An Overview of Using USGS Economics to Estimate the Costs and Benefits of Flooding and Cascading Hazards

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U.S. Department of the Interior

U.S. Geological Survey

General Comments on Economic Analyses

Key Elements of Common Methodology – this section distinguishes the key elements of a common methodology, and the necessary modifications to the proposed methodology.

· One important distinction that is not highlighted in this section is the difference between economic and financial costs associated with flooding events. While lost revenue to government or the private sector is an important metric to highlight, this is often different than economic costs. The distinction between economic and financial costs should be made explicit throughout the methodology.

Updated Version of Methodology – this section identifies direct damages, indirect effects, and losses and additional impacts under the list of impact categories.

General Comments on Economic Analyses

· Identify in each category the suite of methods used (replacement costs, CGE modeling, benefit transfer, etc.) and the data needed to implement. For example, many categories indicate that costs are based on the cost of replacement services (i.e., transportation infrastructure, schools, etc.) but the specific methodology or the information needed to implement the methodology is not explicit. It may be beneficial to list, prior to listing damage categories, all possible methods to estimate flooding costs.

· An important aspect of the evaluation of flood impacts is not to double count the economic costs. This is stated in the document, but not evident in all categories. For example, in the Health category the costs of phycological and stress are mentioned. However, it is not clear how

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impacts due to changes in streams of revenue. These two should not be conflated and careful attention should be made between economic costs and financial impacts.

· In the infrastructure category there is mention of costs associated with construction of walls or dikes. I assume this is to prevent future flooding? These costs are different, unless the construction is to replace existing walls or dikes that were damaged, than the costs associated with damages related to flooding. This distinction should be made clear.

· Effort should be made between estimating replacement costs and expected decline in economic benefits (consumer and produce surplus) into the future. For example, in the tourism category the replacement cost method is discussed. However, there may be significant economic costs to visitors (lost consumer surplus) during the interim time when visitation is limited. This is also the case for producers. While replacement cost of infrastructure and other capital used in the production process is the fists step in costing

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methods. impacts to loss in economic benefits
(producer surplus). Producers may have costs to replace capital for production but may also face difficulty obtaining loans or face other institutional constraints that reduce production over the long run (this would also impact consumer benefits). These ideas come through in most categories. However, this should apply to all categories.

· There may be other non-market losses than just public spaces. This is true of tourism and other categories, such as environment, that frequently involve non-market goods and services.

· The housing category provides an important example of separating decreased economic benefit and transfer of wealth. We want to capture the costs related to flooding and the changes in economic benefits to consumer and producers from long-run changes in economic conditions. However, we don’t want to include ‘rent seeking’ behavior in our assessment of economic costs. Rent seeking results in a transfer of wealth and may not be equated with a change in economic benefits. This should be made explicit in the discussion

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USGS Collaborators: Thank You

- Kristin Ludwig, Staff Scientist, Natural Hazards Mission Area
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- Alice Pennaz and Emily Brooks, USGS co-leads on the Strategic Hazard Identification and Risk Assessment on DOI Lands (SHIRA) project.
- Dennis Staley, USGS Landsides Hazards Program

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Overview of Recent USGS Collaborations Regarding Cascading Natural Hazards

- Assessing Coastal Change Hazard through the Puget Sound Coastal Storm Modelling System: Swinomish and Nisqually Tribes.
- Swinomish Conceptual Model
- USGS Response to Hurricanes-Tools and Products. Warning System for Cattail Creek in the Meskwaki Nation (Sac and Fox Tribes)
- Post-fire debris flow hazard assessment (Nez Perce and the Stanilaus NF in CA).
- Strategic Hazard Identification and Risk Assessment of DOI Lands (includes BIA tribes)

Integrating the Gravity Recovery and Climate Experiment (GRACE) into flood forecasting and Landsat into wildfire management decisions

Decision with earth science: Value is dependent on whether the EO reduces the uncertainty in outcomes.

Microeconomics approach: Estimates the economic impact of a specific decision of with improved scientific information compared to the impact with existing information.

Apply Probabilistic Decision Methods and Benefit – Cost Analysis to evaluate a GRACE-enhanced flood hazard communication, and Landsat for wildfire management, mitigation and restoration

Implementing a probabilistic model to measure the socioeconomic benefits of remotely sensed Earth Observations (EO)

3 components:

- Probabilistic model (ensemble product): Spatiotemporal EO data improve the reliability of existing forecast and monitoring methods of ecosystem services and natural hazards
- Valuation (quantitative method – market, nonmarket): Economic estimation of return on investment (expected benefits) to reduce societal risks
- Empirical analysis: Integration of the probabilistic earth science model and values at risk for impact assessment

2 examples:

- Probabilistic model and valuation: With and without GRACE, NOAA NWS river discharge forecast for floods; With and without Landsat in protecting critical resources from wildfire
- Empirical analysis: An economic model for estimating the societal benefits and savings provided by the information

Use case: Impact assessment of integrating GRACE data into flood hazard communication

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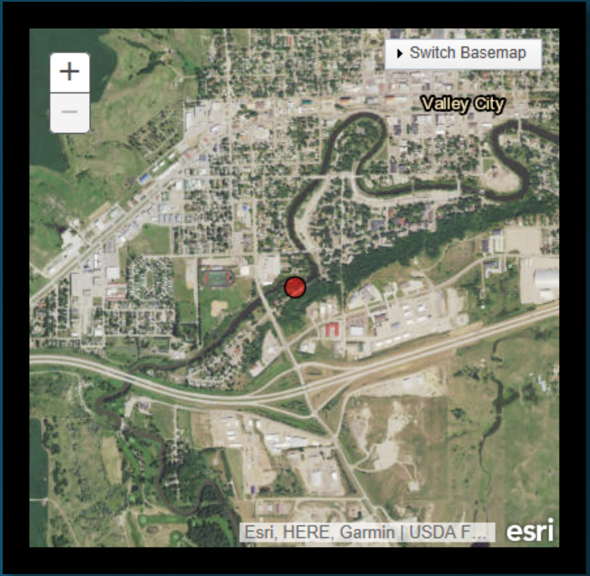
Drivers:

National Weather Service (NWS) Policy Directive 90-2 September 30, 2016 Staffing and Organization NWS Mission and Organization

Department of the Army U.S. Army Corps of Engineers Risk Assessment for Flood Risk Management Studies, Engineer Regulation 1105-2-101, July 17, 2017, Circular No. 1110-2-6074, 31 January 2018, Engineering and Design Guidance for Emergency Action Plans, Incident Management and Reporting, and Inundation Maps for Dams and Levee Systems



Context:

NWS river discharge forecasts are used to estimate flood risks, and to inform decisions about hazard communication, mitigation, and disaster planning and response.

Evaluate the impact to reservoir operations and to what extent those impacts would have resulted in better decisions being made for emergency response / advance measures.

DEPARTMENT OF ECONOMICS RFF VALUABLES CONSORTIUM NASA JOHNS HOPKINS UNIVERSITY US Army Corps of Engineers St. Paul District NOAA NATIONAL WEATHER SERVICE

Probabilistic river flow forecast and GRACE – Data Assimilation

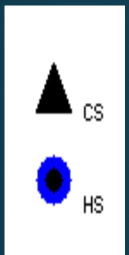
Flood Hazard Communication:

- National Weather Service (NWS) produces expert-based probabilistic river flow forecasts to assist in flood protection and emergency measures
- Consists of the Community Hydrologic Prediction System (CHPS)
- Includes regional updating process to accommodate for local conditions
- Informs USACE and stakeholder flood protection, management decisions and emergency response

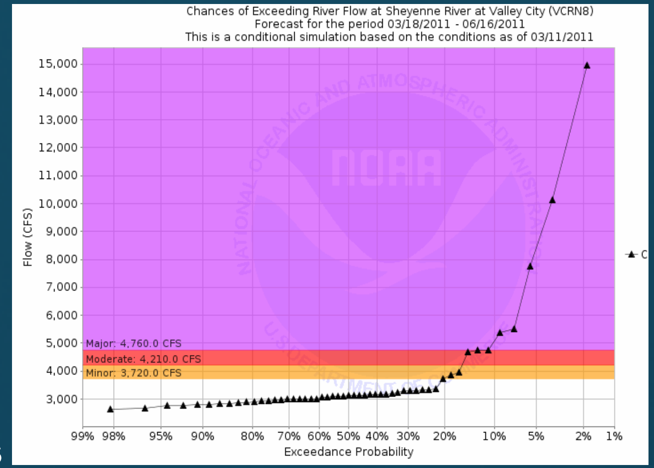
GRACE Soil Moisture Data Assimilation:

- Ensemble of GRACE data and a land surface model provides a distribution of soil moisture storage data to the Sacramento Soil Moisture model
- 3-month soil moisture wetness percentiles as a statistical distribution

Valley City, ND probabilistic forecasts

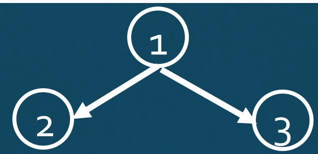


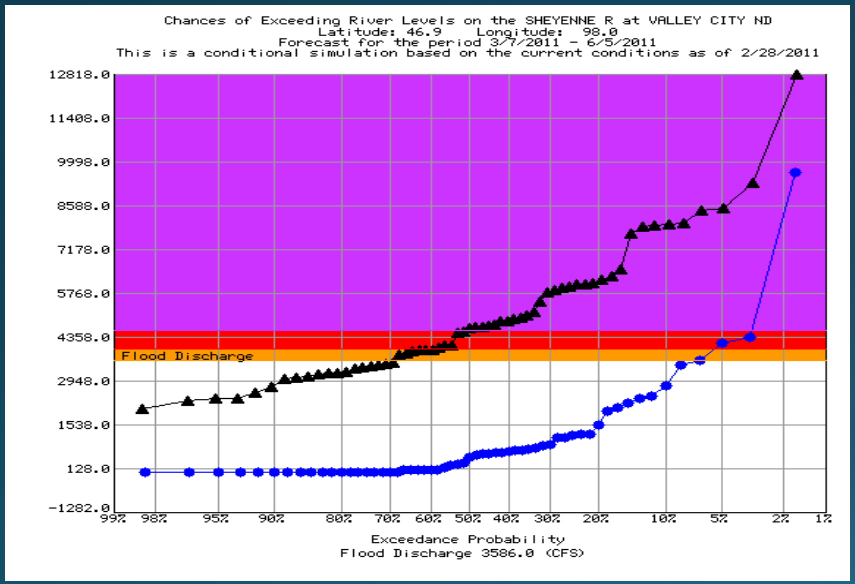
Conditional simulation (CS) line indicates chances of the river going above given levels based on current conditions.
Historical simulation (HS) line indicates the chances of the river going above given levels based on the total range of past levels.

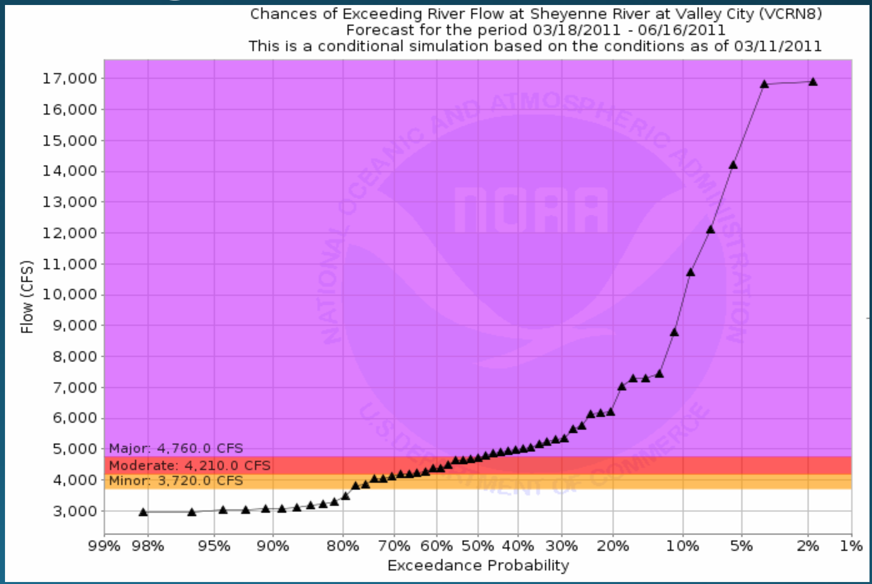


1. ESP Open – 03/11/2011
2. NWS (ESP + MODs) 02/28/2011
3. ESP + GRACE - 03/11/2011

Flood Categories (in feet)	
Major Flood Stage:	17
Moderate Flood Stage:	16
Flood Stage:	15
Action Stage:	12.5







NWS - Chance of Exceeding Stages at VCRN8 3/7/2011 - 6/5/2011

90%	80%	70%	60%	50%	40%	30%	20%	10%
12.8’	14.0’	14.8’	15.9’	17.2’	17.5’	18.6’	19.0’	20.9’

2011 Peak Flood Stage = 20.7 ft.

River flow exceedance probabilities

VCRN8 QINER	10% [cfs]	20% [cfs]	50% [cfs]	Flood risk (%)	Major flood risk (%)
open 01/18/2011 – 04/17/2011	4,841.5264	3,514.3191	3,022.6165	< 20%	10%
GRACE adjust 01/01 01/18/2011 – 04/17/2011	4,475.1245	3,500.7190	2,994.4163	< 20%	< 10%
open 02/18/2011 – 05/17/2011	5,317.7290	4,590.9248	3,126.7170	< 10%	15%
GRACE adjust 02/01 02/18/2011 – 05/17/2011	6,598.2358	5,016.8271	3,081.0168	< 10%	20%
open 03/18/2011 – 06/17/2011	5,372.3296	3,723.9202	3,125.0171	< 10%	15%
GRACE adjust 03/01 03/18/2011 – 06/17/2011	10,733.8594	6,198.2339	4,722.4253	75%	50%
open 04/18/2011 – 07/17/2011	10,559.5576	8,192.2441	5,075.5273	> 98%	75%
GRACE adjust 04/01 04/18/2011 – 07/17/2011	12,752.9688	11,063.7607	8,726.9473	> 98%	> 98%

Source: NWS 2018
Flood Stage = 15 ft. (3720 cfs), Moderate Flood Stage = 16 ft. (4210 cfs), Major Flood Stage = 17 ft. (4760 cfs)

Cost effectiveness of estimated protection cost savings from an improved hazard communication

Evaluate the outcome without (ESP) and with (ESP + GRACE) GRACE DA

- Savings could be realized if emergency measures were "built" in Valley City
- Assumptions for analysis: No change in structural damage to buildings, 1 event determined by USACE as high flow event in April, 2011, mitigation cost of $1.3 million at $16.85 per cubic yard

Savings would have been $6.11 per yard of clay placed
Efficiency gain by planning with a more accurate flood crest estimate by 3/11/11
Waiting caused a scramble for resources late due to the severity of the flood
Resulting in a higher price per yard

Hypothetical example:

- Valley City, ND property at risk = $169M (2009)
- Mitigation cost (Reference) = $3.0M (2011)
- Mitigation cost with GRACE DA (Counterfactual) = $1.3M
- Mitigation cost savings = $1.7M

Use case: Integrating Landsat into wildfire management

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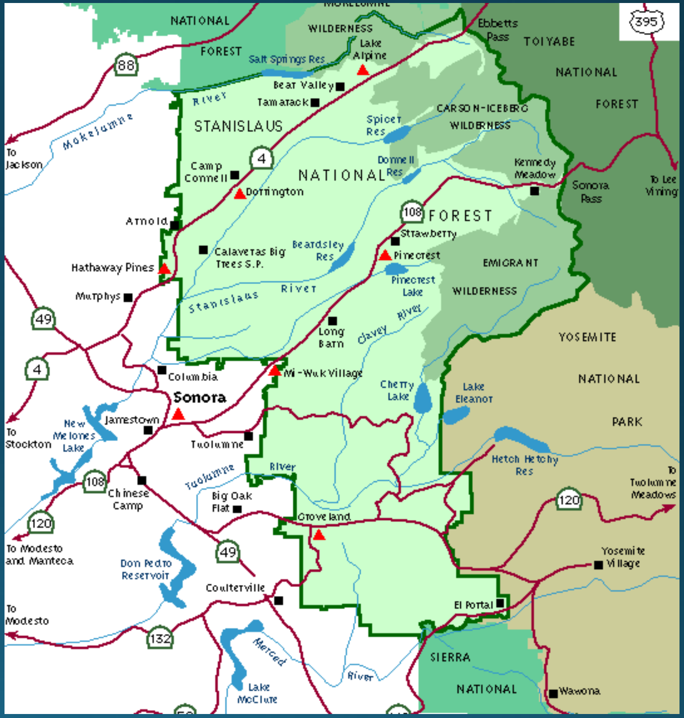
- **Drivers:**
- **Forest Service Manual FSM 2500 - Watershed and Air Management, Chapter 2520 - Watershed Protection and Management (2020) – critical resource assessment**
- **Stanislaus National Forest Plan Direction (2017) – forest management implementation**
- **The Federal Land Assistance, Management and Enhancement Act (2009) – enacted legislation for forest management**
- **Context:**
- **Wildfire is a source of natural and human risks.**
- **Fire is physically characterized by its burn severity (Keely 2009) in a location at a moment in time.**

Evaluate the impact of a severe wildfire on habitat suitability, forest infrastructure and other critical resources

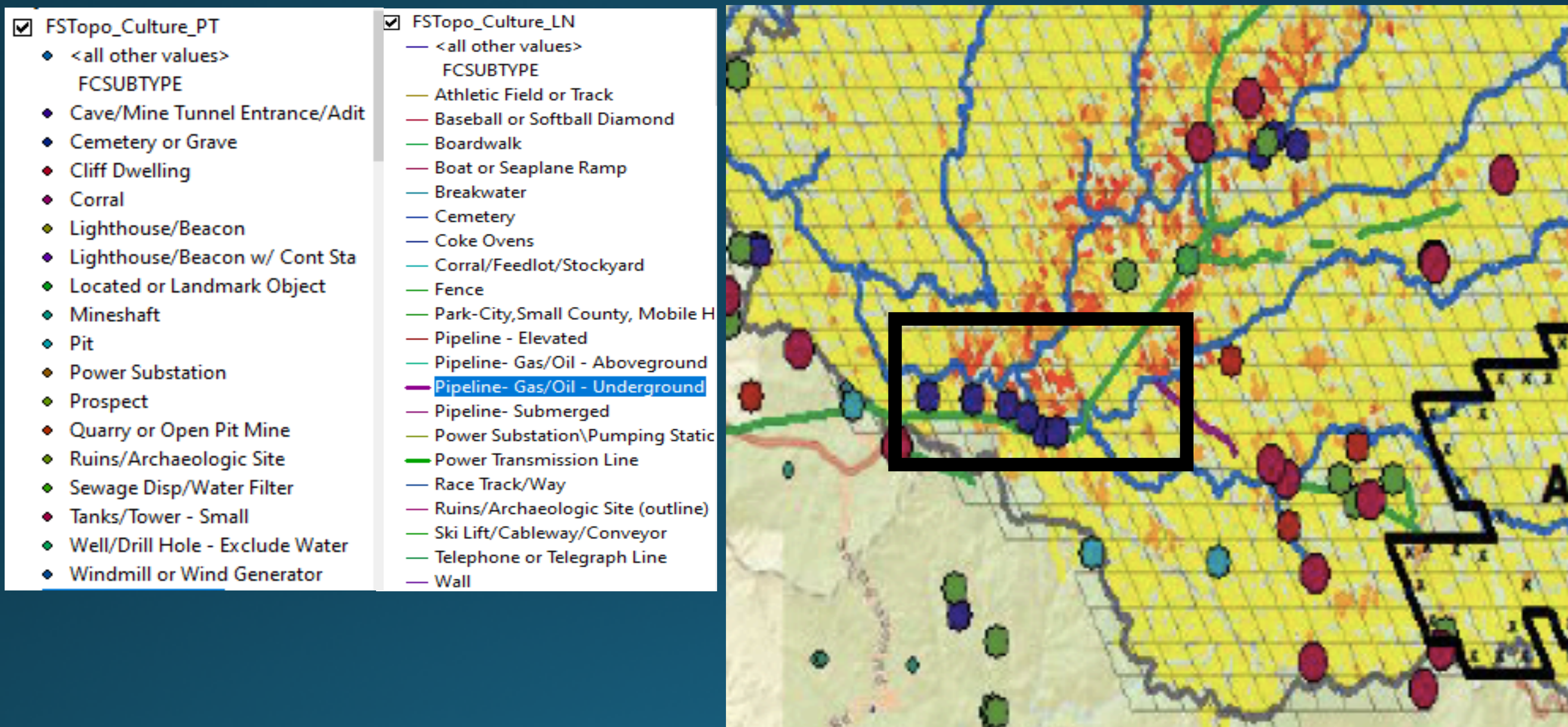


Stanislaus, Sierra National Forests and Yosemite National Park

Steps in a Causal Probabilistic Natural Science / Economics Framework

- Step 1: Rank quality and quantity of critical resources
  - Develop a correlation matrix of critical resources
- Step 2: Create a spatiotemporal model
  - Develop use cases
    - WTP for California spotted owl and black bear habitat
      - Predict probability of habitat suitability (pre and post fire)
      - Monetize the value of a change in spotted owl habitat suitability
    - Risk assessment of post-fire landslides in an ensemble model (current year)
- Step 3: Analyze forest and range policies
  - Estimated the cost effectiveness of prescribed burns in Stanislaus N.F.

Analysis of interdependence of CA spotted owls, landslides, built environment and cultural resources



Estimated benefit of \$1.13M and cost of \$1.55M for a prescribed burn program in Area A to protect spotted owl habitat.
Black bear gets a “free ride” due to positive correlation with the spotted owl.
Debris flow could impact power station and transmission lines

Summary

GRACE DA

- Reduces uncertainty of water storage estimates for flood forecasting
- Adds a data input to improve estimation skill in river flow forecasts
- Tests via statistical analyses demonstrate that DA is an improvement over conceptual models.

Landsat

- **Landsat imagery in support of LANDFIRE can be used to estimate societal values needed to inform wildfire management**
- **Resource managers use LANDFIRE and other scientific information in short term mitigation and restoration decisions and for longer term strategic resource management and planning.**

Cases: What was achieved

- **Utilized quantitative analysis to value EO in a specific decision**
- **Connected satellite information products to an operational application**
- **Measured the economic impact of the information uncertainty to the decision maker**
- **Identified how the scientific information can be used by resource and in local communities**