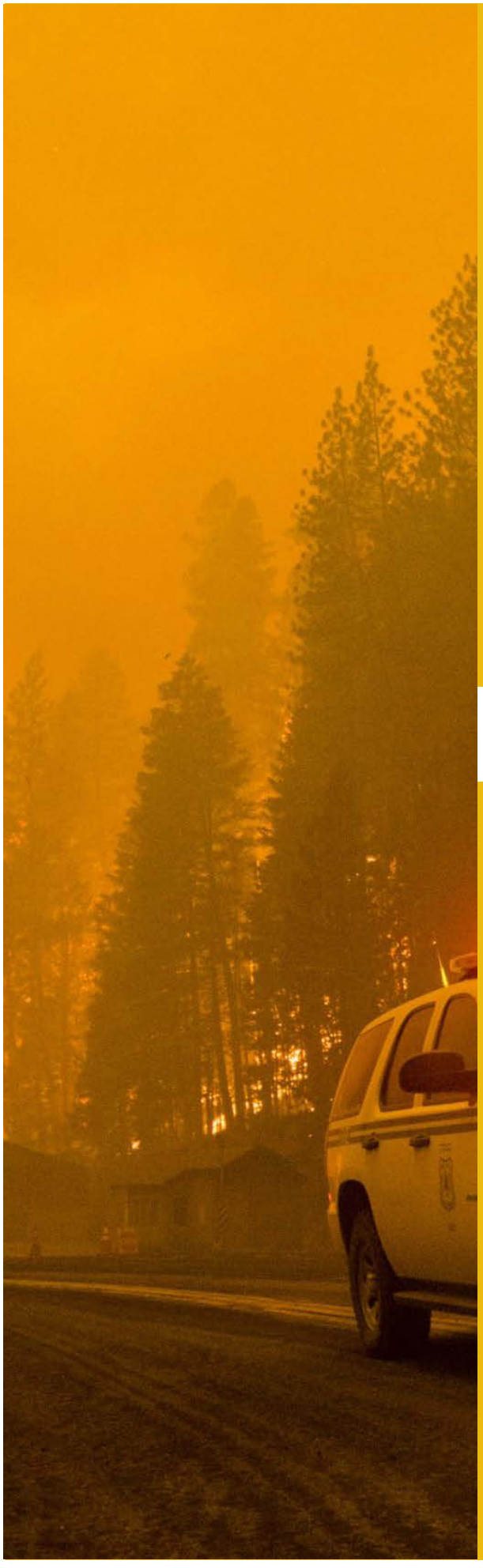

Use of Risk Management Assistance During the 2021 Fire Season

A technical report

AUTHORS: Tyler A. Beeton, Michael D. Caggiano, Melanie M. Colavito, and Ch'aska Huayhuaca

November 2022

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Preface and Acknowledgements: In FY21, the USDA Forest Service Fire and Aviation Management (FAM) requested assistance from the Southwest Ecological Restoration Institutes (SWERI) to assess Risk Management Assistance (RMA) use among line officers and Incident Management Teams (IMTs) during the 2021 fire season. The SWERI developed and deployed an online questionnaire to assess: 1) what RMA tools were used; 2) how they were used to inform decision-making; 3) factors that facilitated and frustrated use; and 4) practitioner recommendations to improve RMA use. The report herein summarizes findings from the RMA use assessment. The assessment provides a baseline understanding of RMA use during fire incidents. Results from this assessment will inform best practices for developing, disseminating, and using RMA tools. This assessment provides a baseline for longitudinal evaluation of the RMA through time and as RMA products and processes evolve.

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Executive summary

The USDA Forest Service developed Risk Management Assistance (RMA) in 2016 to enhance the use of risk-informed management principles and decision-support tools that improve decision quality and accountability and minimize unnecessary risk to firefighters during wildfire response. To evaluate and improve RMA, the USDA Forest Service Fire and Aviation Management (FAM) requested assistance from the Southwest Ecological Restoration Institutes (SWERI) to assess RMA use among line officers and Incident Management Teams (IMTs) during the 2021 fire season. The SWERI developed and deployed an online questionnaire (n=94 usable responses) to assess: 1) what RMA tools were used; 2) how they were used to inform decision-making; 3) factors that facilitated and frustrated use; and 4) practitioner recommendations to improve RMA use.

Incident information: The questionnaire captured RMA use on 69 incidents across 11 states. Twenty of the incidents were over 100,000 acres, and more than 6 million acres were burned in the 69 incidents. 27 IMTs from 9 Geographic Area Coordination Centers were represented in the questionnaire. Type 1 teams were most represented, followed by Type 2 and Type 3 teams. The majority of respondents indicated a full suppression fire management strategy, though one-third indicated a management strategy other than full suppression (e.g., confine and contain, point protection). About one quarter of respondents indicated that multiple fire management strategies were used on the same incident.

RMA tools used: The Suppression Difficulty Index (SDI) and Potential Control Location (PCL) analysis were the most frequently used RMA tools, followed by the Season-ending Analysis, Estimated Ground Evacuation Time, Snag Hazard, and Potential Operational Delineations (PODs). The suite of products used for RMA continues to evolve as developers innovate to meet practitioners' needs. The new Fire Comparison Spreadsheet (and associated prioritization and radar plot tabs), for example, was used by the national and Geographic Area Coordination Centers to prioritize resources across incidents.

How RMA was used: RMA was most frequently used to support incident operations and long-term assessment; inform incident objectives, requirements, and strategy; and evaluate, or re-evaluate, courses of action. RMA was also used to inform dialogue with stakeholders, provide situational awareness on emerging incidents and for incoming teams, support incident level and operational decision-making (e.g., direct and indirect line placement, validate existing or justify new decision), and to prioritize resource allocation across incidents.

Facilitating and frustrating factors: Familiarity with RMA, trust in the accuracy of analytics, receptiveness to new tools and processes, internal capacity and expertise, and the presence of leaders who advocated for RMA use to support fire and land management decision-making facilitated RMA use. The absence of these characteristics frustrated use. A majority of respondents felt that the tools on the RMA dashboard were easy to interpret, relevant to decision making, provided at the appropriate scale, and accurately depicted conditions on the ground. The RMA dashboard was reportedly easy to access and use by practitioners, and provided products that helped develop strategies quickly.

Recommendations: Respondents recommended: 1) more education and outreach before, during, and after incidents (e.g., risk management and RMA training in National Wildfire Coordinating Group (NWCG) coursework; integration into PODs workshops; training for Operations section chiefs and line officers); 2) clear leadership direction and intent (e.g., intended use of RMA; use with the Wildland Fire Decision Support System (WFDSS); support investments in analytical capacity, for example regional analysts, strategic operations positions); 3) enhance tool delivery and more frequent updates (e.g., integrate with other platforms, such as WFDSS and the Interagency Fuel Treatment Decision Support System (IFTDSS); 4) more frequent tool updates to capture changing conditions; and 5) expand products and usage (e.g., integrate with fuels and prescribed fire planning and implementation).

RMA use in non-incident management: Several respondents indicated that they are already using RMA to support non-incident management. Specifically, respondents are using RMA for: 1) pre-season wildfire planning (e.g., PODs workshops, strategic response planning); 2) fuels treatment design and prioritization; 3) environmental analysis and decision-making; and 4) developing shared understanding, communication, and learning with communities and partners.

Conclusions and next steps: This assessment provided baseline information on the use of RMA during fire incidents, contributed to our understanding of what facilitates and frustrates RMA use, and identified actionable recommendations to improve RMA products and processes. Our hope is that this is the first in what will become a long-term evaluation of RMA products and processes. This questionnaire could be readministered longitudinally to track trends in RMA use and determine

the extent to which RMA is useful and used. Additionally, case studies can add local context and nuance to questionnaire findings. Future evaluations should be grounded in the needs and priorities of practitioners and FAM leadership. Next steps for our research team include case studies that: 1) assess RMA use during 2022 wildfire incidents; and 2) document how leadership direction and intent on RMA is conceptualized, defined, and disseminated to lower levels of authority and cooperators. Future work will maintain our focus on co-developing actionable knowledge with practitioners to inform improved decision-making before, during, and after fires.

Introduction and background

Wildland fire management in the western U.S. is increasingly complex. Climate change-driven increases in fire activity and fire season length, continued development in the wildland-urban interface, and interactions between fire and other large disturbances (e.g., pest and pathogen disturbances) combine to increase suppression difficulty and exacerbate risks to human lives and property (Holden et al., 2018; Jolly et al., 2015; Radeloff et al., 2018). These challenges have increased emphasis on—and the need for—risk management principles and decision support tools that provide a framework and structure for collaborative, proactive spatial fire planning and wildfire incident management (Stratton, 2020).

The USDA Forest Service developed Risk Management Assistance (RMA)[1] to integrate a structured risk management processes into fire management. The overarching goal of RMA is to support improved, safer outcomes with structured decision-making and analytics (R. Stratton, Personal Comm.). RMA uses the best available science and spatial analytical tools to evaluate alternate management strategies, consider the likelihood that objectives can be achieved, and analyze trade-offs between multiple incident objectives (Calkin et al., 2021). RMA focuses on pre- and post-fire season training, education, and outreach, fire season support, and line officer development to meet the following core principles: 1) improve decision quality; 2) improve accountability; and 3) minimize unnecessary risks to firefighters (Calkin et al., 2021).

RMA is still relatively new in the suite of tools and processes already available for wildfire management, but its usage has increased rapidly. For instance, in 2016 RMA personnel responded to 8 fire inquires. RMA personnel then responded to 11 incidents in 2017, 35 in 2018 (16 on site and 19 virtual), 29 in 2019, 66 in 2020, and 113 in the 2021 fire season. It is clear from this progression that RMA is increasingly being used to support incident management decision-making. RMA transitioned to completely virtual support mode in 2019. In 2020 the RMA dashboard was developed, at which point users could pull pre-loaded data for individual use.[2]

A small but growing body of research has provided initial understanding of how Potential Operational Delineations (PODs), RMA, and other wildfire decision support tools are used and the factors that support or inhibit their use (Caggiano et al., 2021; Calkin et al., 2021; Colavito, 2021; Greiner et al., 2020; Noble and Paveglio, 2020; Rapp et al., 2020; Schultz et al., 2021; Vásquez et al., 2021). Still, the rate at which RMA has been used on the ground has outpaced the capacity to assess how it has been deployed in different contexts and, more importantly, its impact on decision making and outcomes. RMA products and modes of delivery are routinely revised, enhanced, and adapted to meet different land and fire management objectives. Therefore, it is crucial to build on previous assessments to document how and under what conditions RMA products are used, facilitating and frustrating factors, and needs to enhance the use and usability of such tools.

The USDA Forest Service Fire and Aviation Management (FAM) department requested assistance from the Southwest Ecological Restoration Institutes (SWERI)[3] to develop an online questionnaire to assess RMA use during the 2021 wildfire season. The assessment is framed by the following research questions:

1. Which RMA products are used on wildfires?
2. How is RMA used to inform decision-making?
3. What factors facilitate or frustrate use?
4. How can RMA be improved to enhance its use and legitimacy in wildland fire management?

The questionnaire was administered to fire managers and personnel (e.g., Incident Management Teams [IMTs], Agency Administrators [AAs]) who engaged with RMA products and assistance during the 2021 wildfire season. The report herein summarizes findings from the assessment and describes the state of RMA use in incident management contexts. The audience for this report includes USDA Forest Service FAM personnel and fire management practitioners (e.g., AAs, IMTs, and fire managers). Results from this assessment will inform best practices for developing, disseminating, and using RMA tools. This assessment provides a baseline for longitudinal evaluation of the RMA and as RMA products and processes evolve.

[1] RMA Website - https://wfmrda.nwcg.gov/rma
[2] RMA dashboard - https://nifc.maps.arcgis.com/apps/MapSeries/index.html?appid=c5bc811ee22e4da0bde8abec7c20b8b4
[23] SWERI website - https://sweri.eri.nau.edu/

Methods

We developed an online questionnaire in Qualtrics to address our research questions. The questionnaire consisted of 27 fixed response and open-ended statements and questions. These statements were based on the objectives and research questions of the study, and grounded in a review of the literature on RMA (Caggiano et al., 2021; Calkin et al., 2021; Schultz et al., 2021), other decision-support tools (Colavito, 2021; Noble and Paveglio, 2020; Rapp et al., 2020), and the theory and practice of usable science (e.g., Dilling and Lemos, 2011; Lemos, 2008). Prior to administration, we piloted the assessment with, and received feedback from, 5 fire managers. The questionnaire was also reviewed by the USDA Forest Service Wildfire Risk Management Science team and FAM staff. Feedback was used to revise the questionnaire.

Our sample consisted of fire managers, AAs, and IMTs who were assigned to a wildfire in 2021 where RMA was used. We worked with FAM staff to identify listservs and contact lists for recruitment. The Ecological Restoration Institute at Northern Arizona University administered the questionnaire to fire analysts, fire directors, IMTs, and line officers on March 14, 2022. The questionnaire remained open for 4 weeks and was closed on April 11, 2022. Two reminders were sent to each of the email listservs. We used Qualtrics and Excel to analyze quantitative and qualitative response data. We utilized a thematic analysis approach to document themes (repeated examples of concepts described by respondents) in the qualitative portions of responses (Ryan and Bernard, 2003).

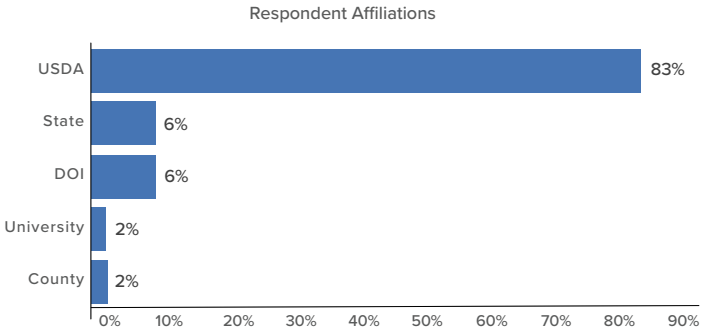


Figure 1: Respondent affiliation. Note: 47 of 94 respondents provided their affiliation information. USDA = United States Forest Service; DOI = Department of the Interior.

Out of a total of 94 useable responses, we received 58 complete responses and 36 partial responses (delineated as questionnaires that were at least 30% complete). All of the questions were voluntary, and several respondents chose not to answer some of the questions. Of the respondents who provided their affiliation information (n=47), the majority were USDA Forest Service employees. A few respondents represented State, Department of the Interior (DOI), county, or university affiliations (Figure 1).

Results

A. Fire incident information

Respondents reported the use of RMA on 69 incidents across 11 states in 2021 (Figure 2; Appendix 1). This sample represents more than 50% of the incidents that used RMA in 2021 (R. Stratton, Personal Comm.). Twenty fires were greater than 100,000 acres and more than 6 million acres were burned in those 69 incidents (Figure 2). Respondents represented 27 Incident Management Teams (IMTs) from 9 Geographic Area Coordination Centers (GACCs). Rocky Mountain Type 1 Team and Northwest Interagency Team 6 (Type 2) were the most represented in the questionnaire (Appendix 2). Respondents were most frequently associated with the Rocky Mountain GACC, followed by the Northwest and Northern Rockies GACCs.

Figure 2: Locations of wildfires and incident information represented in RMA questionnaire.

Wildfire Incident Information

69 incidents

11 states

20 incidents greater than 100,000 acres

6 million acres burned

27 Incident Management Teams

53% Type 1; 38% Type 2; 9% Type 3

69% of incidents used full suppression as management strategy

24% of incidents used multiple management strategies

Type 1 teams represented 53% of the sample, Type 2 represented 38%, and Type 3 represented 9%. Of the respondents who reported which incident management strategies were used on a given fire, 69% indicated the incident was managed for full suppression, while 31% indicated the incident was managed for a strategy other than full suppression (e.g., confine, monitor, point protection, managed for resource benefit). 24% of respondents indicated multiple management strategies were used for a single incident (Figure 2).

B. What RMA dashboard tools and products were used?

The RMA dashboard hosts 15 primary products and several other associated products.[4] The primary products most used included the Suppression Difficulty Index (SDI) (79%), Potential Control Locations (PCLs) (78%), Season Ending Analysis (70%), Ground Evacuation (55%), PODs (54%), and the Snag Hazard (54%) (Figure 3). It is important to note that the suite of products available through the RMA Dashboard continues to evolve as developers improve the tools. For example, the Fire Comparison Spreadsheet—new in 2021— was used to prioritize where to invest resources based on fire modeling, the risk large fires posed to firefighter safety (through evaluating SDI), and critical values and assets of concern (e.g., housing unit density, population, critical infrastructure, drinking water). One respondent noted a customized RMA product that they developed and used:

> *I used SDI, PCL, and merged SDI/PCL rasters in a tool I developed that analyzes and identifies the lowest "cost" lines between likely control points around a fire.*[5]

The RMA dashboard hosts an assortment of other products that are relevant to incident management. The most frequently used among respondents were fire behavior and fire weather tools, including fire danger by Predictive Service Areas (PSAs; 59%), the National Weather Service Fire Weather products (e.g., fire weather matrix; 57%), and the Wildland Fire Assessment System Severe Fire Danger Mapping System (53%), followed by regional quantitative wildfire risk assessments, and wildland-urban interface data products (Figure 4).

C. How were RMA tools used to support incident management?

We asked respondents to select from a list of predetermined response categories that generally represent the fire lifecycle to indicate how they used

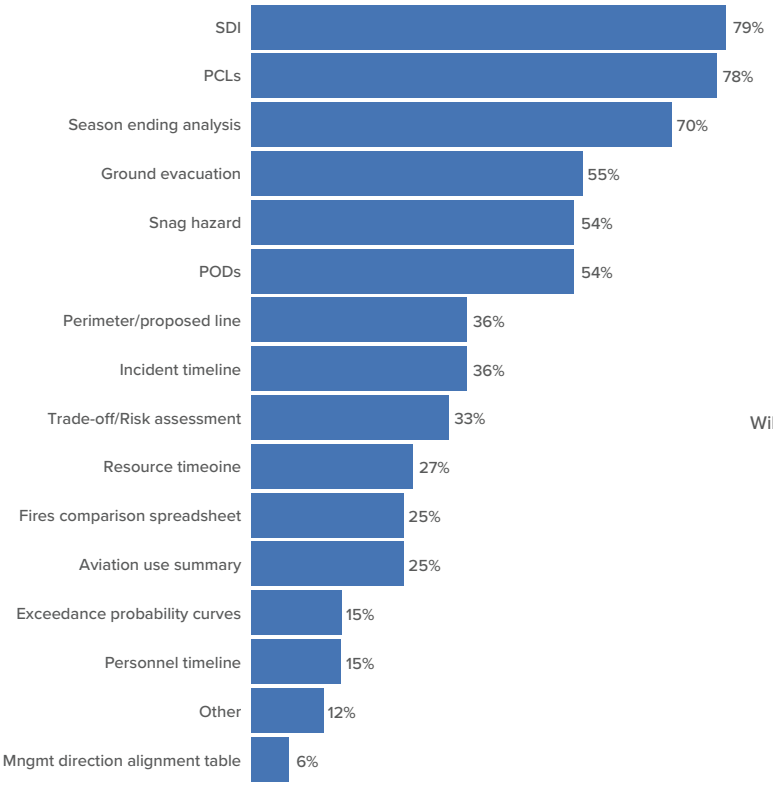


Figure 3: Frequency of RMA products used by respondents. List of products derived from RMA dashboard and personal communication with USDA Forest Service FAM personnel. For an updated product list, see here. Statement: Select the RMA products that were used during the incident(s) (Select all that apply).

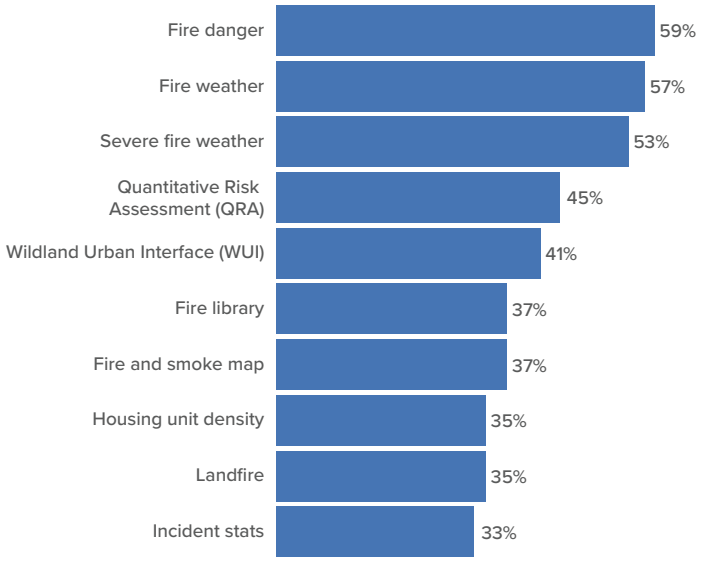


Figure 4: Additional products used from the RMA dashboard. Statement: What, if any, additional tools from the RMA dashboard were utilized in conjunction with RMA products? (Select all that apply).

[4] 2022 RMA product list and explanation. Note: The list continues to be updated.
[5] In other words, the respondent developed a customized product that integrates SDI and PCL to delineate the location of containment opportunities around a fire with the highest potential for control.

RMA products (R. Stratton, Personal Comm.). RMA was used most frequently for: 1) operations and long-term assessment; 2) incident objectives, requirements, and/or strategy; and 3) evaluating different courses of action. Just over half used RMA to frame Wildland Fire Decision Support System (WFDSS) decisions, to delineate management action points (MAPs), and for initial framing of the incident (Figure 5).

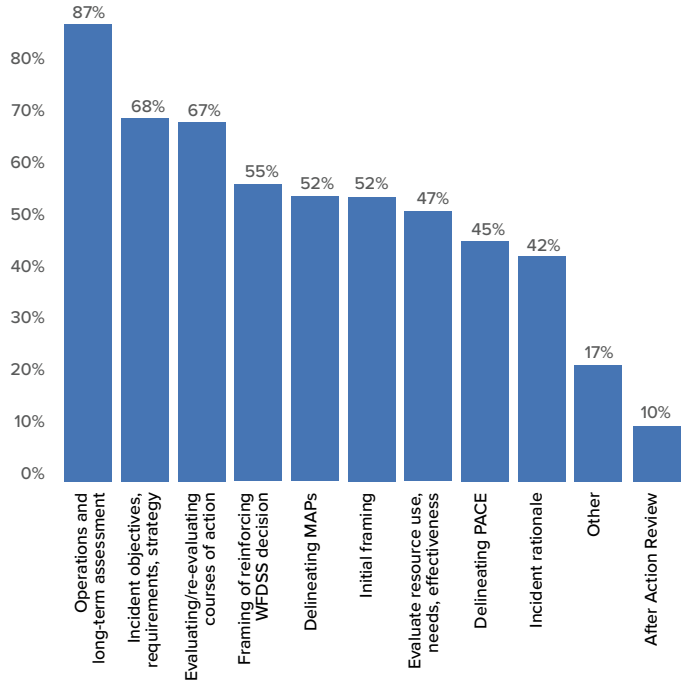


Figure 5: How RMA tools were used to inform fire management. Statement: Please indicate how RMA products were used on the incident(s) (Select all that apply). Lifecycle stages derived from R. Stratton.

We also asked respondents to provide a more detailed open-ended response about how they used RMA products to support incident management. Five themes emerged from the responses, which included the use of RMA to: 1) generate situational awareness for individuals responding to the fire; 2) facilitate dialogue between stakeholders; 3) inform WFDSS; 4) support incident and operational decision making; and 5) facilitate regional prioritization of multiple incidents.

Generate situational awareness

RMA helped respondents generate initial situational awareness for both emerging incidents and existing incidents. RMA was used to quickly help firefighters, agency staff, and other individuals on IMTs better understand the unique fire management considerations, challenges, and opportunities associated with particular landscapes. It also provided situational awareness to support communication internally, with cooperators, and with affected publics, as indicated here:

> *RMA products provide the science needed to efficiently utilize minimal resources to provide the highest level of success. We always get PCL and SDI maps while enroute to the fire to gain situational awareness. We can quickly ground truth this and build more effective plans [with] the safety and OPS [operations section] work[ing] directly hand in hand utilizing several of these products to develop strategic alternatives.*

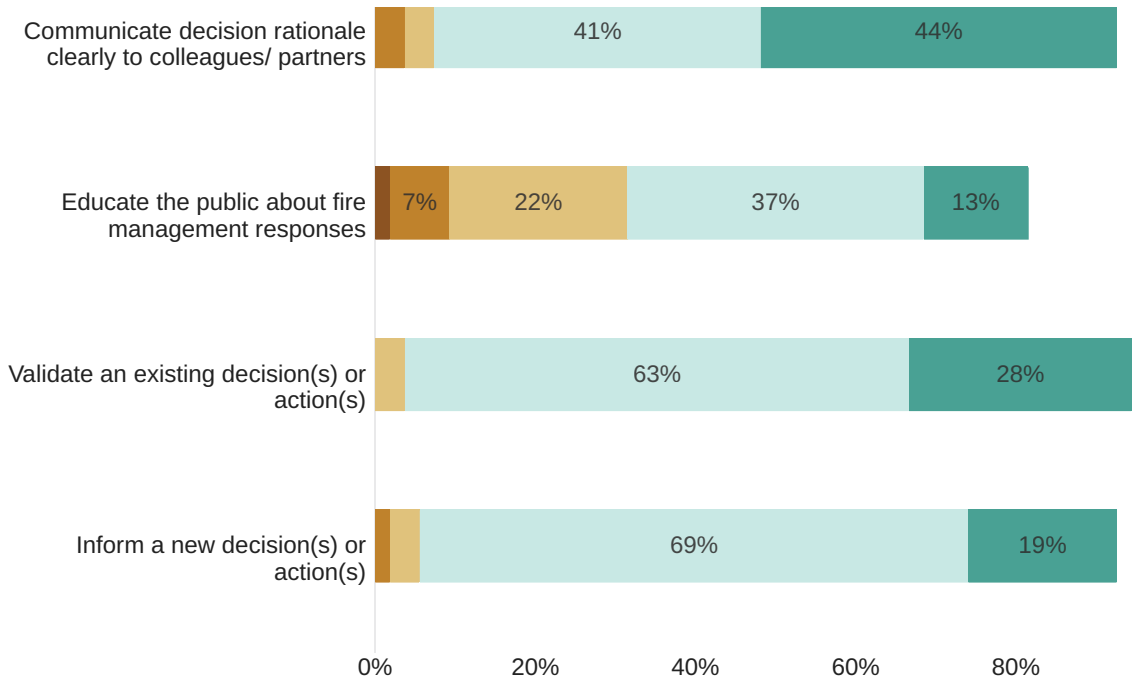


Figure 6: Agreement scale (strongly disagree to strongly agree) on whether respondents felt RMA helped communicate decision rational to partners, educate the public about decisions, validate an existing decision, and/or inform a new decision. Statement: In general, the use of RMA products on wildfire incidents has helped... (if you don't know, select don't know). Responses that selected "Don't know" are not depicted in the figure.

Facilitate dialogue between stakeholders

RMA helped inform discussions between agency administrators, IMTs, cooperators and adjacent units, impacted communities, and the public regarding fire management concerns, operational strategies, challenges, and opportunities; the information created transparency in the decision-making process. RMA helped staff develop a common operating picture from which to explain the logic and rationale behind decisions and articulate incident strategies in relation to resources and values at risk (Figure 6). In the exemplar below, an AA described how RMA tools helped maintain a coherent vision and strategy on long-term events as IMTs cycle through incidents:

> *As an active and engaged AA, I appreciate having multiple sources of information available to me as I work with the multiple IMTs that cycle through long term events. Having RMA products directly available to me allows me to do some exploration on my own, match it up to where we have been and what our current plans are indicating, and then have some rich dialogue with my I*MTs.

IMT members also noted RMA's utility in helping articulate their decision-making process to AAs. RMA was used to develop alignment between IMT sections (e.g., planning and operations). One respondent noted that while functional areas of the IMT use different products, together they help tell a holistic, risk-informed narrative to gain alignment between the IMT and AAs. Similarly, RMA tools were used to develop alignment between federal and non-federal partners, as indicated here:

> *Local cultural differences between the USFS [USDA Forest Service] and our State partners causes occasionally [sic] differences in opinion regarding long-term management of incidents. The [RMA] tools provide a way to model outcomes and display information in order to gain alignment.*

Inform Wildland Fire Decision Support System (WFDSS)

WFDSS is commonly used to document incident strategy and decision-making processes on large wildfires. WFDSS is also closely aligned with RMA, as RMA provides information to help develop incident strategy. Both are spatial decision support systems that rely on fire modeling products and identify highly valued resources and assets to inform planning. One respondent indicated that RMA was used in most of the analyses produced for, and referenced in, WFDSS decisions:

> *RMA products were incorporated in almost all documents and analyses produced, and referenced in multiple WFDSS decisions that I assisted with.*

RMA was used to identify initial planning areas, justify and document decisions, identify management action points (MAPs), and identify primary, alternative, contingency, and emergency (PACE) lines used to contain a wildfire.

Support incident level and operational decision-making

RMA also supported operational strategies and tactics, including the identification of direct and indirect line placement. Staff used RMA to identify potential containment lines, identify areas where there was high or low potential for fire control, and estimate probability of success for different tactics. This proved especially useful when fire behavior necessitated indirect response strategies. RMA tools helped staff understand where landscape and fuel characteristics suggested the fire would likely slow or stop, and where resources would have high probability of success, as indicated by one respondent:

> *We used the SDI, PCL, and Snag Hazard maps to help the team determine probability of success with the actions that they were taking or were planning to take on the incident.*

RMA tools also helped identify the real challenges associated with proposed suppression actions:

> Over*laying specific RMA products over possible suppression actions provided a strong depiction of the realistic challenges inherent in a proposed course of action.*

RMA was useful on incidents where fire behavior was outside the bounds of what was historically experienced on the forest. This was described by a respondent assigned to the Leland Complex:

> *On the Leland Complex, the area the fire was burning had a limited large fire history. Since the fires in the complex already exceeded the size of the largest fires any of the current locals had experience on the forest, they were burned well outside of "normal." The traditional local strategy of direct attack was not successful and indirect actions needed to be implemented. The RMA products were useful in identifying potential line locations. Additionally, using the RMA products to compare where the fire paused or slowed to SDI and PCL data helped identify what fuel changes were needed to stop the fires in the complex.*

RMA was also used to validate decisions. RMA was used to validate potential lines with Operations section staff, inform new decisions, and justify existing decisions (Figure 6), as evidenced here:

> *The SDI and PCL did not drive decisions, but confirmed what Ops [the operations section] and the local unit already knew. They were a good gut-check to reevaluate actions and whether or not they were worth the risk based on the low probability of success.*

Facilitate regional prioritization

Respondents speaking from a regional perspective noted that RMA helped them make data-driven decisions about where to commit resources and IMTs based on values at risk and probability of success, especially when resources were limited and needed to be prioritized. RMA helped respondents standardize, visualize, and assess information provided by IMTs assigned to individual incidents, compare incidents, and then prioritize scarce resources based on need. Specifically, the Fire Comparison Spreadsheet (and prioritization and radar plot tabs) was a notable asset for evaluating incident priorities. One respondent explained:

> *RMA tools are very effective in helping frame up the initial decision of where to commit resources, to the extreme when we ran out of IMT's, where to put the next IMT. [RMA] tools help measure probability of success when making resource allocations.*

D. Did tool use help meet core principles of RMA?

A series of statements assessed whether RMA use supported the core principles of RMA (Calkin et al., 2021). Over 80% of respondents somewhat to strongly agreed that RMA tools improved decision quality. A majority of respondents agreed to strongly agreed that RMA minimized unnecessary risk to firefighters (69%), and a slight majority agreed RMA improved accountability (58%) (Figure 7).

E. Facilitating and frustrating factors

Respondents were asked to provide open-ended responses about what key factors facilitated or frustrated their (or their team's/local unit's) use of RMA products on incidents. We focus first on facilitating factors followed by frustrating factors, and organize results around: 1)

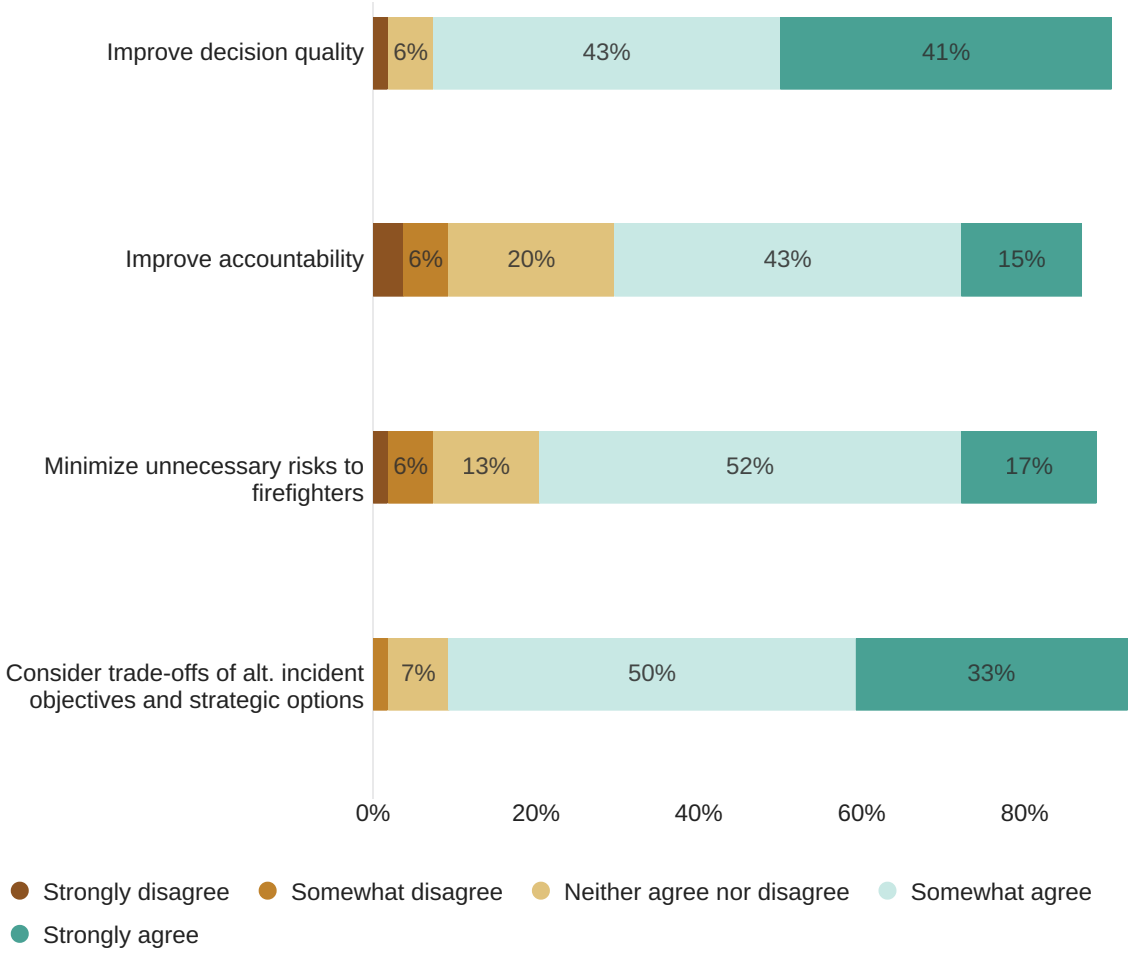


Figure 7: Agreement scale (strongly disagree to strongly agree) on whether participants felt RMA supported core principles of RMA. Core principles include improved decision quality, improved accountability, and reduced risks to firefighters. Core principles were derived from Calkin et al. (2021). Statement: In general, the use of RMA products on wildfire incidents has helped...(if you don't know, select don't know).

Table 1: Factors that facilitated RMA use in wildfire incident management. Question: What key factors supported your (or your team's/local unit's) use of RMA products?

Theme or category	Frequency	Example
Characteristics of individuals, teams, and/or organizations	64	• Previous experience with RMA • Technical expertise/ capacity • Leadership/ champions • Agency or team culture • Receptiveness to innovations • Trust in RMA – related to accuracy
Characteristics of RMA tools	15	• Easy to use or interpret • Accuracy of products or relevance to decision context • Easy to access • Timely
External factors	6	• Uncharacteristic fire weather, conditions and scale • Team transitions • Litigation concerns • Strategic risk and operational planning

characteristics of the RMA tools), 2) characteristics of respondents, teams, and/or their organization, and 3) external factors that facilitate or frustrate the use of RMA tools on incidents (Table 1).

Facilitating factors

Several characteristics of the RMA tools facilitated their use. Specifically, respondents mentioned that the tools were user friendly, easy to access through the RMA dashboard, provided quick, timely information, had high agreement with conditions on the ground, and/or were relevant to their decision context. The RMA dashboard was reportedly easy for practitioners to access and use, and provided products that helped develop strategies quickly. The usability of the suite of tools offered on the RMA dashboard was also reflected in a fixed-response statement (Figure 8). A strong majority of respondents somewhat to strongly agreed tools were provided at the appropriate scale to inform planning and decision-making (94%), were relevant to decision-making processes (87%), accurately depicted conditions on the ground (81%), and were easy to interpret (78%; Figure 8). Respondents witnessed how the products (especially PCL and SDI) aligned with final fire perimeters, which helped them to gain trust in the analytics, which, in turn, supported use.

Characteristics of the individual, team, or organization also facilitated the use of RMA on incidents. The most frequently cited characteristic was previous experience with RMA, followed by having leaders or champions

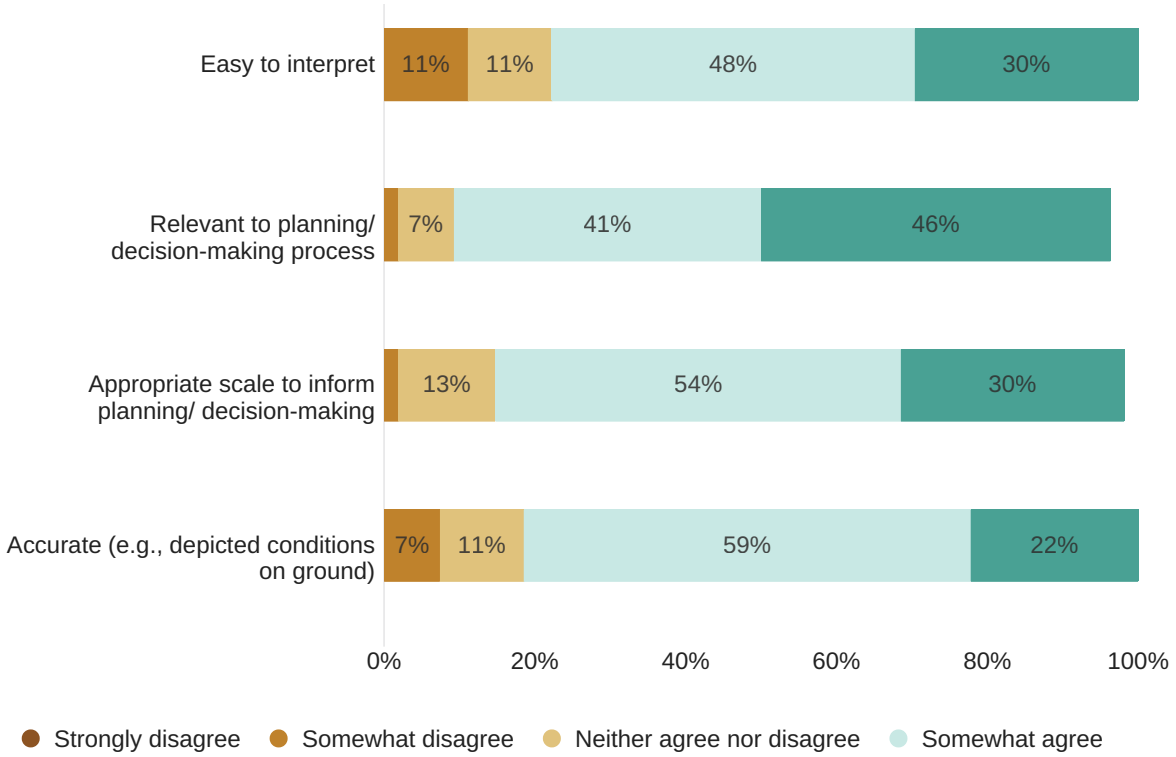


Figure 8: Agreement scale (strongly disagree to strongly agree) on usability of RMA tools. Statement: In general, RMA products were... (if you don't know, select don't know).

provide help in interpreting RMA tools, local agency or team culture, and receptiveness to innovative ways of doing business. Previous experience with the tools and the accuracy of those tools relative to past fire footprints helped built trust in their utility:

> *[Seeing an] assessment of the final foot print of the fires I was on in 2020 compared to where the RMA products showed potential line locations helped me determine the usefulness of the products.*

Leaders are key to integrating new tools and processes into organizational routines. Local and regional leadership encouragement to utilize RMA tools was a key factor supporting their use. Some respondents themselves were key leaders working to integrate the tools with teams, while others worked with leaders that helped train teams and individuals on RMA. For example, one respondent was an AA coach and encouraged AA trainees to familiarize themselves with RMA tools. Further, one respondent described how they are trying to champion RMA use during incidents and in their day job:

> *As the SITL [Situation Unit Leader), I am aware of the products and try to sell them to the team. Ops (the operations section) is not fully convinced of the SDI, PCL, and PODs yet, but [I am] working to get them used to the products and view them early on in the assignment. [I am] also trying to sell them to my local unit (during my day job), including AAs, and progress is being made slowly.*

Others reported team and agency culture and their receptiveness to innovative tools played a large role in facilitating the use of RMA tools on incidents, as indicated by one respondent:

> *Receptiveness of new tools was key. We have a strategic planning unit within our planning section that actively seeks data and analytics to understand the fire's tendencies and how best to inform the operational organization and communicate with Agency Administrators.*

One respondent suggested the openness of the operations section to RMA and fire analytics during their time on the incident was helpful for integrating across the planning and operations sections. Some respondents indicated that turnover of staff provided a window of opportunity to consider new ways of doing business, particularly in the context of using the suite of RMA tools. Turnover often has negative impacts, as it can erode trust and relationships, and diminish institutional knowledge, but it also provides opportunities to take new approaches.

External conditions also facilitated the use of RMA. According to respondents, the uncharacteristic fire weather, conditions, and scale force them to consider other ways of managing and planning for fire. Future fire realities further underscored the need to be receptive to new tools:

> *In the fire behavior business, we are using a 50-year-old approach that has been repackaged various ways. The wildfires we are experiencing are not the same character of fires that occurred 50 years ago. I am looking for new approaches to this issue - so I'm open to seeing new tools.*

Table 2: Factors that frustrated RMA use in wildfire incident management. Question: What, if any, challenges inhibited your (or your team's/local unit's) ability to use RMA products?

Theme or category	Frequency	Example
Characteristics of individuals, teams, and/or organizations	31	• Resistance or hesitance to use • Team/Agency culture • Familiarity/knowledge of RMA • Lack of leadership, champions • Expertise/technical capacity to use and interpret
External factors	17	• Resource capacity • WIFI and telecommunications availability • External support/ guidance (e.g., training on products) • Tool overload, or competes with required products
Characteristics of RMA tools	7	• Complex terminology makes difficult to integrate • Coarse resolution limits applicability • Tools perceived as static, generalized representations of conditions • Fire conditions or fire history limits use, applicability of tools

Others reported RMA tools were used because they were already in use on an incident by the previous IMT, as a tool to address litigation concerns, and in response to the recent focus on strategic risk assessment and strategic operations planning processes.

Frustrating factors

On the other hand, several frustrating factors impeded RMA use. As above, in many cases whether tools were used (or not) depended on individual respondents, their experience on the incident, and incident context. Again, these challenges reflected factors associated with the individuals, teams, or organizations, external factors, and/or characteristics of the RMA tools (Table 2).

The most frequently cited barriers to RMA use among individuals, organizations, or teams was lack of familiarity or knowledge of RMA and hesitance to use RMA tools. According to respondents, some operations and planning section staff and AAs still have limited knowledge of the products, how to use them, and how to interpret them. This was, at least partly, because the RMA dashboard and suite of tools are still relatively new; teams still wanted to validate how tools reflected conditions on the ground, which—while important—takes time and can slow the decision-making process. Respondents indicated that unfamiliar tools will be used less frequently in stressful situations:

> *Folks are unfamiliar with products and default to what they are comfortable with. When stressed we default to what/who we know.*

At times, it was difficult to convince teams and leadership, interagency partners and cooperators of RMA's utility. For instance, some teams who cycle onto an incident may elect to develop their own strategy and not use existing long-term strategies or plans developed with RMA. One respondent suggested that since most fires were caught at initial attack, some fire managers didn't see a need for long-term analyses or large fire prioritization. The same respondent emphasized the need for more leadership awareness and exposure to RMA tools to mitigate this issue. Relatedly, local leaders who fail to share existing products (e.g., local PODs networks) with incoming IMTs also limit the use of those tools:

> *I have also been on fires where the local unit never mentions that they have PODs. If they do not push them, then our Ops [Operations section] will be much less likely to look at them.*

Some managers are reluctant to use RMA tools because they don't trust them yet:

> *Having people to believe in what is being shown is the biggest challenge I see. When the analytics (PCL/SDI, etc.) are showing a big box…they tend to get thrown out and replaced with "local knowledge or experience" and then we end up with yet another indirect line that will either get burned over or never used.*

External factors also limited RMA use. The most frequently cited external factor was resource capacity (e.g., time, competing demands). Fire behavior or rate of spread often dictated whether RMA tools were used or not. In some instances, respondents wanted to use an assortment of RMA and non-RMA tools to inform decision-making, but were afraid that doing so would slow down their decision-making process. Further, GIS specialists are required to produce certain maps to support fire management, which often resulted in no capacity to produce alternative maps that incorporate RMA tools. Some respondents expressed feeling overwhelmed with the existing requirements of their job (e.g., WFDSS, in-briefings, managing multiple incidents) and felt there was limited time to incorporate RMA. A couple of respondents indicated that competing demands locally and at the regional level limited the use of RMA tools:

> *Due to competing demands on my time from supporting multiple incidents, I didn't have enough time to fully explore and utilize new RMA products to their fullest potential.*

Respondents also noted the challenge of utilizing web-based decision support tools in locations with limited WIFI or telecommunications services. Others indicated external support, guidance, or training was lacking. For example, one respondent mentioned they didn't know what tools were available, how to get them, or who to ask for help; another suggested lack of training on the RMA dashboard in the pre-season limited RMA use during incidents.

While the majority of respondents noted RMA tools were provided at the appropriate scale, were relevant to the decision-making process, accurately depicted conditions on the ground, and were easy to interpret (Figure 8), a small number of respondents suggested some characteristics of the tools impeded use. Specifically, the resolution, update frequency, complex terminology, spatial variability in the accuracy of RMA products, and limitations on who can generate some of the RMA tools and data frustrated tool use. One respondent considered RMA sufficient for coarse-scale overviews but suggested they were less useful for understanding fine-scale fire behavior and movement:

> *It is usually the case that we can access information and data from sources like RMA products that are a good overview and somewhat coarse in nature. As we have to take a deeper dive into the nuances and unique characteristics of what is making a particular fire move - the tools like RMA products become less useable.*

Others felt tools would be used more if the products were updated more frequently or varied dynamically with changing conditions. Some respondents noted RMA tools used complex terminology and concepts, which led to them not being readily understood or adopted. Finally, some respondents noted limitations of specific RMA tools and products. For instance, one respondent indicated that the accuracy of the SDI and PCL was spatially variable:

> *RMA products are pretty good out west; RMA products in the lake states need to be improved; risk data/SDI/PCL all needs to be updated.*

Another respondent felt the Aviation Use Summaries in particular were difficult to access "due to the limitation of the number of people allowed to generate that data." Finally, the PCL analysis relies on past fire history to train and parametrize the model. On a particular landscape with limited large fire history, it was difficult for fire managers to use the SDI and PCL to locate control line opportunities:

> *The lack of large fire history in the area did not allow me to exam[ine] where past fires had stopped and compare these with the PCL/SDI data to determine what fuel/terrain changes are typically successful places to locate line.*

F. Recommendations

Little research has been published on the use of RMA (Calkin et al., 2021; Schultz et al., 2021). From what has been published, we identified recommendations for improving the use of RMA for incident decision-making and polled respondents on whether those recommendations are important to consider. Each of the six recommendations listed in Figure 9 were considered very important to extremely important. The three top recommendations were: 1) integrate RMA products and processes with next generation WFDSS (88% indicated this was very to extremely important); 2) invest in local analytical capacity to use and interpret RMA tools (82%); and 3) increase RMA outreach in the preseason, for example during PODs workshops (75%).

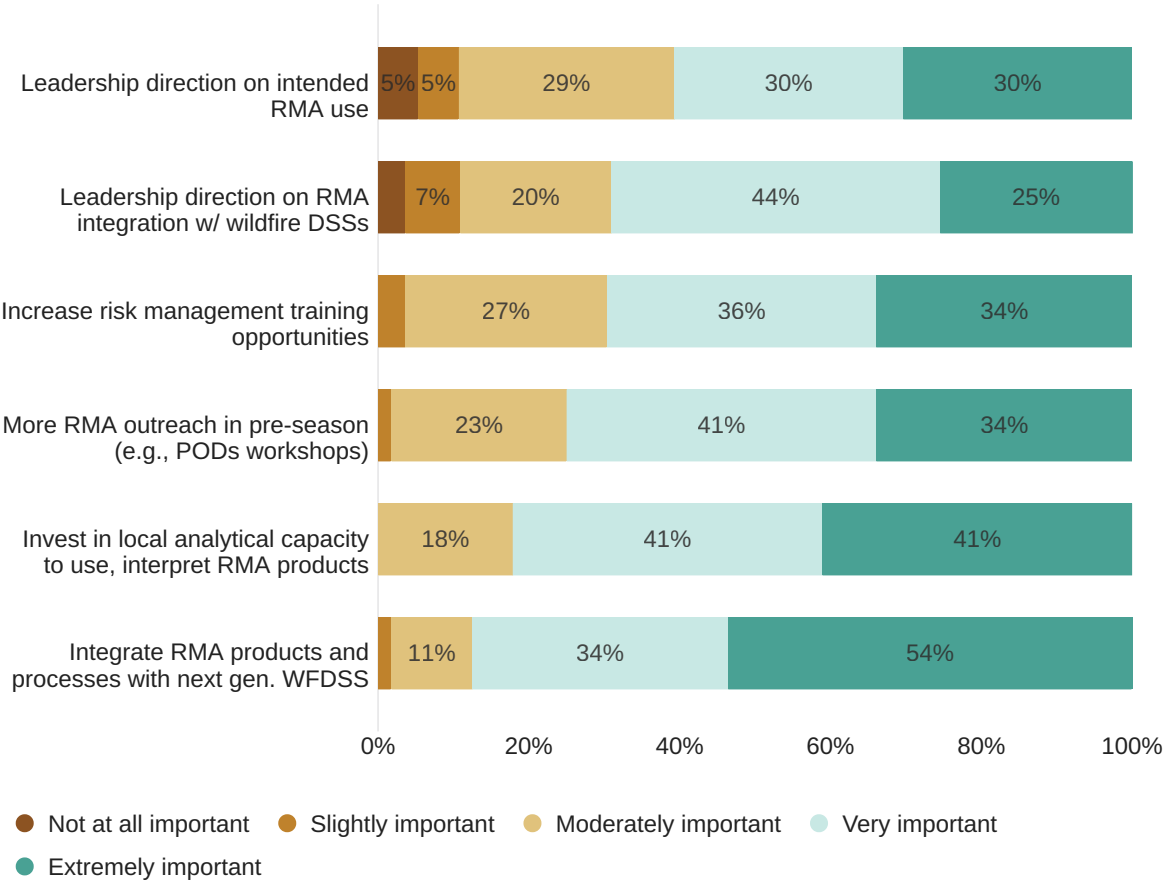


Figure 9: Importance scale (not at all important - extremely important) on the importance of documented recommendations for enhancing RMA tool use. Recommendations derived from Schultz et al. (2021) and Calkin et al. (2021). Statement: Several recommendations have been suggested to enhance the integration of RMA products on incidents. Please indicate the importance of each suggested recommendation.

Respondents were prompted to provide additional recommendations to enhance the delivery and use of RMA on wildfire incidents. Many comments elaborated on the recommendations in Figure 9 and those articulated in the facilitating and frustrating factors section (See Tables 1 and 2, respectively), but additional recommendations were also provided. Responses have been grouped into four broad themes: 1) increase awareness and familiarity through training and outreach; 2) increase RMA use through socialization of tools and processes; 3) improve delivery and experience of existing products; and 4) grow and expand the products available and their uses (Table 3).

Table 3: Recommendations to improve the use and usability of RMA tools for wildfire management. Question: What other recommendations do you have to enhance the delivery and use of RMA products on wildfire incidents?

Theme or category	Frequency	Example
Increase awareness/ familiarity through training and outreach	17	• Training audiences - AAs, ADs, IMTs, Operations Sections Chiefs, interagency partners) • Methods of delivery – short webinars, traveling training teams, incorporate into fire class and coursework at all levels
Integrate RMA use through norming/ socialization	10	• Delineate expectations for use • Change organizational structures • Build/lean on local champions • Increase local exposure to tools
Improve existing tool delivery/ experience	8	• Integrate with other platforms • Improve availability of tools (e.g., Aviation Use Summaries) • Make it simpler/more user-friendly • Consider more frequent updates • Mitigate spatial variability in tool accuracy/quality
Expand products and uses	7	• Integrate with fuels/prescribed fire planning and implementation • Increase tools available on RMA dashboard

Many respondents elaborated on how increased opportunities for training and pre-season outreach could help expand use and overcome barriers to use, such as lack of awareness, familiarity, and trust in the RMA tools. Respondents recommended training for several audiences, including Operations Section Chiefs:

> *The most 'typical' of Operations Section Chiefs need to be trained on and comprehend these products.*

Other audiences mentioned were AAs, Administratively Determined staff (ADs), analysts (e.g., Long Term Fire Analysts, Fire Behavior Analysts), leadership, IMTs, and interagency partners (especially states and local government). One respondent recommended more training for AAs and leadership direction to encourage AA participation in training:

> *The FS [Forest Service] has not been able to bring about a complete package of training for Agency Administrators. We have very little attendance in fire training with line officers and little leadership direction for them to participate.*

In terms of information delivery, respondents suggested short webinars, while others suggested longer-term integration of risk management principles and RMA tools into coursework, such as National Wildfire Coordinating Group (NWCG) RT130 and 200-, 300-, and 400-level courses, to increase RMA familiarity. Respondents suggested 'road show' style in-person presentations to help familiarize audiences and build trust in the products in the pre-season:

> *Advertise a few folks who are experts in this stuff and available to attend pre-season meetings or trainings anywhere to give more people exposure to this valuable resource.*

PODs workshops where fire managers, cooperators, and relevant stakeholders co-develop potential control locations and PODs networks may be an appropriate venue for this. Subsequent engagement with entities and organizations as they integrate PODs into land and fire management objectives could also provide opportunities for RMA education and outreach.

The second theme involves integrating RMA use into typical practice through norming and socialization. Some recommended more exposure to the tools during incidents to build trust in the accuracy of the tools:

> *For some groups of people, it is going to take them actually seeing the products work on the ground before they will fully believe what the science is telling them.*

"Seeing the products work" was noted as a strong facilitating factor by respondents. Respondents highlighted the importance of local or peer demonstrations of the tools' value to IMTs and AAs, and they emphasized utilizing the tools early (i.e., initial attack), often, and throughout extended fire events. In this vein, respondents suggested the need for leaders, or champions, on local units and IMTs to demonstrate the use and utility of RMA. One respondent recommended outreach to Incident Commanders (ICs) on incidents to identify what needs they may have, which could provide valuable on-incident support and help develop future RMA champions. In order for RMA to be used, respondents recommended agency leadership set clear expectations for how to use the RMA tools throughout the fire lifecycle. Further, respondents recommended the need for 1) funding additional analysts and other personnel dedicated to RMA; and 2) changing IMT organizational configurations to ensure teams have the appropriate skillsets and experience in risk management principles and RMA:

> *All IMTs should be required to have a SOPL [Strategic Operational Planner] in their "short team" configuration. There should not always be 'strike teams of Ops [Operations section] chiefs' with exactly the same qualifications rolling out with IMTs. Any IMT that carries more than two Ops Chiefs needs to ensure they carry a SOPL.*

The third theme included recommendations for technical improvements to the existing set of RMA products. For example, respondents recommended integrating these tools into existing platforms and systems in use, including next-gen WFDSS, the Interagency Fuel Treatment Decision Support System (IFTDSS), and the Enterprise Geospatial Portal (EGP). Some respondents suggested expanding the ways in which tools were made available during incidents particularly where internet connectivity is uncertain:

> *It would be good to figure out a way to get it into a format that is better used while on an incident. Sometimes there is limited WIFI capacity or access to printers/plotters… maybe a written handbook or guides when connectivity is lacking.*

Respondents also emphasized the importance of generating RMA maps to support incident response as soon as the first team is ordered and assigned to an incident:

> *RMA maps will be more widely used if maps are created as soon as the leadership knows [the] fire will extend into extended response.*

Respondents requested tools be updated more frequently to represent dynamic and changing conditions on the ground, and to mitigate spatial variability in the accuracy of products. They also suggested increasing the availability of, or access to, Aviation Use Summaries. Tools that would support line identification in areas with limited large fire history was recommended. Where possible, making the RMA dashboard and tools more user-friendly for a variety of audiences by adding features like help links may enhance adoption of RMA products. As one respondent noted:

> *It would be great if the products provided were simple enough for most to understand while providing options for those users with more skills to extrapolate if necessary.*

Some respondents suggested improving RMA use by making the dashboard a "one stop shop" for integrated wildfire mitigation, pre-fire planning, and incident management. One respondent suggested that incorporating more information about how critical values and assets of concern may respond to fire (and the extent to which they may be positively or negatively affected by fire under various conditions) into the RMA dashboard could improve decision making:

> *When line officers are faced with suppress fire small [sic] and commit few resources versus big box and lots of time/resources……then our history shows what way line officers will go despite what the analytics show. Decisions based on risk alone are very subjective (in spite of analytics) where effect on the resource is more science based and provable.*

Respondents saw opportunities to apply RMA tools to wildfire mitigation (i.e., fuels reduction and prescribed fire planning and implementation). They considered RMA tools well-suited to validate the purpose and need for treatments, and where to put them. When managers are able to use the same systems and tools for both wildfire mitigation and response, it increases the exposure and familiarity of the tools to local units, and the lines between mitigation and response begin to blur.

G. How was RMA used in non-incident management contexts?

Respondents indicated that they are using RMA tools in non-incident management contexts, including pre-season wildfire planning, fuels planning, and environmental analysis and decision-making (Figure 10).

We asked respondents to describe how they were using RMA in non-incident management contexts in an open-ended question. Three common themes emerged from those responses, two of which expanded on the fixed-response statement (Figure 10). They included: 1) pre-season fire planning; 2) fuel treatment planning and proposed actions requiring environmental review pursuant to the National Environmental Policy Act (NEPA); and 3) communication, learning, and shared understanding (Table 4).

The distinction between pre-season fire planning and fuel treatment planning refers primarily to the temporal scale in which the planning occurs. In this context, pre-season fire planning refers to shorter- to mid-term tactical planning for the fire season, whereas fuel treatment planning refers to longer-term, strategic planning to implement treatments to reduce wildfire risk or improve opportunities for safe and effective fire management. At the same time, the distinctions between how these were discussed by respondents was somewhat blurry. For example, one respondent described how RMA use can support a range of applications:

> *POD development that uses RMA is being used as a collaborative planning framework, supporting interagency coordination, evacuation planning, CWPP [Community Wildfire Protection Plan] development, etc.*

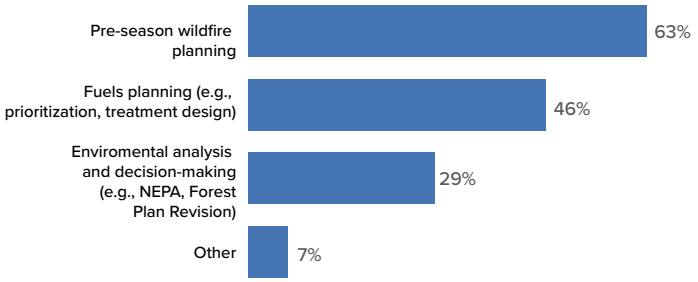


Figure 10: Frequency of respondents that used RMA for non-incident management activities. Statement: I am using RMA products for non-incident management purposes, including... (select all that apply).

Table 4: RMA use in non-incident management contexts. Statement: Please explain how you have used/are using RMA products to support non-incident management (e.g., fuels planning, NEPA, prioritization).

Theme or category	Frequency	Example
Pre-season fire planning	33	• Inform quantitative risk assessments • Use RMA to draft PODs • Use for pre-season training • Bolster grant proposals
Fuel treatment planning	24	• NEPA • Prioritization of treatment type and location • Firesheds • Inform CWPPs
Shared understanding, communication and learning	5	• Situational awareness • Outreach with partners • Coordination of fuels treatments with partners

The most prominent example in the responses was using RMA in the development and use of PODs in pre-season fire planning. One respondent described using these applications to inform potential fire season strategy:

> *[We] use PODs and PCLs to conduct pre-season fire management planning (assess opportunities to manage fire for resource benefit).*

Others used RMA to brief line officers on expected high-problem areas in the event of an ignition. Many respondents also described using RMA products to inform risk assessments:

> *I encourage my Rangers to use this tool [RMA] in development of risk assessments for any activity in the woods.*

Meanwhile, others noted RMA tools were used to support grant applications. One respondent in particular used risk assessments and fire danger products on the RMA dashboard to write Federal Emergency Management Agency (FEMA) Fire Management Assistance Grant applications.

With respect to fuel treatment planning, numerous respondents provided examples of RMA use to support prioritization, NEPA processes, and strategy development. For example, one respondent explained the use of RMA in prioritizing treatments:

> *I have successfully incorporated RMA products (SDI/PCL primarily) in prioritizing fuels treatments in areas with multiple values at risk (VARs) and recently as supporting documentation in an Environmental Assessment (EA).*

Another respondent used RMA for effects analysis on a proposed action, which helped justify where treatments should occur and why:

> *[We] used PODs and PCL in fuels planning as well as NEPA effects analysis. Certainly, [these tools] help[ed] in [developing the] rational[e] for why here, why now.*

One respondent aligned RMA products with the USDA Forest Service Firesheds and 5-year plans to identify new priority treatment areas. Respondents noted that RMA was also used for communication with communities and partners for planning fuel reduction treatments, learning or training purposes, and generating general understanding or situational awareness. Finally, one respondent highlighted how the RMA dashboard helped provide information to increase situational awareness during and leading into the fire season:

> *[We] use the [RMA] dashboard to look at drought/ weather/fuels, past fires on the district, etc. to prepare exercises ahead of the season with my fire staff and crews.*

Conclusion and next steps

The USDA Forest Service Fire and Aviation Management (FAM) department requested assistance from the Southwest Ecological Restoration Institutes (SWERI) to develop an online questionnaire to assess Risk Management Assistance (RMA) use during the 2021 fire season. We framed the assessment around four research questions: 1) Which RMA products are used on wildfires; 2) How is RMA used to inform decision-making; 3) What factors facilitate or frustrate use; and 4) How can RMA be improved to enhance its use and legitimacy in wildland fire management? The questionnaire was administered to fire managers and personnel (e.g., Incident Management Teams [IMTs], Agency Administrators) who engaged with RMA products and assistance during the 2021 fire season. We received 94 usable responses that captured 69 incidents across 11 states and over 6 million acres burned. 27 IMTs, 9 regional Geographic Area Coordination Centers (GAACs), and multiple type 1, 2, and 3 teams were represented in the sample.

Our findings indicated that RMA was overwhelmingly seen as a useful set of tools and processes which helped inform incident decision making. RMA tools were used to facilitate dialogue with cooperators and stakeholders, inform strategic, operational, and tactical decision-making, and support regional prioritization of incidents. Regional coordination and prioritization are especially important given the increased complexity of the fire environment, limited resources, increased reliance on out-of-region teams during high preparedness levels, and increased frequency of multiple, long duration events where numerous teams cycle through an incident.

A majority of respondents felt that RMA met the core principles of the program – improve decision quality, improve accountability, and minimize unnecessary risk to firefighters (Calkin et al., 2021). Most respondents felt that the tools on the RMA dashboard were easy to interpret, relevant to decision making, provided at the appropriate scale, and accurately depicted conditions on the ground. The RMA dashboard was reportedly easy to access and use by practitioners, and respondents agreed that the dashboard provided products that helped develop strategies quickly. A number of factors facilitated use, including familiarity with RMA, trust in the accuracy of analytics, receptiveness to new tools and processes, internal capacity and expertise, and the presence of leaders who advocated for RMA use to support fire and land management decision-making.

Still, practitioners provided several recommendations that could improve RMA use and legitimacy. These included: 1) increased education and outreach; 2) clear leadership direction and intent; 3) more support for regional analysts and incident personnel trained in risk management principles and RMA; and 4) more frequent tool updates and tool enhancements. More education, training, and outreach on RMA was recommended. Suggestions included targeted webinars, integrating RMA and risk management principles into the National Wildfire Coordinating Group course curriculum for firefighters and agency administrators, introducing RMA products and processes during Potential Operational Delineations (PODs) workshops, and additional opportunities for peer learning and knowledge exchange. Peer-to-peer learning and training during incidents (e.g. Strategic Risk Analysis and Strategic Operations) and extending training to local fire managers and Type 3 teams could help bolster the use of RMA on extended and emerging incidents. National-level peer learning networks, such as the PODs user group, are key to supporting education, outreach, and social learning around PODs and RMA. In addition, more frequent, and regionally-focused communities of practice would be beneficial to further the socialization of RMA, its applications, and innovations in the field. Many respondents indicated the use of RMA for non-incident environmental analysis and decision making for fuels and other land management objectives. When managers are able to use the same systems and tools for wildfire mitigation and response, it increases the exposure and familiarity of the tools to local units, and the lines between mitigation and response begin to blur.

Respondents recommended clear leadership direction on

how RMA should be used on incidents and incorporated within existing decision-support tools, including the Wildland Fire Decision Support System (WFDSS). Opportunities to distill leadership intent and direction could be achieved in the IMT, at annual coordination meetings, or through the delegation of authority on incidents. There is a need to invest in analytical capacity on units, teams, and at the regional and national level to use and interpret risk-informed spatial analytics and RMA tools in particular. Regional analysts are becoming more common and could be integrated in all GACCs to support multiple incidents and regional prioritization. IMTs could incorporate strategic operations positions in planning and operations sections who are trained in risk management principles and analytics. Learning modules and help links for tools in the RMA dashboard was recommended. Also, adapting delivery systems so that tools are updated more frequently as conditions change may support usage.

This assessment provided baseline information on the use of RMA during fire incidents, contributed to our understanding of what facilitates and frustrates RMA use, and identified actionable recommendations to improve RMA products and processes. Our hope is that this is the first in what will become a long-term evaluation of RMA products and processes. This structured and systematic questionnaire could be readministered longitudinally to track trends in RMA use and determine the extent to which RMA is useful and used. Additionally, case studies can add local context and nuance to questionnaire findings. These should be grounded in the needs and priorities of forest and fire practitioners and FAM leadership.

Next steps for our research team include case studies that: assess RMA use during 2022 wildfire incidents that will help further explain questionnaire findings; document how leadership direction and intent on RMA is conceptualized, defined, and disseminated to lower levels of authority and cooperators; and share recommendations for improving the suite of analytical tools and products available on the RMA dashboard. We are particularly interested in collaborative planning processes facilitated by RMA. Future work may evaluate the strategic risk assessment and strategic operations processes, particularly with regard to how RMA was integrated into these processes by coaches and IMTs. There are also opportunities to learn more about those who do not use RMA and why, as our survey focused specifically on fires where RMA was used. We will maintain our focus on co-developing actionable knowledge with practitioners to improve decision-making before, during, and after fires.

References

Caggiano, M.D., Beeton, T.A., Gannon, B.M., White, J., 2021. The Cameron Peak Fire: Use of Potential Operational Delineations and Risk Management Assistance Products (No. CFRI-2106). Colorado Forest Restoration Institute, Fort Collins, CO. https://cfri.colostate.edu/wp-content/uploads/sites/22/2021/06/CameronPeakFirePODsReport.pdf

Calkin, D.E., O'Connor, C.D., Thompson, M.P., Stratton, R., 2021. Strategic Wildfire Response Decision Support and the Risk Management Assistance Program. Forests 12, 1407. https://doi.org/10.3390/f12101407

Colavito, M., 2021. The Human Dimensions of Spatial, Pre-Wildfire Planning Decision Support Systems: A Review of Barriers, Facilitators, and Recommendations. Forests 12, 18. https://doi.org/10.3390/f12040483

Dilling, L., Lemos, M.C., 2011. Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. Global environmental change 21, 680–689. https://doi.org/10.1016/j.gloenvcha.2010.11.006

Greiner, S.M., Schultz, C.A., Kooistra, C., 2020. Pre-season fire management planning: the use of Potential Operational Delineations to prepare for wildland fire events. Int. J. Wildland Fire. https://doi.org/10.1071/WF20124

Holden, Z.A., Swanson, A., Luce, C.H., Jolly, W.M., Maneta, M., Oyler, J.W., Warren, D.A., Parsons, R., Affleck, D., 2018. Decreasing fire season precipitation increased recent western US forest wildfire activity. Proc Natl Acad Sci USA 115, E8349–E8357. https://doi.org/10.1073/pnas.1802316115

Jolly, W.M., Cochrane, M.A., Freeborn, P.H., Holden, Z.A., Brown, T.J., Williamson, G.J., Bowman, D.M.J.S., 2015. Climate-induced variations in global wildfire danger from 1979 to 2013. Nature Communications 6, 7537. https://doi.org/10.1038/ncomms8537

Lemos, M.C., 2008. What Influences Innovation Adoption by Water Managers? Climate Information Use in Brazil and the United States1. JAWRA Journal of the American Water Resources Association 44, 1388–1396. https://doi.org/10.1111/j.1752-1688.2008.00231.x

Noble, P., Paveglio, T.B., 2020. Exploring Adoption of the Wildland Fire Decision Support System: End User Perspectives. Journal of Forestry 118, 154–171. https://doi.org/10.1093/jofore/fvz070

Radeloff, V.C., Helmers, D.P., Kramer, H.A., Mockrin, M.H., Alexandre, P.M., Bar-Massada, A., Butsic, V., Hawbaker,

T.J., Martinuzzi, S., Syphard, A.D., Stewart, S.I., 2018. Rapid growth of the US wildland-urban interface raises wildfire risk. Proc Natl Acad Sci USA 115, 3314–3319. https://doi.org/10.1073/pnas.1718850115

Rapp, C., Rabung, E., Wilson, R., Toman, E., 2020. Wildfire decision support tools: an exploratory study of use in the United States. International journal of wildland fire 29, 581–594. https://doi.org/10.1071/WF19131

Ryan, G.W., Bernard, H.R., 2003. Techniques to Identify Themes. Field Methods 15, 85–109. https://doi.org/10.1177/1525822X02239569

Schultz, C., Miller, L.F., Greiner, S., Kooistra, C., 2021. A Qualitative Study on the US Forest Service's Risk Management Assistance Efforts to Improve Wildfire Decision-Making. Forests 12, 344. https://doi.org/10.3390/f12030344

Stratton, R., 2020. The path to strategic wildland fire management planning. Wildfire 29.1, 10. https://www.iawfonline.org/wp-content/uploads/2020/01/Wildfire-2020-01-Strategic-fire-management-Stratton.pdf

Vásquez, F., Cravero, A., Castro, M., Acevedo, P., 2021. Decision Support System Development of Wildland Fire: A Systematic Mapping. Forests 12, 943. https://doi.org/10.3390/f12070943

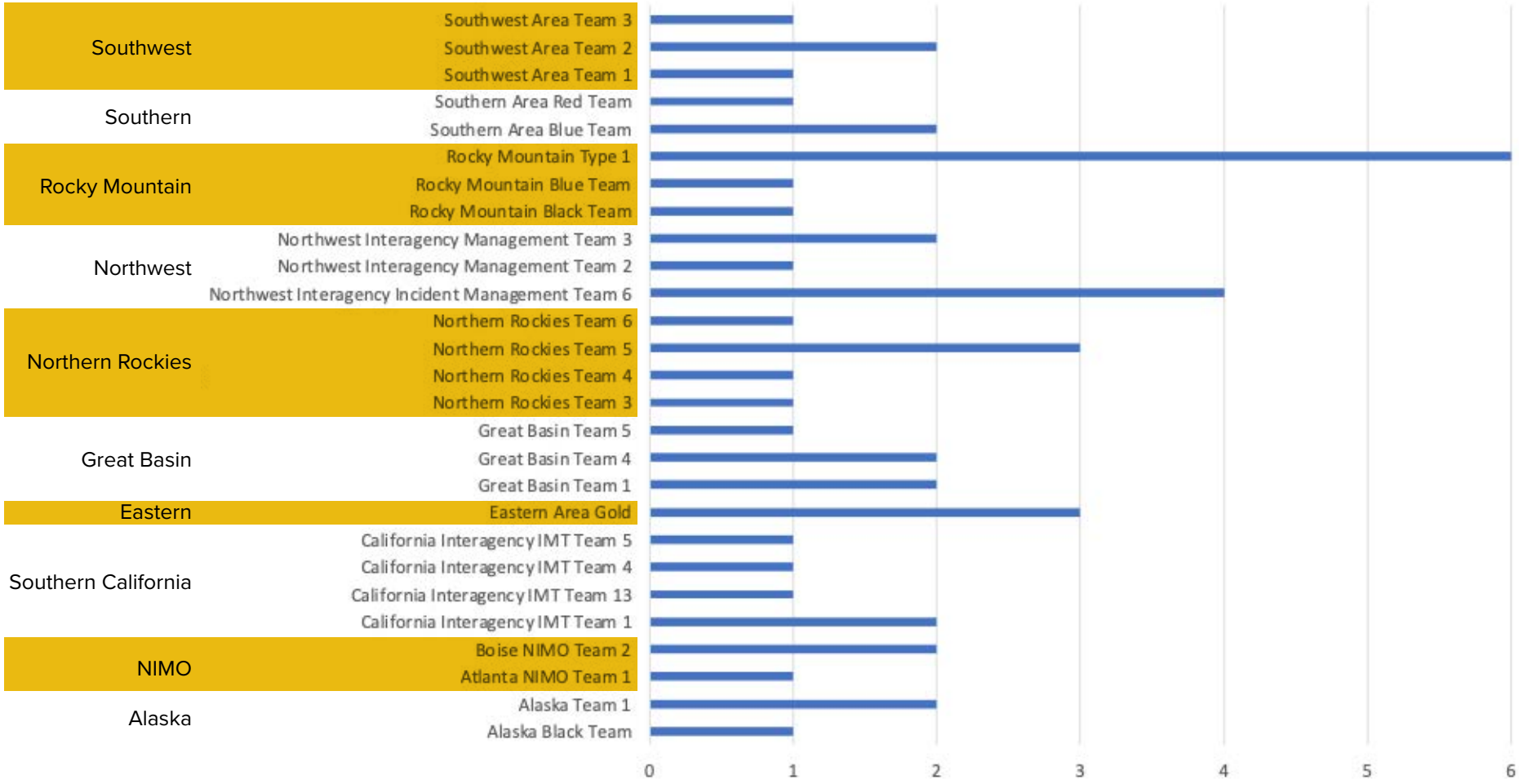
Appendix 1: Frequency distribution of number of respondents by incident.

Incident Name	Frequency
Alder Creek	7
Devils Knob Complex	7
Trail Creek	7
Dixie	5
KNP Complex	5
Rough Patch Complex	5
Balsinger	4
Bootleg	4
Bull Complex	4
Cub Creek 2	4
Jack	4
Tamarack	4
Green Ridge	3
Greenwood	3
Middle Fork Complex	3
River Complex	3
Sylvan lake	3
Telegraph	3
Antelope	2
Backbone	2
Black Mountain	2
Cedar Creek	2
Haystack	2
Lick Creek	2
McCash	2
Monument	2
Ptarmigan	2
Twenty-five Mile	2
12 mile	1
American Fork	1
Beckwourth	1
Black Butte	1
Boulder 2700	1
Burnt Peak	1
Caldor	1
Chickadee	1
Christensen	1
Cornville	1
Cougar Peak	1
Cougar Rock Complex	1
Crater Ridge	1
Darlene	1
Delta Lake	1
Gales	1
Goose	1
Granite Mtn	1
Greenside Butte	1
Haystack (AK)	1
Johnson	1
Johnson Creek	1
Lava	1
Leland Complex	1
McFarland	1
Pack Creek	1
Pinnacle	1
Rafael	1
Red Apple	1
Rincon	1
Robertson Draw	1
Robinson	1
Rush Creek	1
Snake River Complex	1
Storm Theatre Complex	1
Thorne Creek	1
Too Kush 2	1
Vinegar	1
West Lolo	1
Windy	1
Woods Creek	1

Appendix 2: Frequency distribution of Incident Management Team representation in the survey

Respondents who were on the same team for multiple incidents (respondents could include up to three incidents) were only counted once.

IMT	Frequency
Rocky Mountain Type 1	6
Northwest Interagency Incident Management Team 6	4
Eastern Area Gold	3
Northern Rockies Team 5	3
Alaska Team 1	2
Boise NIMO Team 2	2
California Interagency IMT Team 1	2
Great Basin Team 1	2
Great Basin Team 4	2
Northwest Interagency Incident Management Team 3	2
Southern Area Blue Team	2
Southwest Area Team 2	2
Alaska Black Team	1
Atlanta NIMO Team 1	1
California Interagency IMT Team 13	1
California Interagency IMT Team 4	1
California Interagency IMT Team 5	1
Great Basin Team 5	1
Northern Rockies Team 3	1
Northern Rockies Team 4	1
Northern Rockies Team 6	1
Northwest Interagency Incident Management Team 2	1
Rocky Mountain Black Team	1
Rocky Mountain Blue Team	1
Southern Area Red Team	1
Southwest Area Team 1	1
Southwest Area Team 3	1



GACC **IMT** **FREQUENCY**