Enhanced Forecast Design Through Experimental Gaming and Social Impact Assessment of Connected River and Floodplains

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1. **Background**. Little is known about how flood hazard risks are perceived across different regions of the United States, nor is much known about how individuals from different demographic backgrounds and direct experiences with those hazards perceive risk and process risk communications associated with water hazards. Factors that may influence risk perception and resultant individual behaviors are complex and include social and economic influences (Baird & Thomas, 1985), messages or policies, social values, moral persuasion, and psychological components (Ajzen, 1991; Kahneman, D., & Tversky, A., 2013). Risk information and communications govern how the response, recovery and long-term planning for resiliency are undertaken at individual (Baan & Klijn, 2004) (e.g., buying flood insurance, land use practices or relocation, early warning signals), community (e.g., rebuilding critical physical and social infrastructure) and institutional (Birkholz, Muro, Jeffrey & Smith, 2014) (e.g., improving/creating policies) scales. The EFD team (Shrum, Merrill, Zia and Koliba) has extensive experience with employing risk perception surveys at national and regional scales (Shrum et al., 2022; Spett et al., 2020).

The NWM is already being used to the develop 'value-added' products (such as Pin2Flood and the Brazos Water Operations Model) employed by emergency responders and water managers and planners to support decision making. To date, the efficacy of these products to inform decision making has been evaluated primarily with qualitative assessments. Sharpening our understanding of how products are perceived and used will allow for modification to better suit the needs of NWM users. Behavior can have feedback effects that exacerbate the frequency, intensity or cost of water-related hazards (Walker and Salt, 2012; Wilson, 2012). Serious games have been used to observe responses to experimental treatments such as communication strategies and information display (Clark et al., 2021; Clark et al., 2020; Merrill et al., 2019; Merrill et al., 2019; Merrill et al., 2021; Schattman et al., 2021; Trinity et al., 2020, Zia et al., 2020). In addition, members of the team have studied flood hazard distribution (Diehl, Wemple), risk perception and hazard mitigation and adaptation (Koliba, Zia). Others on our UVM team have supported the study of human behavioral responses to water quality incentives and policies (Zia, Koliba, Merrill, Schroth, Rizzo) (see Zia et al, 2016; Zia et al., 2020; Zia et al., 2022; Koliba et al. 2016).

Resilient watershed management requires innovative institutional mechanisms that provide the awareness, interest, resources, and opportunities for stakeholders to engage in collective responses aimed at building resilience. Understanding how communities presently use knowledge of water hazards from NWM outputs can be used to develop communication strategies to provide an optimal lens through which NWM products may be used for planning and adaptation. Better understandings of the relationship between forecasting and data visualization of NWM products and the ability of individuals and communities to use these knowledge products for early warning and long-term planning is needed. The ability of the NWM to contribute to community resilience is predicated on knowledge of how NWM products and emplaced systems are communicated, understood, developed, and used. This knowledge is best pursued by triangulating multiple data streams and through deep engagement with stakeholders. Members of the EFD team (Koliba, Merrill, Zia) have led the design and implementation of deep engagement activities, including convening delphi panels and focus groups for water hazard mitigation (Coleman et al., 2017).

Regular exchange of water between rivers and connected floodplains offers nature-based floodwater storage to mitigate downstream flooding impacts and risks to lives, property and infrastructure. However, many floodplains are modified, which limits hydrologic connectivity and exacerbates the impacts of floods downstream (Opperman et al., 2010; Scott et al., 2019). Growing awareness of the importance of floodplain functioning for climate resilience has led to initiatives to remove barriers, restore channel and floodplain form, and set aside conservation easements to allow the perpetuation of natural process (Bernhardt et al., 2007; Remo et al., 2012). Currently, stakeholders engaged in natural resource projects (e.g., government or non-government environmental groups) lack a way to prioritize investment of limited resources or mechanisms to evaluate benefits. In part, this limitation is due to two things: underdeveloped models of connectivity in flood plains, and simplistic social-ecological impact assessments that fail to appreciate the full range of ecosystem services proffered by highly connected river and floodplains. Because rivers and floodplain processes are inherently linked to the upstream watershed, and influence downstream communities, planning tools must be at multi-level scales, especially to find synergies among green infrastructure projects (Seddon et al 2020). The NWM provides an ideal framework to plan and evaluate these impacts because of its CONUS coverage and provision of hydrograph predictions, including in ungauged basins. Ecosystem services frameworks are increasingly being used to calculate social and ecological costs to enhance forecast design and stakeholder use, including by NOAA's Office of Coastal Management Digital Coast program. The EFD team have made extensive advances to modeling of floodplain connectivity (Wemple, Deihl, Underwood), while members of the EFD team have pioneered the development and implementation of payment for ecosystem services programs (Ricketts and Fisher).

2. **Goals.** *Goal 1: Broaden capacity for forecast design by* (1) improving the ability of first responders to understand how forecasts will be understood and used by individuals and communities, and (2) providing insights to inform longer-term community planning. The pursuit of this goal provides a significant contribution to CIROH's efforts to advance social, economic, and behavioral science to improve water prediction and forecast uses. All four tasks under the EFD subproject will be informed by input from NOAA social scientists and hydrologists and other CIROH partners. *Goal 2: Contribute to the development of the CIROH Forecast Design Center by evolving forecast platforms that take into account the heterogeneity of risk perception and behavior, and decision heuristics relative to water hazard mitigation that may be integrated into NWM products.* The EFD project introduces novel and impactful approaches to the incorporation of regional variation, experimental design, and ecosystem services to the NOAA and CIROH consortium. In addition to undertaking focused work in specific watersheds, EFD's knowledge and methods will be shared widely and likely implemented across other regions and water hazard areas (including droughts, sea inundation, and water pollution) in future years. These tasks are designed to: 1) gauge general public awareness and uses of water hazard forecasting products, including factors impacting variability of risk perception and efficacy of risk communication; 2) create a platform to test changes to risk perception and communication resulting from alternative forecast design parameters and treatments through a modular experimental gaming platform; 3) improve integration between stakeholder input and forecast design using representative regional empaneled focus groups; and 4) integrate river and floodplain connectivity to better estimate social impacts and costs using an ecosystem services framework.

3. **Research Plan Overview.** The research program of EFD will be undertaken within and across four discrete but inter-related tasks.

Task 4.1: National Water Hazard Risk Perception Surveys. This task will be led by Trisha Shrum and supported by Chris Koliba, Scott Merrill, Asim Zia, Brendan Fisher, and Taylor Rickets, as well as a GRA, a Social Psychology and Risk Behavior Post Doc 1, and data science technician, Eric Clark. The objectives of NWHRP survey are as follows: Objective 4.1.a: Fill a critical gap in the understanding of public risk perceptions, preparedness, and unmet needs related to water hazards with a nationally representative survey of U.S. adults with a particular focus on choices between and among ecosystem service criteria; Objective 4.1.b: Identify key stakeholder groups who are active and potential end users of NWM products (e.g., farmers, real estate industry, departments of transportation, city planners, advocates for vulnerable populations) and, from these groups, recruit an end user panel for a multi-year study commencing in year 2; Objective 4.1.c: Launch a baseline survey of the panel of NWM end users to measure common ground between NWM end users and the general public with an additional focus on unmet information needs and critical gaps in available tools and resources that could limit potential resilience to flood hazards; Objective 4.1.d: Deliver findings from surveys to NOAA and CIROH to inform stakeholder engagement strategies and knowledge product development.

The NWHRP survey will extract and elucidate regional variations in information use, vulnerability (Cutter, Boruff & Sirley, 2003; Cutter, Burton & Emrich, 2010), water hazard risk perception, mitigation, and response and recovery planning. The initial survey of the general public and the annual surveys of the NWHRP user panel general public will be developed using Qualtrics software and pre-tested for clarity and cohesiveness. The general public survey will focus on 1) awareness and current/potential use of NWM products, 2) perceptions of flood hazard risks and how those risk perceptions vary with communication framing, 3) strategies, preparedness and information needs to handle flood hazards, and 4) perceived value of ecosystem services (specific to flood risks). In addition, we will include questions pertaining to trust in science, including uncertainties in long-range or short-range forecasts, preferences in information media and modalities, and basic demographic questions. The end user panel baseline survey will include the general public survey to identify gaps and differences between end users and the general public that will serve as waymarkers for communication between the two groups. In addition, the end user survey will include questions pertaining to use of forecasting products generated by NOAA, local weather forecasters, and emergency managers to inform practices at the appropriate temporal scale (e.g. inform daily commuting to work timing/strategies or mid-range event planning, or long-term strategic planning such as farming or infrastructure development) and proactive responses to extreme precipitation events or droughts (e.g. whether they have formulated evacuation plans, developed electricity grid failure contingencies, consciously avoids water hazards, planned for water shortages or irrigation restrictions). Regional and demographic variation will be rendered, as will be baseline understanding of what proportion and segments of the population rely on NOAA knowledge products, or may be interested in NWM intelligence. We will note misalignment of communication strategy intent and observed or perceived responses to risk messaging. We will analyze each survey by summarizing key measures and identifying regional and demographic differences in risk perceptions, responses to communication frames, water hazard preparedness, and values of ecosystem services. Using cluster analyses, we will characterize respondents based on their similarities and identify how different clusters can be defined with observable characteristics (e.g., geographical, demographic, or industry affiliation). The NWM end user surveys will be compared to general public surveys to develop clear guidance for how end-users can adapt their communication to the public to bridge gaps in perceptions and information. Longitudinal data from the end user panel will be used to measure shifts in perception and track the impacts that experiences with water hazards and/or increased uses of NWM products over time. We will also introduce new questions to the panel to respond to critical issues as they arise.

Task 4.2: Regional Water Hazard Mitigation Experimental Games (WHMEG). This task will be led by Scott Merrill with support from Koliba, Zia, Shrum, and Fisher, as well as the EFD GRA, the Social Psychology and Risk Behavior Post Doc, and data science technician, Eric Clark.
The objectives of the WHMEGs are as follows: Objective 4.2.a: Assess how decision support tools and simulations inform individuals' preferences using serious game technologies and simulations; and Objective 4.2.b.: Assess how specific water hazard intelligence products and risk communication messages influence individual planning and practice behaviors.

Serious games provide a synthetic environment in which communication strategies, messages, policies, and the behaviors of others (norms) can be varied and in which participants will experience controlled experimental conditions, and can therefore complement behavioral data collected through surveys. To achieve these objectives, in years 1 and 2 we will build a regionally-specific serious game and experimental simulation (Crookall, 2010; Parigi, Santana & Cook, 2017) of the Winooski watershed, drawing on a regional flood inundation model developed by Diehl et al., 2021 and leveraging the planning and decision-support capacity developed under Vermont's Functioning Floodplain Initiative, led at UVM by Underwood (see project 2.). We seek to understand how flood inundation intelligence may be used to influence behavior in the domains of agricultural planning, real estate, department of transportation, and vulnerable populations. This development/testing pattern will be repeated with new serious game platforms in future years designed to study other water hazards (drought, coastal flooding, water quality). Treatments can be modified to test efficacy of policies and communication strategies. Participants of the serious games will come from multiple audiences, tailored to the hypotheses being tested. Data from the NWHRP survey will be used to assess participate demographics, prior exposure to water hazard risks, and risk perception, and further will be leveraged and triangulated with the dynamic serious game data to develop nuanced and contextualized understandings of likely responses to, new data products, policies and interventions. Serious game participants will be aligned with the NWHRP panel developed for survey work (see tsk 4.1). Additionally, an empanel focus group (see task 4.3) comprised of stakeholders from the Winooski region will play the serious games to initiate discussions and provide response data. Serious game platforms and simulation versions are expected to generate approximately 100,000 response data points, in addition to risk metric and demographic data. Outputs from serious games will provide data related to perceptions, behaviors and responses to NWM products and intelligence.

The longer term expected outcomes of this work will (1) contribute to the greater understanding of the role of hydrological models on individual, community and institutional behavior; and (2) improve regional community resilience to water hazards through improved outreach and communication strategies. We will develop games using Unity software (Unity Version 2021.2.7). Serious games will be hosted online, with data transferred and secured on UVM servers to protect participant confidentiality. Cluster analyses, structural equation modeling, mixed-effect logistic regression modeling and machine learning approaches will be used to provide insight into efficacy of communication strategies, interpretation of NWM products, and intelligence. Additionally, following each serious game, participants will answer a selection of survey questions, providing additional demographic, risk aversion, and social preference data that will allow for further analyses and coupling to serious game-derived behavioral response and decision-making data.

Task 4.3: Regional Impact-based Decision Support Empaneled Focus Groups (DSEFG). This task will be led by Chris Koliba and supported by Shrum, Merrill, Ricketts, Fisher, Wemple and Zia, as well as the EFD GRA. The objectives of the DSEFG are as follows: Objective 4.3.a: Understand how water hazard information is processed at a community scale; Objective 4.3.b.: Scope out the treatments and parameters of a spatially explicit, regional watershed serious game of the Winooski watershed; Objective 4.3.b.: Co-design water hazard early warning systems and long-range planning using NWM products.

Public participation in scientific research has been demonstrated to improve social capital (Stepenuck and Green 2015) and will be used to increase interaction and engagement with individuals and communities. Specifically, we will take a participatory modeling approach that is designed to generate knowledge that incorporates both community and scientist perspectives (Baum et al. 2006). This approach empowers local communities to address challenges through collaborative communication with researchers, followed by planning, action and then evaluation (McTaggart 1991). In years one and two the Winooski watershed of Vermont will serve as the pilot location for the first empaneled focus group and will include local decision-makers, and landowners who have experienced flooding or drought, and who represent different socioeconomic classes, beliefs, and cultures, business owners and emergency managers. In addition, we aim to include members of the public who collect water level or flow data observations because their knowledge as data generators of data similar to the National Water Model (NWM) may enhance their ability to understand information and products generated by the NWM or to identify ways in which NWM outputs and products may aid in addressing community challenges. The Winooski ERG will meet quarterly over the course of the two years and be facilitated through a series of mediated modeling activities that draws on generative processes found in community of practice (Koliba and Gajda, 2009) and collaborative learning (Daniels and Walker, 2001) frameworks The Winooski EFG will support the initial scoping of experimental game, pilot testing of Winooski region games, provide advice to hydrological modelers, and eventually engage in scenario planning (year 2) to generate recommendations for future outputs, products or communications of the NWM that would improve resilience to water hazards using serious gaming platform. Recommendations for altered products or communications from the NWM to better aid in building community resilience will be developed, as will the empaneled focus group protocols used to guide facilitated dialogue and decision making (Gajda and Koliba, 2007).

Task 4.4: **Mapping and Tracking Floodplain (Dis)connectivity and the Social and Ecological Cost of Floods (SEC).** Faculty leads for this task include: Brendan Fisher, Taylor Ricketts, and Beverley Wemple with support from Koliba, Merrill, Shrum, and Zia and an Ecological Economics Post Doc. The objectives inherent to this task include: Objective 4.4.a: The development of a prototype mapping tool of river channel and floodplain hydrologic connectivity and the distribution of expected flood damages relative to specific river reaches where green infrastructure projects will be impactful on minimizing the social and ecosystem service costs of flood events for the Winooski watershed; Objective 4.4.b: Make the mapping tool responsive to changes in discharge and land use/land cover captured by the NWM and specific to social and private costs and benefits; Objective 4.4.c: Undertake a systemic inventory of impacts of high flow events on the ecosystem services of the Winooski watershed; Objective 4.4.d: Develop cost and benefit estimates to inform social and ecological impact assessment parameters in connected flood inundation models and experimental games.

Stakeholders with responsibilities for water resources management need to be able to access an adaptive framework that evaluates and tracks the degree of hydrologic connectivity of river channels and their floodplains and estimates the social costs of flood events. Drawing on results from project 2, we will develop an approach to calculate the degree of hydrologic connectivity and the magnitude and distribution of socioeconomic impacts given current conditions, but that is responsive to shifts in climate, land use, channel morphology, or restoration projects that modify the landscape or remove physical barriers, detected from the NWM, and from shifts in infrastructure and socioeconomic factors. This work assumes that the next-generation water model will be responsive to regular changes in topography (i.e., from regularly updated DEMs) and land use and land cover characteristics. An ecosystem service (ESS) evaluation framework will be applied to evaluate the impacts of changing biophysical and social dimensions on the landscape, and to ascertain stakeholder sentiment toward ESS values and priorities. Specifically, drawing on survey (task 4.1), experimental games (task 4.2), empaneled focus group (task 4.3) and source document analysis, we will develop ecosystem service costs and benefits for high flow events relative to water quality, sediment transport, flood inundation and impacts on habitat. Specifically, this work will assess 1) ESS across the landscape; 2) how the ESS's change given river and flood plain connectivity and infrastructure; and 3) changes in benefit flows (and to whom) and changes in the values of those flows. The ESS value of flooding over space will be estimated using depth-damage curves and data on houses, infrastructure and socioeconomic factors and integrated within an ecosystem services framework. At annual intervals, NWM analysis and assimilation hindcast data will be used to update connectivity metrics and the economic value of damages and their distribution among racial, wealth, and other groups (Gourevitch et al 2021). In years one and two we will develop this framework for the Winooski water of Vermont, where extensive, peer-reviewed stream geomorphic data sets are available for field-verifying incision ratio and floodplain (dis)connectivity has been classified using a machine learning approach (Underwood et al., 2021). Impact assessments on transportation, energy and agriculture infrastructure will be conducted, as will cost estimates for infrastructure divestment options, as well as the social, environmental and economic costs of structural and non-structural flood mitigation scenarios.

4. Milestones and Expected Outcomes. The tasks associated with the Enhanced Forecast Design subject will tie into NOAA's positionality as the federal authority on climate services by advancing knowledge of regional variations relative to water hazard risk perceptions, employing experimental design approaches to understanding the efficacy of NWC forecasting tools, advancing stakeholder engagement protocols that allow for regional inputs into the design and uses of forecasting tools, and advancing the use of river and floodplain connectivity to the assessment of ecosystem services. These suite of activities will serve to strike a balance between the environmental costs of water hazards and the economic costs of water hazards. By doing so the EFD project will build extensive understanding of the design parameters that best support "impacted-based" decision support systems using next general NWP products and services. By doing so the EFD project will allow for the pursuit of proven mechanisms (risk communication and knowledge commons) to enhance the adoption of NWM products across the country. The early year applications to one region will be used as a prototype to be shared across NOAA and CIROH stakeholder groups. To achieve this overarching outcome, the EFD team, lead by Koliba, will convene NOAA and CIROH user groups (social and natural scientists) in quarterly online "design charrettes" that will be used to disseminate new findings and best practices relating to forecast design, serving as initial "community of practice" to support the evolution of the CIROH Forecast Design Center.
Specific Milestones and Outcomes associated with EFD Project 4 is provided in the table below.

Table 4.1.

Focal Area	Annual Achievements
Scientific Advancement	• Y1: National Water Hazard Risk Perception (NWHRP) survey designed and implemented

	• Y2: NWHRP instituted annually- panel data collected • Y1: High flow experimental game for Winooski watershed developed • Y2: High flow experimental game for Winooski watershed with integrated connectivity and ESS developed • Y1: Empaneled focus group for Winooski watershed conveyed and invited to inform EGs and ESS cost estimates • Y2: Empaneled focus group for Winooski undertakes scenario planning using EG outputs • Y2: ESS framework modules developed for incorporation into NWM products
Products and Documentation	• Y1 &2: Produce NWHRP survey results on public facing website • Y1 &2: Publish public-facing EG (v.1 & v.2) to demonstrate proof-of-concept • Y2: Provide open access to NWHRP and EG results • Y2: Publish user guide for integration ESS into forecast design • Y2: Publish stakeholder engagement guide for forecast design
Operational Change	• Results from surveys, EGs and ESS applications are used to design NWM products and services. • EFD team convenes CIROH and NOAA community of practice focusing on forecast design, leading to deeper collaboration, coordination, and integrated scope of work Y3+.
Broader Impacts	• Advance NOAA's knowledge of forecast design and use through the use of experimental gaming and ecosystem service valuation • Advance NOAA's mission to be the federal authority for impacts-based climate services
Overall Summary	• Publish 4 peer reviewed articles by the end of Y2 • Deliver 7 presentation at national conferences • Mentor 2 post docs and 1 Ph.D. student • Publish national survey results on open source platform

5. **Dependencies, Risks, and Mitigations**. The dependencies inherent to the research with other projects and actors outside of the project 4 team lies in task 4.4, in which the river and floodplain connectivity hydrology modeling will be needed to overlay an ESS framework and integrate into EGs.
Internal dependencies lie at the intersections of tasks 4.2 and 4.1 and 4.4. Mitigation: early development of ESS framework and scoping of early EGs can be undertaken without the integration of a connected hydrology model. Potential risks include: Personnel departure. Mitigation: provide robust documentation, redundancy of tasks and knowledge sharing. Year 2 serious games will synergize with results from national survey work, Social Costs, and ESS work. Specifically, game design will lean on identified gaps in knowledge from work completed in Year 1. Mitigation: Treatments, temporal scales and audiences that could provide the most relevant data may be iteratively reframed through collaborative work with other NOAA and CIROH partners. Thus, collaborations may provide pivot points, allowing us to use the existing serious game framework to investigate more pressing concerns during development of the next-generation NWM, such as refining risk and uncertainty messaging to create behavioral responses that are more appropriate to conflicts faced by NWM users and stakeholders.
Survey design risk – general public comprehension of survey questions can vary widely, especially for more complex subjects. Mitigation: conduct thorough pretesting and piloting of the survey and utilizing experienced survey designers to guide survey development and refinement. Panel recruitment and retention risk – accessing end users of the NWM can prove challenging. Retaining panel participants over time is also difficult. Mitigation: Developing relationships with stakeholder groups (e.g., meeting with leaders of

departments of transportation, using network contacts for real estate and developer associations) and sending research assistants to conferences and other gatherings of key end users (e.g., renting a booth at a farmer convention); Focusing on developing a smaller panel (N = 200) and providing competitive compensation for survey panelists (e.g., $20/survey). Departure of empaneled focus group members over time. Mitigation: replacement members will be sought that provide comparable expertise and experience.

6. **Work performance sites. The Social-Ecological Gaming and Simulation**. The Social Ecological and Simulation (SEGS) Lab is a transdisciplinary research lab focused on modeling and simulating Social-Ecological Systems from a complex systems perspective by drawing on a range of data sources from simple metadata to "big data". The SEGS lab is dedicated to using complex data science tools and human resources to tackle Wicked social-ecological problems faced by society. The SEGS lab was founded in 2014 to work on understanding the influence of human behavior and decision making in complex social-ecological systems. A unique feature of the SEGS lab is its focus on the design and implementation of a variety of serious games and computational models. The SEGS lab is a dedicated technical laboratory with capacity for advanced simulation, gaming and data processing, including capability for in-house and remote workshops. Core team members Shrum (Behavioral and environmental economist), Clark (Data Scientist and Complex Systems), Merrill (Experimental Gaming, Systems Ecology, Data Analysis and Modeling), Koliba (Policy and Governance) and Zia (Integrated Modeling, Artificial Intelligence, Machine Learning and Social-Ecological Systems) have worked extensively together on multiple projects.

7. **Data Sharing Plan**. The primary families of data generated by this research proposal are broadly grouped as Serious game data, Modeling data, Focus Group data and National Survey Response data. Neither type of data will include identifying information from participants. **Serious Game data** includes use data from each game. Recorded game inputs will include the time series of user inputs and resulting outputs as well as simulated game treatments**. Survey Response data** includes demographic data, and data associated with perceptions and behavior associated with NWM products and intelligence.

Data Plans *and Intellectual Property Agreements*

Format and standard of primary data: Metadata and formatting will comply with the standards set by the Inter-University Consortium for Political and Social Research (ICPSR), "Guide to Social Science Data Preparation and Archiving".

Metadata to be collected and disseminated with the primary data: The data from this project will take numerous different formats and require different metadata content. Social and economic science statistical data will be stored in text, database, or excel files. These data will be stored on the SEGS Lab server and be accessible through a network file share. Work will be conducted in full compliance of Institutional Review Board requirements. Metadata and formatting will comply with the standards set aside by the Inter-University Consortium for Political and Social Research (ICPSR), "Guide to Social Science Data Preparation and Archiving" [2009]. This directly follows the recommendations in the recent National Science and Technology Council Subcommittee on Social, Behavioral and Economic Sciences prospectus entitled "Social, Behavioral and Economic Research in the Federal Context." [NSTC, 2009] Metadata will include: time and date, study title, data description, and license.

Timetable of release of ALL data, consistent with privacy and other concerns regarding sensitive information: Access to data will be limited to proposal team members until publication of the main findings and made public afterwards by incorporation into ICPSR no later than publication of the main findings. All types of data will be archived and preserved using national and international archives that follow the best practices in archiving as outlined by Fienberg (1994) so that data are found on the internet, that data are accessible while taking into account relevant legislation with regard to personal information and intellectual property and that the data are usable, reliable and can be referred to. Social science data will be archived and preserved at the ICPSR database. The ICPSR is an international consortium of roughly 700 academic institutions and research organizations that maintains a data archive in the social sciences, housed at the Institute for Social Research at the University of Michigan in Ann Arbor.

Intellectual Property Agreement and Timeline: Data will be distributed in the ICPSR database. Authorship for publications arising from each objective will be determined by the objective lead. We do not anticipate any financial benefits of intellectual property. Authorship disputes will be resolved by engaging a mediator from the UVM Office of Research Integrity. Data use and intellectual property agreement drafts have been developed that include the following language:

1. The Parties agree that dissemination of Project findings and intellectual property, by publication or otherwise is a valuable objective of the Project. Joint publications are encouraged with authorship of such publications decided according to commonly accepted conventions for scientific publications.
2. Collaborators shall provide UVM access to, either electronically or in paper form, a copy of every publication of material based on or developed under this agreement for use and distribution on the Social Ecological Gaming and Simulation website.
3. Neither Party shall use the other Party's name, trademarks, or other logos in any publicity, advertising, or news release without the prior written approval of an authorized representative of that Party.
4. Timeline: The term of this Agreement shall be for duration of the project plus two years, after which all data will be made public by incorporation into ICPSR.
5. Access policies for data and intellectual property are based upon the recognition that data from publicly funded research needs to be made public while being mindful of the need for researchers to publish their results. Access to data will be limited to the project researchers until publication of the main findings and made public afterwards no later two years after the termination of this award, following recommendations from studies of best practices for data access (Jones, 2009; Ball, 2010). A data sharing agreement template which outlines who will have access to the data, how they will access the data, and the specific allowed uses of the data, including re-distribution, if applicable, has been created and will be used to structure any collaborations (e.g. USDA APHIS) which require data sharing.

Public repository to be used: Data will be archived and preserved at the ICPSR database. The ICPSR is an international consortium of roughly 700 academic institutions and research organizations that maintains a data archive in the social sciences, housed at the Institute for Social Research at the University of Michigan in Ann Arbor.
All data will be archived and preserved using national and international archives so that data are accessible while taking into account relevant legislation with regard to personal information and intellectual property and that the data are usable, reliable and citable.
License for use: Data use will follow ICPSR access policy.
Constrains on release: None.
Person(s) responsible for the release: Merrill will be responsible for the data release.
Software and code: All code from the analysis and agent-based model will be made available through GitHub no later than when the main findings are published.

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