Coastal Storms Project: Ecological Assessment of Storm Impacts to the Lower Columbia River Watershed by Risk Assessment, Modeling, and Toxicological Testing

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Keywords: risk assessment, contaminants, storms, modeling, surface and groundwater runoff, transport and fate, grass shrimp, toxicity testing, Lower Columbia River

INTRODUCTION

Surface and groundwater runoff from storms can carry contaminants from surrounding areas into aquatic systems, causing the disruption of sensitive ecosystems, including fish kills. It is often difficult to identify the specific cause of a fish kill partly because of the large number of potential causes. There are 3000 chemicals produced in or imported into the US at more than one million pounds per year. Over 40% of high-production chemicals have had no toxicity or environmental fate tests, and only 7% have had all basic toxicity and fate tests (EPA, 2004). As part of the Ecological Assessment component of NOAA's Coastal Storms Project, contaminants potentially posing a risk to the lower Columbia River Watershed were compiled and ranked in a preliminary risk assessment. Through this risk assessment, three contaminants that pose elevated risks to indigenous aquatic fauna were identified. The risks were further characterized using detailed toxicity testing and transport and fate modeling (Figure 1).

RISK ASSESSMENT

Approximately 432 pesticides, 19 PAHs, and 17 metal compounds were identified as potential products used within Lower Columbia River watershed. These contaminants were associated with agricultural, residential and commercial applications; rooftop and roadway runoff; and other non-point sources. Detailed data relevant to application amounts and locations, known toxicity thresholds, and chemical characteristics that affect each contaminant's transport and fate were collected and compiled into an online searchable database (http://www.chbr.noaa.gov/easi). The ecological risks were ranked according to this information, and two pesticides (carbaryl and diquat dibromide) and one PAH (fluoranthene) were identified as posing significant hazards and potentially occurring at high levels after heavy rains. These three contaminants therefore became the focus of the modeling and toxicological testing.

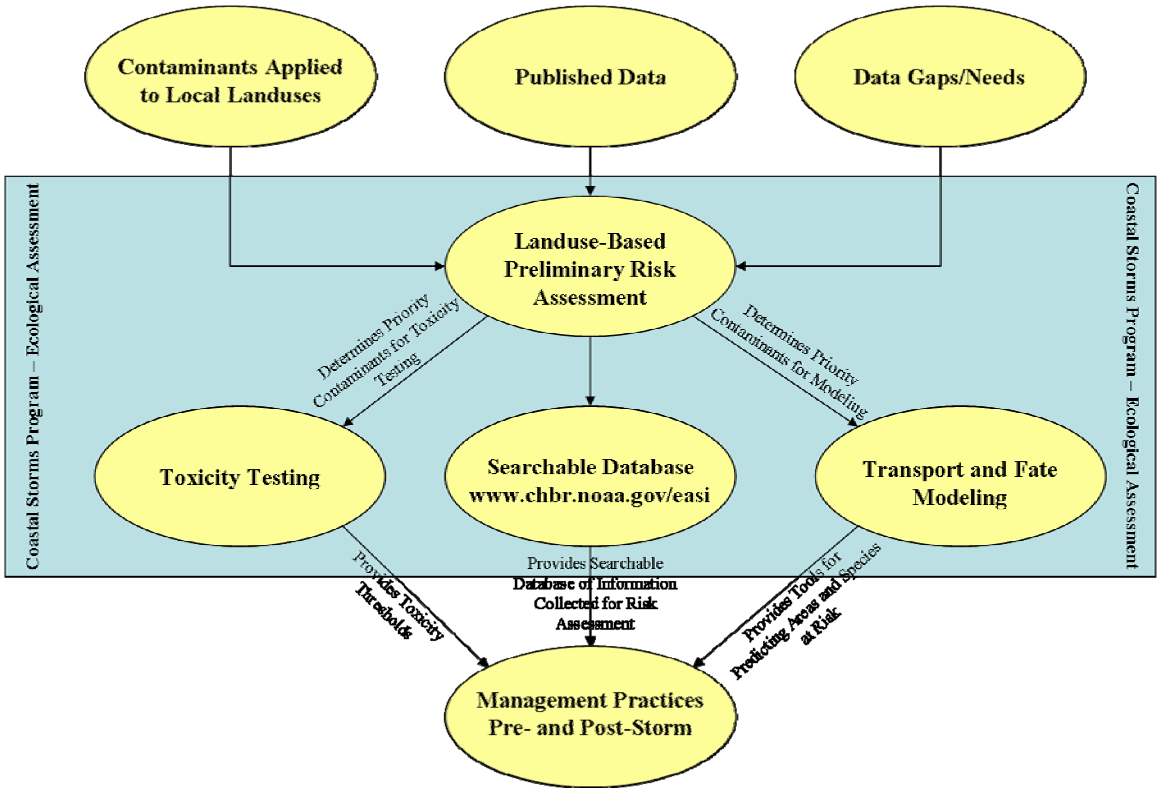

Figure 1. Integration of Ecological Assessment Components

FATE AND TRANSPORT MODELING

The three contaminants were modeled using The Pesticide Root Zone Model (PRZM) (Carsel et al., 1995) and the Exposure Analysis Modeling System (EXAMS) (Burns, 2001). The headwaters of Johnson Creek (a stream located outside Portland, OR) were chosen as the modeling location because Johnson Creek is an urbanized, freshwater stream and a historical salmon spawning habitat with surrounding landuses typical of the Northwest US. The watershed was segmented according to predominant landuse (ie. agricultural, urban, and forested). In the PRZM model, applications of the pesticides were made at the maximum allowed rate one, six, or 16 days before the simulated 2-yr, 25-yr, and 100-yr storms. Fluoranthene was not included in the PRZM modeling but entered the EXAMS model along with other PRZM output. The PRZM model is dependent upon determination of application rates on permeable soil, and fluoranthene readily adsorbs to soils with only small quantities transported through soil (Takada et al., 1991; Yang et al., 1991). Fluoranthene loading was estimated from reported roadway runoff concentrations (Hewitt and Rashed, 1992) and entered into the EXAMS model on days of rain.

The models predicted that concentrations of carbaryl, diquat dibromide, and fluoranthene were dependant upon storm type, with the greatest concentration exhibited after the 100-yr storm. Predicted concentrations in Johnson Creek were up to 370 percent higher following 100-yr storms compared to 2-yr storms, depending upon contaminant. Carbaryl and diquat dibromide runoff concentrations demonstrated dependence on application date. The highest concentrations of carbaryl were predicted when it was applied one or six days before the rain while diquat dibromide was highest when applied 16 days before the rain (Figure 2). Surrounding landuse also had an impact with the highest levels of carbaryl and fluoranthene in the forested region (due to silviculture practices for carbaryl and amount of roadway for fluoranthene) and the highest levels of diquat dibromide in the agricultural region. These results are discussed (Chiovarou and Siewicki, 2007) in terms of risks to spawning salmonids and major prey organisms.

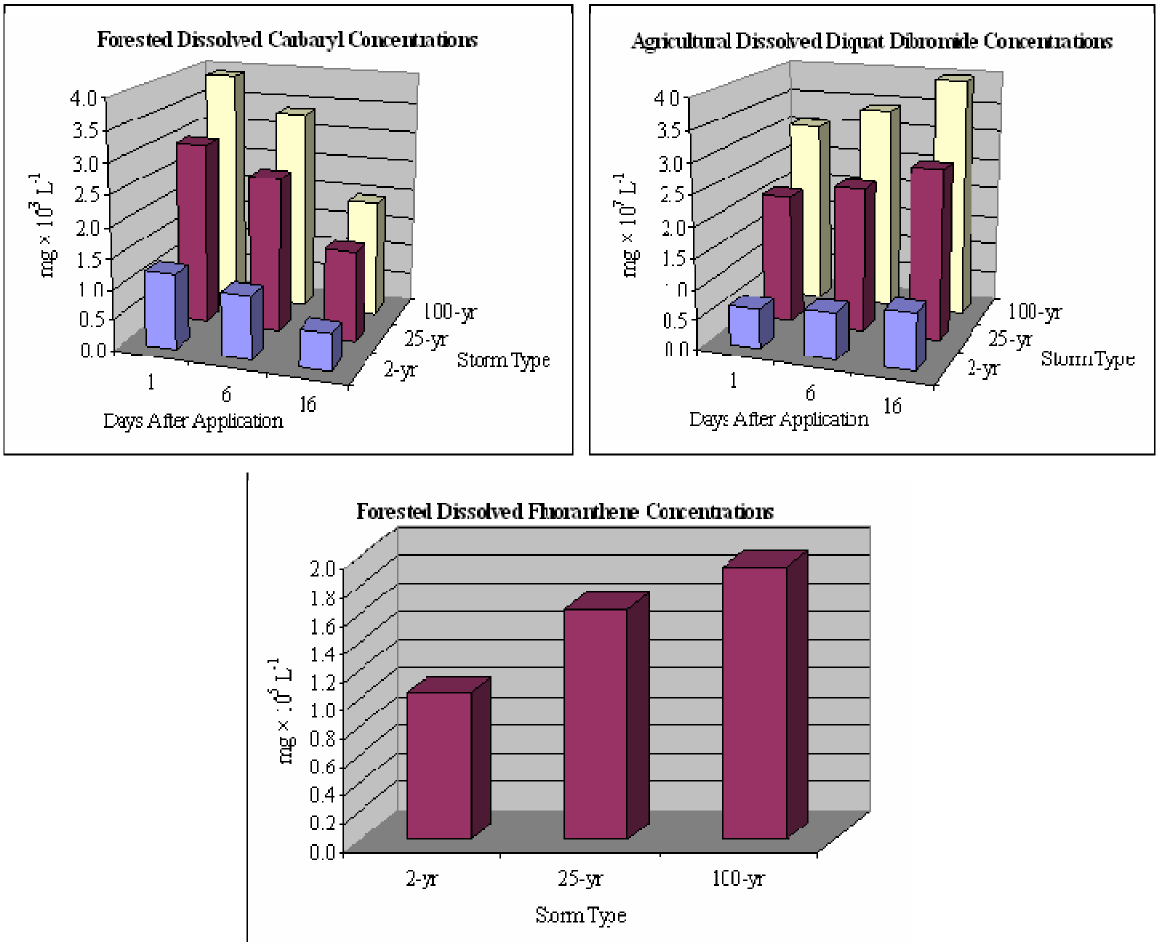

Figure 2. Predicted dissolved concentrations of contaminants in the compartment of Johnson Creek having highest levels following different storm types and application dates: (a.) carbaryl, (b.) diquat dibromide, and (c.) fluoranthene (application date not applicable)

TOXICITY TESTING

The effects of exposure of the three compounds, carbaryl, diquat dibromide, and fluoranthene, both separate and in mixture, were tested on larvae of the grass shrimp, *Palaemonetes pugio*. Fluoranthene was the most toxic chemical with a 96-h LC50 value of 32.45 µg L^{-1}, followed by carbaryl (43.1 µg L^{-1}) and diquat dibromide (1624 µg L^{-1}). In the chemical mixture tests, all mixture combinations displayed the expected additive effect. The binary carbaryl/diquat dibromide mixture and the ternary carbaryl/diquat dibromide/fluoranthene mixture had a stronger additive effect than the binary mixtures of carbaryl/fluoranthene and diquat dibromide/fluoranthene (Chung et al., 2007).

IMPLICATIONS

It is apparent from these studies that all three components of our ecological assessment triad are necessary to characterize risks caused by runoff contaminants after major coastal storms. The results from the risk assessment database, modeling, and toxicological testing can help identify areas and species at risk after a storm and provide tools to help reduce those risks. The web-accessible database can be a useful tool for preliminary risk estimation in a variety of locations. The toxicity testing gives a rare look at mixture toxicity of contaminants found throughout the United States. The PRZM and EXAMS models work together to help identify sensitive species and geographic locations under a variety of conditions and can help focus pre- and post-storm mitigation strategies.

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