Building better flood risk maps: Lessons learned from the electric car

An invited comment by Bob Freitag, Dave Carlton, and Joe Hamman

Engineers have long depended on historic flow information for creating food insurance rate maps (FIRMs), determining the benefits of mitigation projects, and determining design standards for future projects. The longer the period of record, the more comfortable they feel with their projected outcomes.

Flood risk analysis assumes stationarity. For example, it assumes—removing seasonality—there is no long-term trend in the distribution of flooding over time. The 100-year flood in 1970 is the same as the 100-year flood in 2000 is the same as the 100-year flood in 2030.

But the assumption of stationarity is changing under changing climate conditions. "Assumptions on the occurrence of major hydrologic events to analyze extremes are based on the notion of stationarity, yet observational evidence increasingly shows that this assumption is untenable," according to the National Research Council's 2011 report *Global Change and Extreme Hydrology: Testing Conventional Wisdom*.

Using this logic—that the past predicts the future—almost stranded Karl Kim and his electric car.

Karl heads the University of Hawaii Natural Disaster Training Center. His office is in Honolulu, about 10 miles downhill from his Manoa home. Years ago he had installed solar cells on his roof, but with his kids off to college, he found he had extra power. What better way to use this surplus electricity than to charge an electric car? He bought the all-electric Nissan Leaf.

Shortly after he purchased his car, on his way to work, he noticed the car's computer estimated a 50-mile range. With 10 miles to work and 10 miles to return home, he felt confident the trip was well within the car's anticipated range.

The problem was that the car's computer, not unlike the algorithms used to develop Federal Emergency Management Agency flood insurance rate maps, was based on historic information. On the way to work, Karl was going downhill. Driving home uphill, the car's range projection was less than 10 miles. The estimate his car made earlier that day made no sense now.

Karl made it home, but barely.

For future trips, Karl has done what every electric or hybrid car owner does. He mentally devised alternative forecast scenarios.

One of the authors of this piece, Bob Freitag, also has an electric car. Well, sort of. It's an older Honda Insight hybrid. It can get close to 70 miles per gallon if he devises and sticks to a scenario. Unlike Karl, Bob does have a 67-horsepower, one liter gasoline engine. Although the risks are less dramatic, Bob has the same need to develop scenario-based projections for many trips. Bob's car is not as energy efficient, but he has more choices. He can better deal with changing conditions.

For instance, Bob lives in Seattle. His in-laws live on a ranch in Oregon. The best route to the ranch is over the Cascade Mountains. To make 70 miles per gallon he has to deplete all electrical power reserves when reaching the summit. This requires him to continually reevaluate and adjust his scenario as he ascends. If he depletes his charge before getting to the top, his little car chugs up the mountain with its one liter engine, often averaging less than 20 miles per gallon, and suffering the embarrassment of being passed by 18-wheelers. The risks to Karl are much greater, but so are the opportunities. Karl can make well over a 100 miles per gallon equivalent, but he may not reach his destination if he miscalculates.

Establishing the FIRM

So what does this mean for flood insurance rate maps? It means that we have to stop fooling ourselves into believing that our extensive historical data sets allow us to always provide realistic projections of flood risk today, or in the future. FIRMs, not unlike Karl's trips in his electric car, should be based on scenario-based projections that account for changing environments. The greater the potential for change, the less applicable our historic information.

What could possibly change how water spreads over the historic floodplain? Changes in land cover and climate are the most obvious. But there are many more, including agricultural withdrawals, reservoir operations, and stormwater management. To account for these changes, we should base our projections on scenarios driven by the road ahead and not solely on historic information. These scenarios must be watershed based, considering changes in climate, land cover and land use as well as the communities' capabilities to mitigate these changes.

What would scenario-based flood risk maps look like?

Following Karl's lead, we could develop future condition scenario-based flood risk maps (SFRMs) based on an evolving landscape and climate. The SFRM would provide discharge and inundation estimates that could be used for planning, zoning, and building. Many communities have developed and are currently using future conditions maps to guide development and land use decisions.

In the same way that the FIRM is not appropriate to define future risks, the SFRM would not be appropriate to define current risks for setting insurance premiums. However, a SFRM could be used to design one end of a time varying probability distribution for discharges beginning with the current FIRM. (See figure below.)

Using a SFRM as the endpoint, we could develop a distribution of future flood risk beginning with the existing FIRM. The current risk would be determined from the curves illustrating varying discharges beginning with the FIRM and ending with that representing the chosen scenario. The discharge at any point in time for any return frequency could be mapped. This scenario-driven flood insurance rate map (SFIRM) would differ from the current FIRM in that insurance rates would be based on an estimated risk for a given time period. Insurance premiums would change with time as risk estimates change.

Applying existing National Flood Insurance Program (NFIP) principles to the SFIRM would result in structures being built within the SFIRM floodplain, implementing floodplain management construction regulations while not being required to purchase flood insurance at the time of construction. Construction built to be safe from future floods is a key rationale for land use planning. Insurance would still be an incentive by allowing for the purchase of flood insurance at any time.

Leora Waldner, in her 2007 article "Floodplain creep and beyond," suggests an approach for developing a scenario-based risk map. She says the amount of the nation's land considered to be at risk of flooding is growing. So we must reassess how we define floodplains and risk. She mentions four "next generation" issues to be addressed. These represent a starting point for the development of a SFRM. We have added a fifth, climate change:

- expansion of the floodplain resulting from increased impervious surfaces and development;
- the unrestricted development of homes in the 100-year floodplain;
- the possible cumulative riparian effects of widespread cut and fill practices;
- lack of information for prospective homeowners of floodplain-burdened property or property that may be floodplain-burdened in the future; and,
- natural and anthropogenic climate change are influencing flooding patterns in many watersheds.

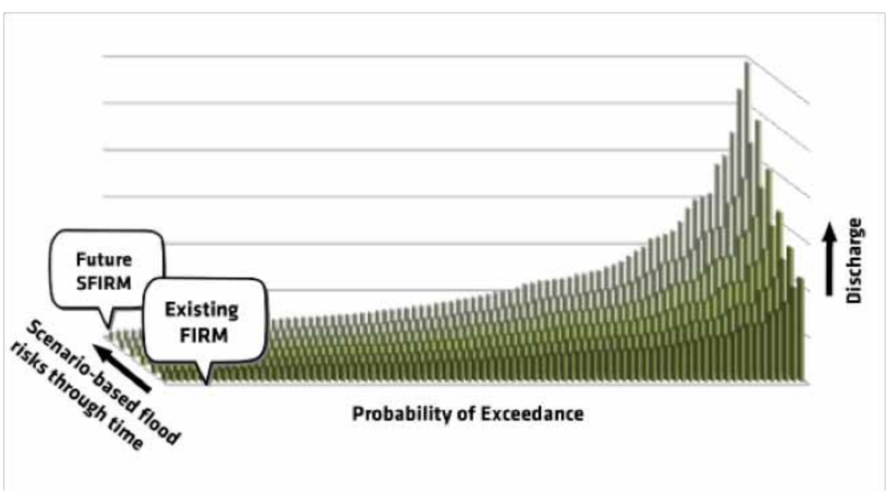


Illustration of varying probability distribution for discharges over time. In this illustration risk is seen to increase through time but that may not always be the case. There are scenarios in which changes in climate, land use, etc.) would reduce flood risk for a given region.

Waldner's list, with the addition of climate change, offers a good place to begin our search for how we might create scenario-based risk maps.

Keying off the items offered by Waldner, we can begin defining future flood risk scenarios. With the exception of her "lack of information" variable, which is more of a capability and not easily mapped, we can begin developing scenario-based flood risk maps that incorporate:

• built-out condition along with a continuance of similar patterns of impermeable land use;
• existing patterns of unrestricted development in the floodplain;
• cumulative effects of projected cut and fill practices; and
• climate change impact scenarios, including changes in water storage as ice and snow, sediment mobilization, watershed vegetative succession, and other factors.

These provide the criteria for developing one or more future conditions scenario-based flood risk maps. These maps would be used for planning a community's built environment.

What can communities do to alter their future conditions scenarios?

These future conditions scenarios do not have to be cast in stone. We are influencing our climate, but we could slow the rate of change or even reverse the trend. Communities could adopt "no adverse impact" measures and reduce discharges. Downstream communities could partner with upstream communities to manage the watershed. Transfer of development rights and increased storage could be options within the watershed.

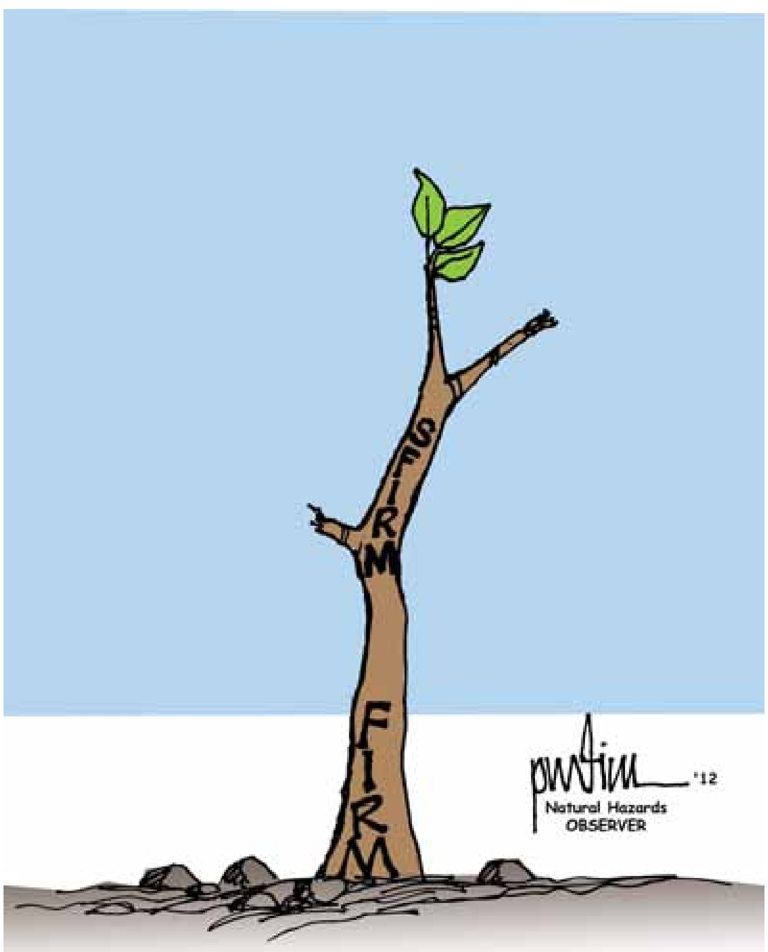
With action, communities can change their risk. Looking at the five variables as examples of a set of opportunities, communities could reduce their risk and their insurance premiums by:

• increasing permeability with low impact development practices, off channel storage, forest land expansion (reduces flood flows);
• restricting development in the floodplain, especially restricting elevating on fill (reduces at risk development);
• expanding riparian areas, increasing storage and connecting floodplains with river corridors (reduces at-risk development and increased flood flows);
• providing actionable information to prospective homeowners of flood-burdened property or property that may be flood-burdened in the future; and
• instituting adaptive climate change measures.

This approach follows the lead of the NFIP Community Rating System. The CRS goals of reducing flood losses and providing better flood hazard management are enhanced when CRS communities adopt the SFIRM approach to mapping their hazard and then developing mitigation strategies. A scenario-based approach to mapping, regulation, and watershed management provides floodplain managers the opportunity to enact flood adaptation and mitigation strategies based on future conditions.

Just as we have the technical knowledge to build an electric car, we can produce flood risk and insurance maps that recognize and help plan for future conditions. In the same vein, it will take a significant shift as we move from flood risk estimation based on the historical record to a more dynamic scenario-based system that takes into account the many non-stationary variables at play in each watershed.

Karl's car and his approach to driving with risk, provides a model for producing better scenario-basd flood risk maps and scenario-based flood insurance rate maps.



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