

Predicting fire behaviour

A Scion Impact Statement 2009

Every year there are, on average, around 3,000 wildfires in New Zealand. They burn some 6,000 hectares of rural lands and forests, and cost the taxpayer around \$5 million dollars (and rising) to control. Expensive aircraft make up nearly half the cost of suppression. However, the cost of prevention, training and preparedness adds at least another \$20 million to the annual bill, not to mention the economic loss and social impact on rural communities. Climate change scenarios suggest things could get worse.

Helped by \$1.5 million from New Zealand's rural fire sector stakeholders¹ and the Foundation for Research, Science and Technology (FRST) which has funded research into fuels and fire behaviour, Scion has developed a fire behaviour toolkit that can help to reduce these costs, through more effective forecasting and planning. Even in their first few months of use, the electronic and paper-based fire behaviour tools have already saved the country hundreds of thousands of dollars in suppression costs and improved safety for fire fighters and communities.

The toolkit is now an integral part of the operations of the NRFA, Department of Conservation, the NZ Fire Service, NZ Defence Force, NZ Federated Farmers, forestry companies and fire officers working for local authorities throughout the country. The toolkit is being used through all four phases of fire risk management – reduction, risk, response and recovery, with the following benefits:

- Fire controllers can now assess likely fire behaviour more quickly. This enables them to make better decisions faster, and allocate resources more effectively, resulting in quicker suppression and lower costs.
- By improving operational efficiency and safety, fire controllers can reduce the dangers and disruption to the lives of fire fighters, many of whom are volunteers. In addition, the very real risks, upheavals and economic and social impacts wildfires can have on rural communities can be reduced.

New Zealand Fire Behaviour Toolkit

The New Zealand Fire Behaviour Toolkit provides a major advance in the level of tools available to assist decision-making by fire managers across the country. The user-friendly software package incorporates the current knowledge on fuels and fire behaviour in the New Zealand fire environment and is based on fuel and fire behaviour models in the field manual. The Toolkit was developed in conjunction with Scion's ATLAS Technology Group, co-funded by the New Zealand Fire Service Commission's Contestable Research Fund.

Toolkit modules have been developed for specific purposes and levels of use.

Features

- **Fire Behaviour Calculator** - designed for quick and easy determination of fire potential in any New Zealand fuel type
- **Fire Behaviour Worksheet** - based on the field manual worksheet. This is used for predicting fire behaviour over a period of time for a specific fire, and/or to evaluate effects on fire behaviour of different conditions (i.e. changes in weather conditions, fuel types or slope).
- **Firebreak Effectiveness** - allows the user to determine either the probability of an existing firebreak being breached by a fire of known intensity, or the width of a firebreak required to contain a head fire of known intensity.
- **Fire Intensity** - calculates fire intensity based on an observed flame length, or flame length from a known fire intensity.
- **Fire Behaviour Rules of Thumb** - a list of "rules of thumb" for quick and easy reference.
- **Resource Productivity** - provides general guidelines for resource productivity in New Zealand fuel types, e.g. for people, bulldozers etc

¹ National Rural Fire Authority, Department of Conservation, NZ Forest Owners Association, NZ Defence Force, territorial local authorities and Federated Farmers of New Zealand

- The ability to model what-if scenarios is valuable in training and education. Such models can be used to set conditions for fire permits and help to win the cooperation of rural land owners, reducing out-of-control burn-offs and preventing wildfires before they start.

The economic benefits from the above are substantial ranging from tens of thousands of dollars of savings in resource use and improved management decisions, to several millions of dollars for wildfires avoided or better managed.

How is the fire behaviour toolkit being used by people in the field, and what do they think about it?

Forewarned is forearmed

Rural fire managers believe there is a “Golden Hour” – just 60 minutes before a fire reaches its potential and becomes too risky for ground crews, with control the only option because suppression is no longer possible. This is why they put so much emphasis on response times, and being prepared for rapid deployment of the right resources.

Murray Lane, DoC rural fire officer in Canterbury's Mahaanui area office, says he uses the fire behaviour software almost every day. It enables him to model the fire risk and ensure people and resources are on standby on the bad days.



"It's been the best thing that's happened in my career as far as the electronic side of things goes.

“Regardless of the time of year, I keep a very close eye on the drought codes and the FWI system. I have three areas I monitor... Canterbury, Banks Peninsula and Godley Head at the entrance to Lyttelton Harbour. Every morning I look at the weather prediction for the next 24-hour period, and then I use the calculator to work out, if there was a fire today under the present weather conditions or the predicted conditions, what

sort of situation would we be faced with. From there, I can make decisions about how we will deploy our staff.

"Coming into our summer period, I can tell my manager we need to put staff on standby today, or they must stay within radio contact. It's a really good management tool and for ten minutes inputting in the morning I can give my manager good information and the staff good sound reasons as to why we're putting some restrictions on them.

“Before the calculator, this was very time-consuming. I was doing it manually so I'd only do it once a week, now using the calculator it takes me a few minutes to do three calculations and I'm doing it daily.”

Smart decisions under pressure

In the pressure-cooker environment of a live fire, Murray says he would previously never have contemplated trying to carry out manual calculations but the fire behaviour decision support software has now made this easy.

"I can bring up the weather station for that area, plug the information in and instantly see we've got a serious problem... it's not just a heli response Level 1 it's a Level 3 and we're going to have to back it up with four crews and probably tankers. So we can start looking at a realistic call on resourcing rather than waiting until a heli response crew gets to an area and then says 'hey, we've got a big problem here'. We've actually got that

Resource calculation made easy

“The heat, intensity and speed of a fire dictate the resource. The tool gives you a rate of spread for the fire and its perimeter, and how much per hour that perimeter is increasing. You can then reference other efficiency tools, for people on the ground, bulldozers or for aircraft, and see how much they can put out in an hour.

“By using the outputs from the toolkit to reference these production rates, you get an idea as to what sort of resources are needed. As a simple example, you could have a fire moving at a forward spread rate of 2 km/hr with a crew working on one flank putting out 300 m/hr. That tells you that you need at least three times that resource just to keep up with it.”

- Mike Grant, principal rural fire officer in Southland

information as we're going out the door."

Murray's territory lies in some of the most wildfire-prone country in New Zealand.

"Last year in the Mahaanui area we dealt with 45 ignitions. They varied from hedge fires and burned out cars to a plane crash which started a large fire. It was really good to be able to start using the calculator halfway through the season. I'm convinced that a lot of the fires towards the end of the season didn't get away because we were well prepared, and the calculator was the basis for that. I can't speak highly enough of it -- it's a really good tool and has lifted our game considerably."

Cost-efficient strategies

Simpler scenarios

What-ifs are a vital part fighting a rural fire, e.g. what if the wind changes direction, what if it gets stronger. Keith Marshall, principal rural fire officer, with the Christchurch City Council says that with the simplicity of the toolkit he can give data to people who have computer skills but little or no fire behaviour knowledge, show them where to put the figures and they can be running iterations, freeing him up to do something else until he is needed to interpret the result.

"The toolkit didn't cost us an arm and a leg, it can run on almost any computer because it isn't memory-hungry, and almost anybody, once you run them through it, can do the base calculation," he says.

"It has opened up enormous possibilities for doing what-if scenarios a lot more easily. That's the key thing about it — sure, we could always do these scenarios manually, but it took a lot more time. The other thing is that it will give us some justification for our decisions... why did you make that decision to evacuate the village for example. Well the computer says that this fire is going to reach this particular point in two hours, so rather than wait until the fire is nearly at the village to say it's time to get out, for safety purposes we'll move these people out now. If we can stop the fire before it gets there then no great harm done - at least the people got out before we had to do a panic act.

"The other thing is it will enable us to run models retrospectively. Say we managed to contain the fire in a day or two days, but what if the wind had been up at 15 km or 20 km an hour instead of five - what would have been the outcome? We've got to look at it beyond just going to fires - we can use it in training and say right here is some data, now predict where this fire is going to go."

Fire managers must always be asking the question, is this cost effective, and where is this fire going?

Again, this is where the calculator is good, Murray says. "There might be a situation where there's no threat to life or property, say in an alpine area, where it's going to run out to scree. Is it worth spending \$100,000 to put out a fire that is going to go out anyway? You might think about just trying to control it and keep it running towards that safe area, rather than trying to put the head fire out. A quick calculation on the fuel loadings and the weather predictions and you can say OK this is the strategy. The calculator does this in a matter of seconds."

"You can save and print your calculations and they can go into the incident action plan so they can be scrutinised and referred to. Everybody knows what decision has been made and why, and as incident controller you can start making good tactical decisions. That also becomes important when somebody gets the bill for suppression costs because it's a breakaway or unauthorised burn that winds up in litigation. When you go to court you've got a good basis to back up your decisions. In the past that has been difficult - we've made decisions based on gut feeling and the knowledge in our heads. Now we've got a tool that in a matter of seconds you can save that information, and if someone asks why did you make these particular decisions you can show them.



"Over the years I've made decisions that have cost a lot of money. Since getting the calculator I've revisited some of those fires and put the information in - the fuel loadings and so on - and it's come up with what actually did happen on the day. But if I'd had the time back then to do those calculations, in some cases I might have made different decisions."

Protecting communities

Murray Lane says that the fire behaviour tool is useful for predicting how far a fire is going to spread in 30 minutes, in an hour, two hours and so on. With a good mapping program they can draw lines on a map and begin to plan possible evacuations or advise farmers to move stock.

"During the mop-up stage after the Mt Cook fire I was doing calculations of where the fire would have been under certain wind changes." Murray explains.

"I had to do those manually, and it took ages. If that fire had still been roaring - and you're talking a \$1 million fire - and the weather patterns had changed towards the north, there was the potential to evacuate Tekapo township and the Tekapo military base, so we were talking serious amounts of money," says Murray. "I was able to give that information to the controller but it took a long time. If I'd had the calculator, it would've taken ten minutes including printing the maps."

Firefighter safety

"Another reason I like the calculator is, it identifies when extreme fire behaviour is likely to occur. If there's a fire and I crunch the numbers, and they say the headfire intensity is going to peak at between 50,000-75,000 kW per metre, that immediately tells me we've got major hazards for our firefighters. We then know we have to think about how to resource that from a safety point of view. The key thing is if we can be prepared and respond quickly - that's always a great help.



It's a really exciting tool and I can't speak highly enough about it. I hope other people throughout New Zealand buy into it, whether they be in the Department of Conservation or in a territorial authority, or where-ever."

Tony Teeling, senior rural fire officer for the Department of Conservation's Canterbury region agrees. He has supplied the fire behaviour manuals and calculators to all the Department's rural fire officers in Canterbury

"It's not just a fire suppression tool. They can use it for reference when they're doing fire permits, for determining fire breaks and setbacks, for example. We'll run up scenarios with the fuels that we've identified on the ground and then run scenarios of different conditions, work out what sort of width firebreak is needed to be able to hold it, or a lighting pattern to keep the intensity down. It's got good uptake with the rural fire officers in the field and Stuart (Scion fire researcher Stuart Anderson) has come to our fire specialist meetings and showed them how to use the electronic version as well."

Scion's Rural Fire programme is the only programme of its kind in New Zealand. Current investment from FRST is some \$470,000 per annum plus co-funding and in-kind support from the New Zealand stakeholders. However, Scion's team are also active participants in Australia's Bush Fire CRC which is a \$110 million programme over 7 years. This small national investment therefore leverages substantial value from the much larger programme in Australia. It is also an excellent example of international collaboration, addressing a common problem for both countries. In 2009 the Scion programme received an "Excellent" grading by an independent panel of experts appointed by FRST due to its level of innovation and track record in transferring these innovations to the end-users.

Calculating the safety margins

David Hunt, Deputy National Fire Co-ordinator for the Department of Conservation used the fire behaviour toolkit to manage a shrubland fire at the Torohape Wetlands on the Hauraki Plains in December 2008. The Torohape Wetland is a highly significant reserve, established by DoC to protect the remnant of what was once a large peat dome. It is home to several endangered species including the giant rush *Sporodanthus* and the fern bird. The fire was probably deliberately lit, with high fuel loadings of flammable, dense material, and it quickly became obvious that conditions weren't safe for ground crews.

Not only was the boggy ground unstable underfoot at the north end of the fire site, but areas of unburnt fuel caused a hazard to crews through re-ignition. There was also the risk of booby traps associated with drug activity. Nevertheless the fire had to be contained rapidly, not only to stop it spreading but also to prevent it penetrating the peat.

"There are a couple of things with fire management. The first is getting a grip on where the perimeter of the fire is, then what amount of effort do you put into which parts of the perimeter," says David. "We had five helicopters; a heavy lift helicopter, three Squirrels, a Jet Ranger for reconnaissance, plus about 30 people on the ground. With the fire behaviour calculator you get a feel for how hot the fire is going to be and from there you can work out the tactics and where and where not to put people.

"There is a range of heat that you can put people in. You can put people with pumps in from the black end of the fire in up to 1000 kW of heat. When it gets a bit hotter you can put in things like bulldozers which will still look after the edges of the fire, but when it gets very hot, once your flames get more than 2.5 m, you're into 4000 kW of heat per metre, and you can really only attack it with an aerial response. The fire behaviour calculator means that you can take the readings on the site, put these numbers into the calculator, and identify what sort of fire it is, what sort of resources can be used and, more importantly, what are the safety issues in terms of using the right resources for the appropriate parts of the fire.

"Not only that, you can model it, and say alright, if the conditions get hotter, or colder, or windy, or wetter, what is the fire going to do? You can run multiple scenarios over four hours, 12 hours, 24 hours. In the past we've had to do all that manually but the calculator enables people to do it a lot faster and direct effort where the priorities are. It's being able to get a better feel for the fire and what resources and techniques you can use to manage it safely and efficiently, so you're not putting D6 bulldozers into a place where you only need D1s, or using heavy lift aircraft at \$3000 or \$4000 or more an hour.

"Big isn't always beautiful - if you've got a low intensity fire in a difficult place you can get by with smaller helicopters. Once you get past the initial phase of getting things under control, you can use the fire behaviour forecasting to decide, for instance, that tomorrow you only need three of these not five. While part of that is the cost side, whenever there's a machine in the air there's always a small risk. That's the overall philosophy - that you apply the appropriate amount at any one time that you can."

Scion's fire behaviour manual and software are based on the current state of knowledge of fuels and fire behaviour in New Zealand, providing fire managers and fire fighters with science-based tools that can be used to reduce the risks and costs associated with wildfire. They also form the basis of fire behaviour prediction training that over time will create a pool of trained professionals to provide accurate and timely information when required during fire emergencies.