Table 2 is a useful summary of the contribution of each research program to the overall EJ research activities. The BOSC felt, however, that the contributions of certain programs may be under-represented in that table. In particular, the BOSC was surprised not to see a check mark for Safe and Sustainable Water Resources (SSWR) for Tribal Science, and perhaps also for SSWR and Health Disparities and Cumulative Risk.

Recommendation:

4.1 Describe the roles of the CSS and HHRA programs in screening and developing provisional risk numbers for previously untested contaminants.

5. How effective is the draft Environmental Justice Research Roadmap in identifying areas of integration across the six programs?

The Roadmap is fairly effective in identifying areas of integration across the programs, especially in the Cross-Agency "Making a Visible Difference" (MVD) strategy, the area of cumulative risk assessment, and in climate adaptation. There is also significant potential for integration in the three cross-cutting areas identified in the Roadmap as research gaps (community engagement, assessing outcomes, and training the next generation). Activities on these three 'gap' areas would require significant cross-program integration.

There are several other areas for integration that are not articulated in the Roadmap. These include rapid response, exposure science, and socio-ecological disparities. EPA has extensive Emergency Response and Management activities, in which ORD is actively involved. Many emergencies affect EJ communities, in part because many EJ communities are located in areas that are vulnerable to chemical spills, explosions, fires, and other disasters. It may be beneficial for EPA to consider articulating an EJ component to their emergency response preparedness research and response activities.

Exposures to potentially hazardous substances are a common concern in EJ communities. Some of the themes in the Roadmap relate to exposure science, including rapid sensor technologies, and some of the decision support tools. There is exposure science research going on in all the programs within ORD, and it may be fruitful to consider ways to better integrate the exposure science research across program areas and media. Such an effort would be relevant to EJ, but may also be beneficial beyond EJ issues.

The awareness of the links between human health and ecosystem services is an important and growing area of research. This issue is mentioned in the Roadmap as it relates to Tribal Health, and to some degree also to climate justice. However, the connections between human and ecological health (e.g., the "One Health" concept), and the issue of socio-ecological disparities is an important crosscutting theme that is relevant to several program areas and might be an additional area to consider for potential integration.

Recommendations:

5.1 Consider articulating an EJ component to emergency response and preparedness research and activities.

5.2 Consider ways to better integrate exposure science research across program areas and media.

5.3 Consider developing the connections between human and ecological health, and the issue of socio-ecological disparities as a crosscutting theme.

C. Global Climate Change (GCC)

Charge Question:
How effective is the Draft Global Climate Change Research Roadmap in presenting a problem statement, elucidating key research topics and important scientific gaps appropriate to the mission of the EPA, capturing relevant research in each of the six programs, and identifying areas of integration across the six programs?

General Comments:
There was agreement among the BOSC members that the GCC Roadmap represented a substantial effort. However, we still find some deficiencies in the Roadmap overall. Based on our responses to the Charge Question and our other comments and observations, we would appreciate the chance to review the next revision of the Roadmap.

We appreciate that the climate program of EPA is part of a much larger enterprise involving many partners across the Administration. As a result, it is a constant challenge to make progress on some goals if they are dependent on outside Agency partners, such as NOAA or USGS. However, this also makes it a challenge for the BOSC to determine where EPA can make a value-added contribution to climate change research and where they can make a significant difference. It would be extremely helpful to create a figure that shows, for a given medium (e.g. water) what the impacts of climate change might be (e.g., decreased flows, flooding, changes to evapotranspiration and the hydrologic cycle, changes to water quality and to TMDL studies, increases in hazardous algal blooms, changes in pollutant transport, etc.). For each of these impacts, indicate which are under the primary responsibility of EPA (water quality, TMDLs), and which are less so (changes in flows) – and then link these to the work plan in the Roadmap. This would not only be illustrative, but perhaps help guide planning in the future. In that regard, the figure could be used to illustrate how the Climate Change Roadmap research topics were selected as key topics, making sure that the reasons for selection are transparent.

The Roadmap, while largely complete, was found to be poorly written. It suffers from redundancies in the text, a lack of cohesion and flow, and numerous typos and incomplete sentences. It appears to have been the product of many authors pasted together. The document would greatly benefit from a rigorous copy-edit. The lack of clarity and differentiation between the Needs and Current Research, and the Gaps, was to some extent due to the format ORD requested them to follow, but the distinction between these two sections could be greatly improved.

Comments on Answers to Charge Questions

1. How effective is the draft Climate Change Research Roadmap in presenting a problem statement?

In essence, the extended problem statement is not effective. It would be helpful if the problem statement were directed toward EPA's particular focus on climate change. We suggest the phrase "way of life" be replaced with "wellbeing" given that is the accepted terminology. Further, there is no mention of climate change adaptation in the problem statement.

2. How effective is the draft Climate Change Research Roadmap in elucidating key research topics appropriate to the mission of the EPA?

While there was general agreement on the topics that were identified in the Roadmap, several key topics were missing, for example (1) invasive species, new pests introduction including effects on pesticide use; (2) post-disaster debris management, with focus on research on effective and safe approaches; (3) human health effects of mold.

Throughout the report, the emphasis is on impacts, but missing are the interactions between/among impacts, as well as the adequacy of local governance and infrastructure capacity. In short, the report seems focused on the sensitivity and exposure (impact) side of vulnerability, ignoring adaptive capacity in natural systems and in human systems. The report was missing social drivers and impacts (behavioral, attitudinal, and governance) that have direct implications for mitigation of air and water changes.

In places, research topics are identified without sufficient explanation of their relevancy to climate change. For example, on page 17 of the Roadmap the bullet "Life cycle assessments related to materials management" is identified below the topic of "wildfires at contaminated sites" without any explanation of how life cycle assessment might be used in that situation. Further down page 17, the Roadmap mentions "ongoing research on the potential leakage of biofuels into groundwater" with no explanation concerning the climate change relevancy of this research.

Cookstoves are briefly discussed at several points, but how widely are cookstoves used in the U.S.? If cookstoves are an EPA priority, then the Roadmap should explain how the cookstove issue is part of EPA ORD's purview. Thus, although this issue is more widespread for people abroad, the report should note that the cookstoves are an Administrator priority, and thus provide greater context for this priority.

Adaptation is the main focus of the climate change roadmap. However, the Science Challenges and research topics (particularly for water, air, human health, and ecosystems) are all framed in terms of understanding the impacts. A research program focusing on adaptation to climate change would presumably need to go beyond understanding impacts, to examine the range of adaptation strategies in terms of their cost-effectiveness, cultural acceptability, efficiency, etc.

A few final observations are: (1) identification of needs should be an articulated process, and (2) multimedia (i.e., water, air, soil, freshwater, and the entire environmental system, including people) interactions of the science challenges need to be incorporated in the Roadmap.

3. How effective is the draft Global Climate Change Research Roadmap in elucidating important scientific gaps appropriate to the mission of the EPA?

The Roadmap emphasizes mitigating emissions from energy production from fossil fuels. There does not appear to be an integrated strategy for focusing on emission reductions. For instance,

little or no attention is given to the role of forests, agriculture, industrial activities (e.g., cement), and buildings in reducing emissions for effective mitigation of the impacts of climate change.

There is considerable attention on water quality and air quality impacts of climate change. Given that management of water quality and air quality is often a local endeavor, more attention to the adaptive capacity and infrastructural capacity of associated utilities and jurisdictions is warranted. Water supply is also a local issue and climate change impacts and adaptation are complicated by water rights.

With respect to gaps, the document highlights social science as a general gap, but greater specificity would be highly valuable. As currently written, this is a vague (but important) research gap. In addition, co-benefits of mitigation and adaptation are a gap that warrants discussion.

Most EPA-supported research does not begin with complete ignorance of a topic of interest; rather, there is a base of knowledge that is expected to be built upon with proposed new research. Consider that much is already known about how high temperatures affect meaningful endpoints in aquatic systems. This knowledge results simply because surface water temperatures vary around the globe. While it must be acknowledged that studies of subtropical aquatic ecosystems may not be highly reliable indicators of how surface water temperature increases will affect aquatic ecosystems in temperate climates, they should provide some *a priori* understanding. Perhaps this knowledge base should be a starting point for some of the climate change research, rather than starting from a base of little understanding, as appears to be the case in the Climate Change Research Roadmap.

4. How effective is the draft Climate Change Research Roadmap in capturing relevant research in each of the six programs?

The Climate Change Research Roadmap identified many research activities in the six programs that might be expanded to include climate change assessments. However, for many of the identified program projects, the Climate Change Roadmap provided few or no details concerning how these projects might be modified to include climate change research. Thus, it is not clear that the authors of the Climate Change Research Roadmap have had much interaction concerning the feasibility of this collaborative research with the six programs.

For example, text could be added relating the impacts of climate change on ecosystem goods and services/ecological integrity and the SHC tools used for assessing these impacts (e.g. make deeper connections to the SHC work being conducted in ecological health and wellbeing).

5. How effective is the draft Climate Change Research Roadmap in identifying areas of integration across the six programs?

As a cross-cutting program, the Climate Change Research Roadmap should describe integration among the six ORD research programs. The Roadmap does a reasonable job in identifying research needed in SSWR and in ACE, but given the overarching focus on climate change

impacts on ecological and human wellbeing, the connection with SHC's research and tools is worth more attention.

More text is needed to underscore the opportunity for integration with SHC and SSWR in terms of the impacts of climate change on ecosystems and land, specifically on impacts such as flooding and sea level rise. For example, there is a greater incidence of mold related to the greater incidence of flooding expected from climate change; EPA could play a role in this research. The Global Climate Change Program should also work with SHC to determine how to better interact with communities. In addition, there is an opportunity to integrate with the CDC on the issue of invasive species which is a climate change and human health and wellbeing issue, and to integrate with HHRA in the emission reduction program.

A redraft of the Climate Change Research Roadmap should include the role CSS has on water quality and human health, specifically the chemical and microbial elements that may be relevant to climate change that are outlined on page 11 of the Roadmap.