Using Prescribed Burn Fire Severity Assessments to Estimate Postburn Hydrologic Risk

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Abstract—Research conducted via the Australian Bushfire Cooperative Research Centre (BCRC) developed methods for assessing postfire hydrologic risk to human life, infrastructure, and water quality. End users of BCRC products identified the project for utilization, and a small team of practitioners and researchers was established. The utilization team developed a three-phase plan. Phase one was an Australia-wide assessment of postfire hydrologic risk and the development of national guidelines based on general principles. Phase two was the application of the national risk guidelines to the water catchments of the Australian Capital Territory. The tools developed included risk algorithms based on geographic information systems, combined with an Australian adaptation of the FIREMON fire severity mapping system. Phase three is aimed at parameterizing the postfire hydrologic models for specific catchments to deliver quantitative information. The project has generated some lessons about the research utilization process: 1) End users must be clear about what they need and have a sound technical understanding of the research, 2) all parties need to have a common picture of what is to be developed and how it is to be used, and 3) researchers should be prepared to synthesize their work such that the complexity of processes does not impede the development of practical tools.

Keywords: burn, fire, hydrologic, quality, risk erosion, sedimentation, water

INTRODUCTION

Heavy rain in areas burned by bushfire can mobilize enormous volumes of sediments and nutrients into rivers and water reservoirs, threatening the quality and supply of water to Australian cities and damaging freshwater ecosystems (Nyman et al. 2011; Sheridan et al. 2009). This is primarily because burned headwater catchments contain large amounts of ash sediment and debris that are readily flushed into rivers and water supply reservoirs by surface runoff. High sediment loads from debris flows cause high turbidity and water contamination due to increased nutrients and metals from pollutants in the runoff (Langhans et al. 2017; Nyman et al. 2015).

This type of contamination occurred in mountainous regions of south-eastern Australia on three occasions in the past 15 years. Postfire debris flows after the Canberra fires in 2003 resulted in water restrictions

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in the Australian Capital Territory (ACT) (White et al. 2006) until a new water treatment plant was constructed. Similar contamination occurred in the Ovens River after the Eastern Victorian alpine bushfires in 2003 and in Lake Glenmaggie after the 2007 bushfires in Victoria. Serious postfire water quality issues have also been documented in the Nattai Catchments near Sydney in New South Wales and the Lofty Ranges near Adelaide in South Australia. These scenarios from various landscapes across south- eastern Australia highlight the importance of considering water quality issues when managing fire in high value water-supply catchments (Nyman and Sheridan 2014).

RESEARCH

The problem that fires pose to water quality was recognized by fire and land management agencies represented on the former Bushfire Cooperative Research Centre (BCRC). In response, the BCRC commissioned the forest hydrology research group of the University of Melbourne to investigate the effects of forest fire on catchment processes. The project was part of the Fire in the Environment theme, which ran from 2010 through 2014 (Bell et al. 2014). Research investigated how fire severity and rainfall intensity in steep hilly landscapes contribute to sedimentation and pollution in forested water supply catchments in south-eastern Australia (Jones et al. 2014). The aim was to deliver findings that could help inform and guide development of tools and resources for land and fire managers to assess and address risks to critical water assets in forested catchments. The work built on many years of research conducted by the forest hydrology research group in collaboration with Melbourne Water and Victorian Department of Environment, Land, Water and Planning (e.g., Sheridan et al. 2009, 2011).

Research Methods

The research addressed two key questions: 1) What are the real risks to uninterrupted water supply if catchments are burned by bushfires? and 2) Can the risk be reduced with prescribed fire? The scientific methods included reviews of the international research literature, surveys of extreme erosion events, and field experiments to quantify the relationships between fire severity, aridity, and postfire erosion (Nyman et al. 2011). The field studies encompassed a wide range of forest environments in Victoria burned during the 2009 Black Saturday bushfires.

Research Outputs

The research showed that at the study site water quality risk was primarily associated with slope, fire severity, and aridity. Risk increased on steeper slopes, at higher fire severities, and in drier landscapes. The relationships between the factors were characterized in a series of models and published in international journals (Langhans et al. 2017; Noske et al. 2016; Nyman et al. 2013a,b, 2015; Sheridan et al. 2016).

Another key outcome from the research was that the results showed the risks to water quality are largely associated with large-magnitude events that are threshold driven. Thus, during most erosion events the risks to water quality are relatively small. But in a few cases the combination of rainfall intensity, fire severity, and slope result in extreme events such as debris flows, and these are the ones most likely to have consequences for water supply and infrastructure. The focus of model development is therefore to represent the conditions when thresholds of extreme events are exceeded.

SCIENCE TO ACTION

Utilization of the research commenced with a meeting between the lead end users, researchers, and the Australasian Fire Authorities Council (AFAC). A key issue going into the meeting was: To what extent can novel research outputs from a Victorian catchment be applied to the landscapes of AFAC members, which span Australia and New Zealand? The challenge was to make practical sense of the science and translate it so that the value was maximized for all AFAC members (AFAC 2017).

The solution was found in recognizing that the validity of the detailed knowledge obtained from the study site decreased as the domain over which it was applied increased. This was represented in a matrix that aligned management objectives against the state of knowledge and data availability (fig. 1). Quantitative predictions about the amount of sediment that was likely to be produced following fire were valid for the study site. Qualitative predictions about hydrologic

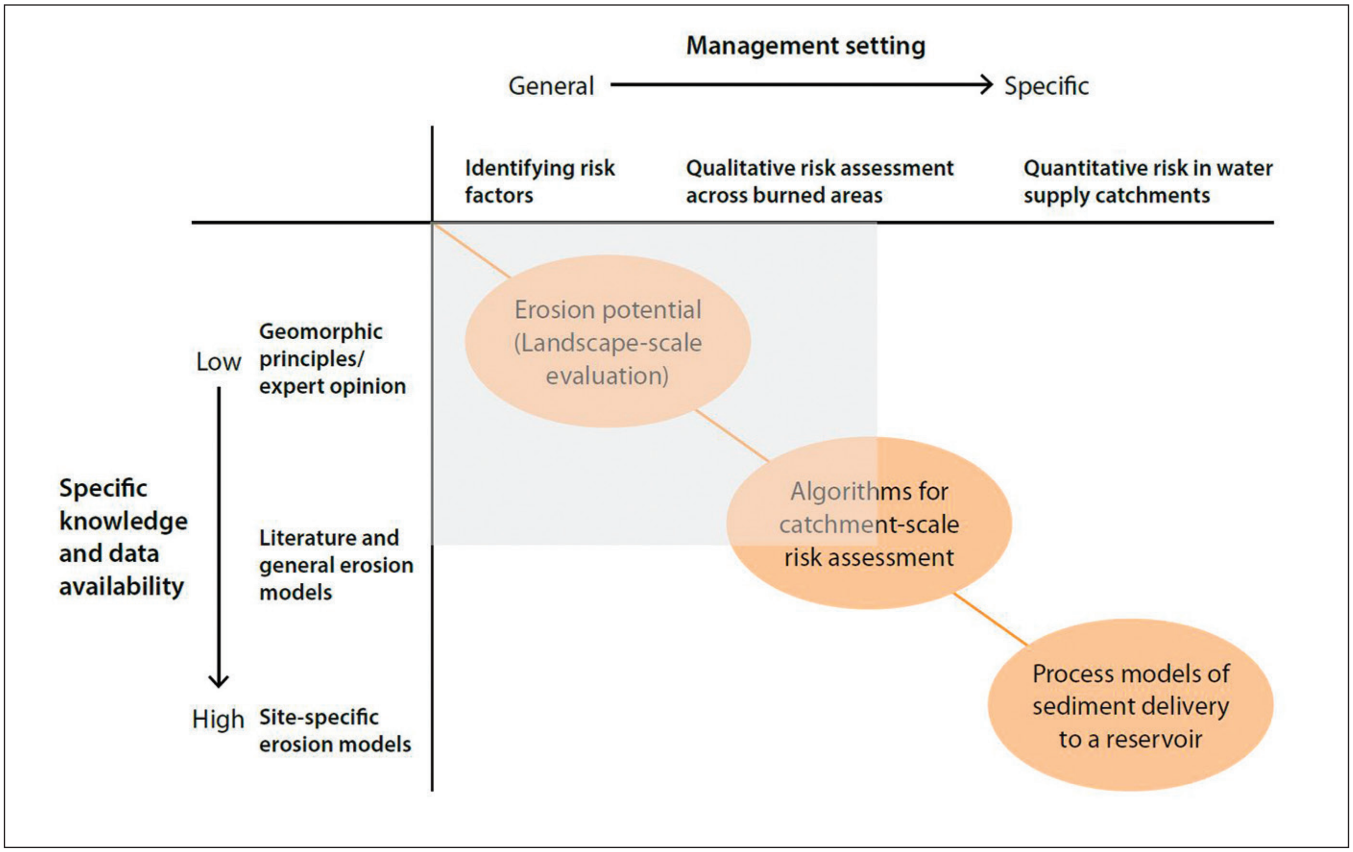


Figure 1—Diagram illustrating how science gained from one specific site could be translated generally for application in different contexts. The types of models for risk assessments vary depending on the management setting (top axis) and the scientific knowledge (left axis) of the underlying hydrogeologic processes. The shaded area represents the region of the science-management space that was targeted in the first phase of utilization.

risk were valid for similar landforms with the same hydrogeomorphic properties. In light of this matrix it was also established that the broad assessment of risk associated with bushfire could be carried out at a landscape scale across Australia and New Zealand using existing data and models. The resulting research utilization plan had three phases reflecting the stages identified in the matrix.

Phase One: National Guidelines

The first utilization product, funded by AFAC, was an Australia- and New Zealand-wide assessment of erosion risk associated with wildfire (Nyman and Sheridan 2014). The work assessed the postfire erosion potential in water catchments in every Australian State and Territory and New Zealand and was accompanied by generic guidelines for evaluating risk to water quality. Spatial data generated during the project were distributed to each jurisdiction, and the report was made available to AFAC members from the AFAC website.

Phase Two: Risk Assessment Tools for the Australian Capital Territory

The second utilization product, funded by ACT Parks and Conservation Service, was a suite of geographic information system tools that generate postfire risk assessments of erosion, flooding, and water quality for the ACT. The tools were developed by combining the results of the BCRC research with other work funded by the Victorian Department of Environment, Land, Water and Planning for use by the bushfire rapid risk assessment teams in Victoria. The tools were tested successfully during the 2015–2016 bushfire season and are in use in the ACT.

Phase Three: Quantitative Predictions

Implementation of the third phase of utilization in the ACT requires the calibration of models to deliver quantitative predictions. Data for this purpose are being collected in conjunction with the burning program. Rainfall gauges, turbidity monitors, streamflow monitors, and sediment traps (fig. 2) are installed in suitable locations as soon as possible after burns to gather these data. Controls are installed in permanent watercourses above and below burns and in representative gully lines adjacent to areas planned to be burned.

OPERATIONS

The Australian Capital Territory Parks and Conservation Service uses the postfire hydrologic risk tools for two purposes: 1) to plan prescribed burning operations and 2) to target drainage and infrastructure works in identified risk-prone areas with significant water assets and important ecosystems.

Conducting a Fuel Reduction Burn

The workflow for incorporating water quality risk into a prescribed burn has four stages, illustrated using the Wombat Creek fuel reduction burn conducted by ACT Parks and Conservation Service in April 2017: 1) assessment of the proposed burn for erosion sources (fig. 3); 2) completion of the burn plan, taking account of water quality risk (fig. 4); 3) assessment of fire severity (Key and Benson 2006; Leavesley et al. 2015) (fig. 5); and 4) assessment of the postfire hydrologic risk using the tools (fig. 6).

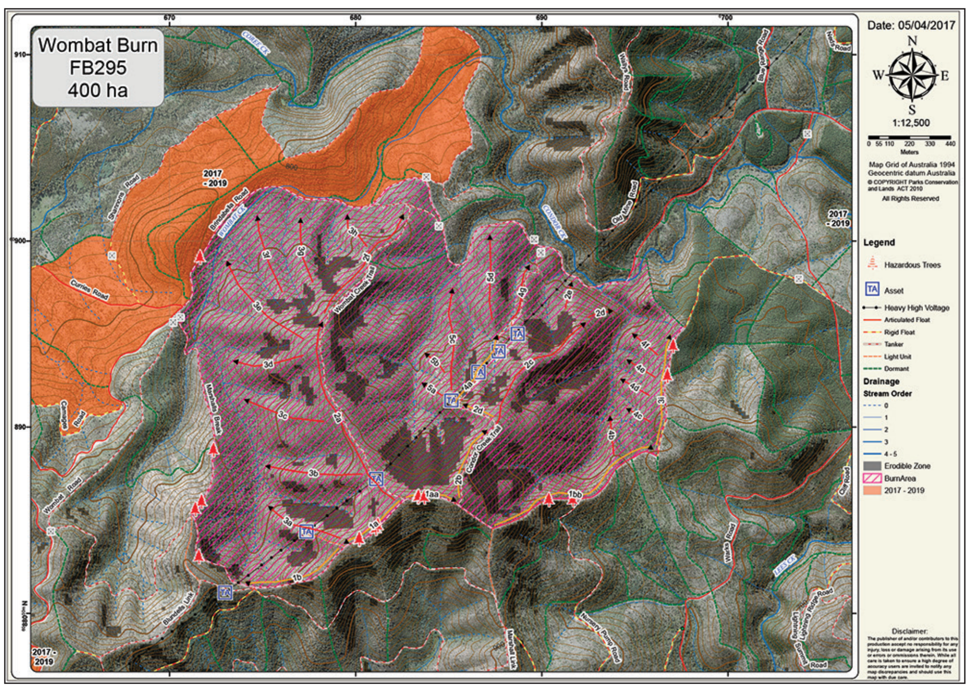
Identifying Risk-Prone Areas After a Wildfire

The identification of areas prone to hydrologic risk following a fire is a two-stage process requiring an assessment of fire severity (figs. 7 and 8) and an assessment of the postfire hydrologic risk (figs. 9–11).

Figure 2—A sediment trap and a V-notch weir installed in a burned gully.

Figure 3—Potential sources of debris flow within the Wombat Creek (Australian Capital Territory) burn; erosion source areas are indicated by brown shading.

Figure 4—Operational burn map for the Wombat Creek burn (Australian Capital Territory). Pink cross-hatching indicates the fireground, brown shading indicates potential sources of erosion, and red arrows indicate the ignition plan. The ignition pattern was designed to minimize burning over the potential erosion source areas on southeastern aspects of the burn.



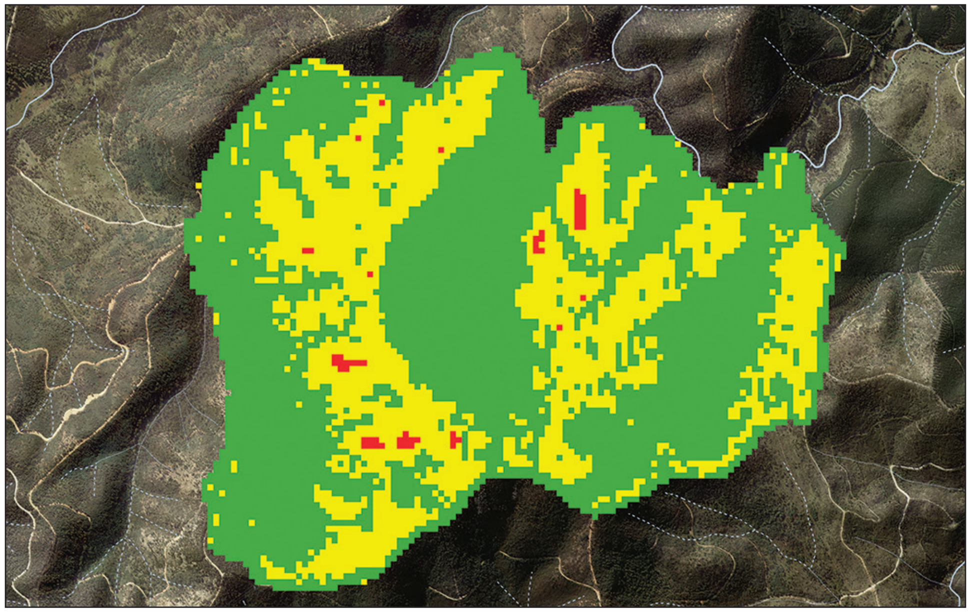


Figure 5—Fire severity assessment of the Wombat Creek burn (Australian Capital Territory; ACT) using the FIREMON method developed by the Forest Service, U.S. Department of Agriculture and adapted for the ACT. Green indicates unburned area; yellow indicates minimal burn effects to the canopy, and red indicates substantial canopy scorch or consumption. The objective of minimizing burning within potential erosion source areas was achieved.

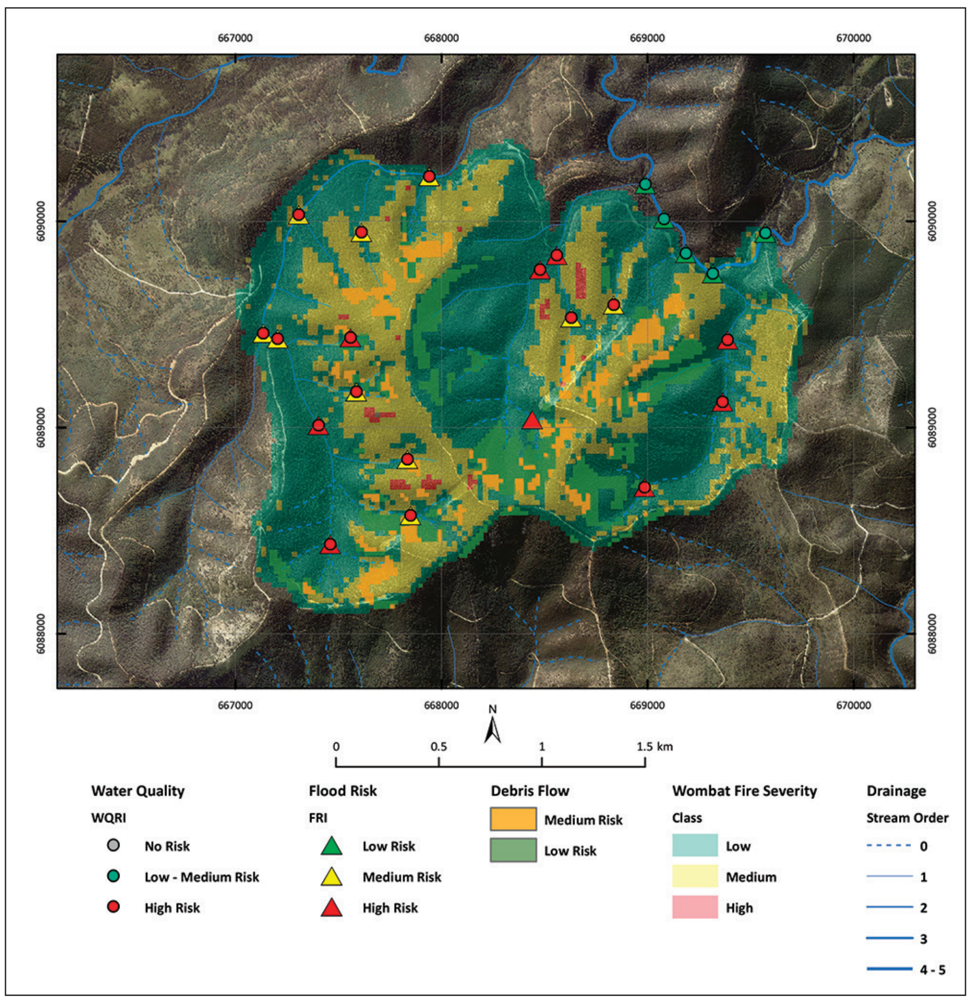


Figure 6—Postfire hydrologic assessment of the Wombat Creek burn (Australian Capital Territory). The burn was conducted in steep terrain with relatively high risk of postburn hydrologic effects. The burn increased the erosion risks, but the effects were limited to the burn area so that the effect at the nearest main stream, Condor Creek, was low.

Figure 7—Aftermath of the Brandy Flat burn (Australian Capital Territory), which escaped containment across a creek and burned at high intensity, causing full canopy consumption or scorch over a wide area.

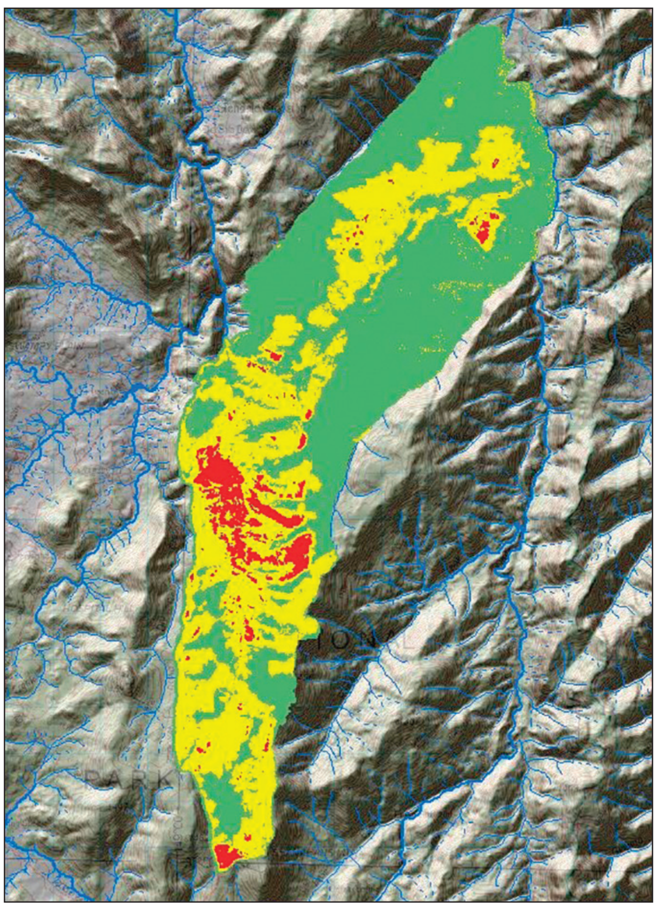


Figure 8—Fire severity assessment of the Brandy Flat burn (Australian Capital Territory; ACT) using the FIREMON method adapted for the ACT. The burn was conducted in April 2016 and escaped containment across a creek. The fire then burned at high intensity. Green indicates unburned area, yellow indicates minimal burn effects to the canopy, and red indicates substantial canopy scorch or consumption.

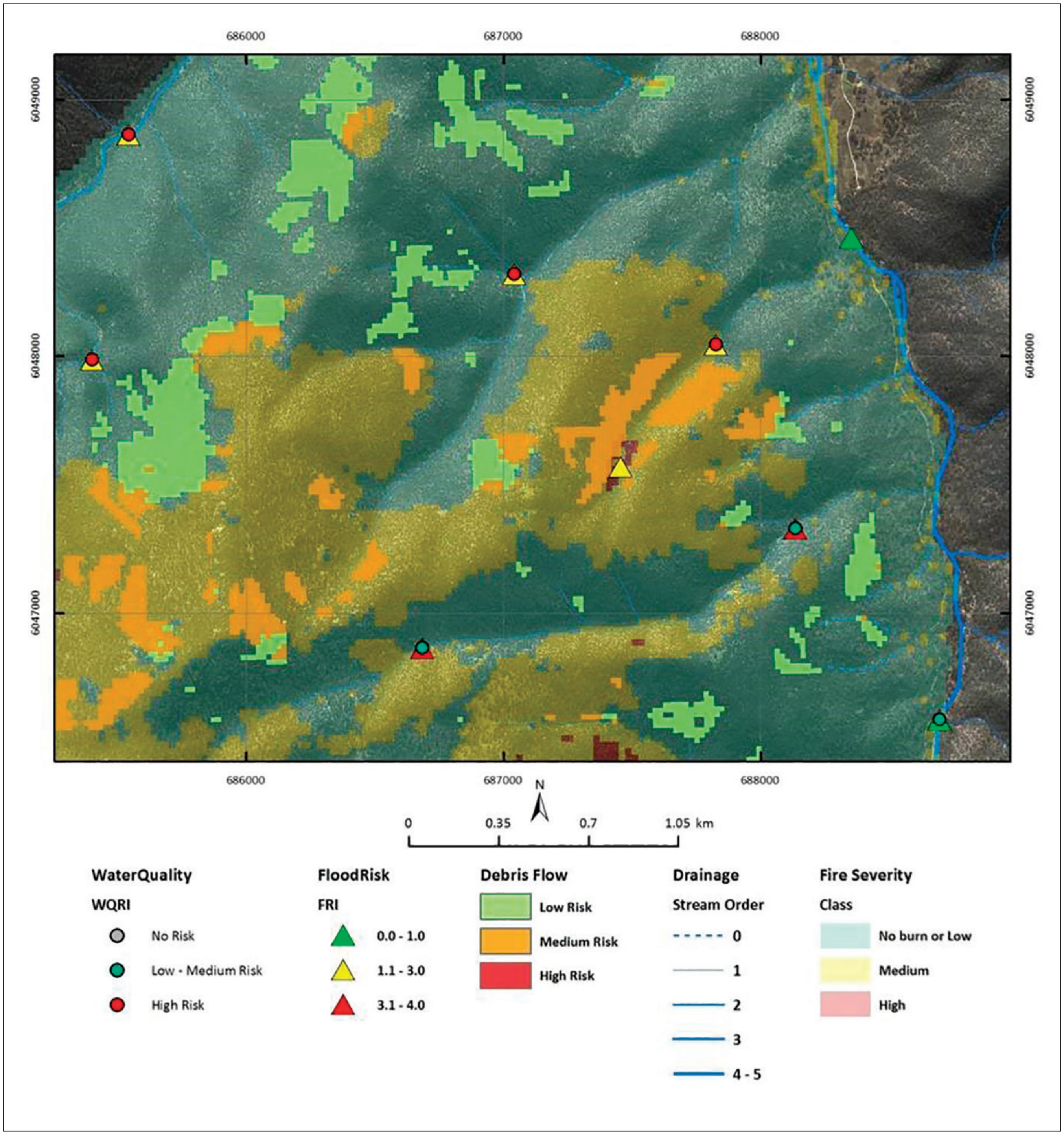


Figure 9—Postfire hydrologic assessment of the northern end of the Brandy Flat burn (Australian Capital Territory). The burned gully in the center of the picture (grid square: 687 047) was subject to erosion during intense rainfall 2 weeks after the burn. The assessment shows increased hydrologic risk in the gully but only low risk in the Naas River (east of easting 688) into which it flows.

Figure 10—A burned hillside that was the source of erosion following the Brandy Flat burn (Australian Capital Territory) in 2016.

Figure 11—Sedimentation in the Naas River (Australian Capital Territory) in 2016 after the Brandy Flat burn. The boulders in the background of the photo at left are from a previous and much larger event, possibly associated with the Canberra bushfires in 2003. Eroded material consists of ash, organics (right top), and mineral soil (right bottom).

UTILIZATION: CRITICAL SUCCESS FACTORS

The critical factors in improving the management of postfire hydrologic risk were the creation of a strong researcher-end user partnership, appreciation of the science and research methods, and a shared commitment to collaborative discovery in the utilization phase (AFAC 2017).

There are three key lessons from this research utilization process.

1) Members of the ACT Parks and Conservation Service staff undertook the lead end-user role during the BCRC research phase of the project and were motivated to do so because a high proportion of the ACT is water catchment. This meant that there was end user involvement early in the project, ensuring that researchers were aware at the outset of the context in which the bushfire sector would need to use the information.
2) Continuous engagement in the partnership made end users comfortable with supporting the project as it traveled the path of investigative discovery. This was important because the results of research are by definition uncertain, so it is not usually clear where a project will lead or what might be delivered at the end.
3) The shared commitment to collaborative discovery in the utilization phase allowed the complexity of the research models to be simplified for operational use in a way that maintained the quality of the information. This type of work can be particularly challenging for researchers, whose research work typically involves a focus on details and a concomitant expansion of complexity.

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