OMB Number: 0690-0032
Expiration Date: 08/31/2021

DEPARTMENT OF COMMERCE
RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

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AWARD INFORMATION	
1. Federal Agency: Department of Commerce / NOAA	2. Federal Award Number: NA19NWS4680002
3. Project Title: Determining Criteria for Messaging NWS Red Flag Warnings	
4. Award Period of Performance Start Date: 06/01/2019	5. Award Period of Performance End Date: 05/31/2022
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR	
6. Last Name and Suffix: Brown , null	7. First and Middle Name: Timothy , null
8. Title:	
9. Email: tim.brown@dri.edu	10. Phone Number: 775-674-7090
AUTHORIZING OFFICIAL	
11. Last Name and Suffix: Stuart , null	12. First and Middle Name: Margie ,
13. Title: Business Manager	
14. Email: margie.stuart@dri.edu	15. Phone Number: 775-674-7028
REPORTING INFORMATION	
Signature of Submitting Official: Margie Stuart	
16. Submission Date and Time Stamp: 10/27/2022	17. Reporting Period End Date: 05/31/2022
18. Reporting Frequency: ○ Annual ◉ Semi-Annual ○ Quarterly	19. Report Type: ○ Not Final ◉ Final
RECIPIENT ORGANIZATION	
20. Recipient Name: NEVADA SYSTEM OF HIGHER EDUCATION	
21. Recipient Address: 2215 RAGGIO PKWY, RENO, NV 89512-1095 USA	
22. Recipient UEI: MV1JFXA4S621	23. Recipient EIN: 886000024

ACCOMPLISHMENTS

24. What were the major goals and objectives of this project?

The purpose of this project was to scientifically define weather and environmental criteria that drives extreme fire behavior and develop a standardized methodology to provide guidance for issuing a Red Flag Warning (RFW). When this project began there were 524 variants of RFW criteria across the country. This project attempts to align RFW with the goals of the Hazard Simplification Program. By providing a scientifically verifiable and actionable link between fire danger and fire behavior, more meaningful warnings will be available to fire managers and the public, increasing the salience and reliability of these forecasts. The primary issues defining the project are:

- RFW criteria lack a nationally standardized methodology
- Fuel dryness is inconsistently incorporated
- The current warning structure does not adequately communicate severity or uncertainty information

25. What was accomplished under these goals?

1) A Master's degree was awarded to Sarah Jakober.
2) A journal paper was submitted but reviewer comment indicated major revision required. These comments will be considered and the paper resubmitted.
3) A set of recommendations for NWS describes various aspects of improving RFW.
4) The project expanded the partnership between an academic institution (DRI) and NWS (both some WFOs and SPC).
5) Numerous fire management personnel provided input during the project that helped formulate the process and recommendations.
6) Besides this final project report, a second project report will be prepared for broader agency distribution.

ACCOMPLISHMENTS *(cont'd)*

26. What opportunities for training and professional development has the project provided?

A graduate student successfully completed her Master's degree resulting from this project. The student is also a USFS firefighter, thus allowing knowledge exchange from this project with fire management personnel.

27. How were the results disseminated to communities of interest?

NWS and fire agencies were kept informed of the project status as part of the project co-production activity.

A project webinar describing the project and final results was presented as part of the NWS Fire Weather Program "Fire on the 5s".

ACCOMPLISHMENTS *(cont'd)*

28. What do you plan to do during the next reporting period to accomplish the goals and objectives?

This project has concluded. A second phase is being started to undertake a next phase of tasks building upon the work accomplished.

PRODUCTS

29. Publications, conference papers, and presentations

A paper was submitted to the Journal of Operational Meteorology; major revision was recommended by reviewers.
A project webinar describing the project and final results was presented as part of the NWS Fire Weather Program "Fire on the 5s". This took place in October 2022 after the official project end date in May 2022.
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PRODUCTS *(cont'd)*

30. Technologies or techniques

To analyze occurrences of extreme fire behavior, a database of documented large fires occurring in the United States from 1999–2014 (ICS209 All-Hazard Dataset 1999-2014) containing the daily maximum rate of spread corresponding to each incident was used. A large fire is defined here as anything exceeding 100 acres (~40 hectares) in a timber fuel type and 300 acres (~120 hectares) in grass or brush fuel types. These maximum rates of spread were listed as area (acres) of growth per day with the calendar date at which the maximum occurred, documenting the most active fire behavior occurrence for each incident. Maximum rates of spread, dates of occurrence, and geographic locations were collected from twenty states in diverse geographic regions. Associated meteorological conditions corresponding to each incident were extracted from a 4-km gridded surface climatology (GRIDMET) containing Energy Release Component (ERC-G in the legacy NFDRS systems, ERC-Y in the new NFDRSv4); BTU/ft2), daily minimum relative humidity (%) and wind speed (mph) measured at 1300 LST.
ERC, RH, and wind speed values obtained from the gridded climatology for the date of each qualifying incident were normalized to site-specific values spanning 1999–2014 to yield percentiles. These percentiles were assigned a score according to categories (Figure 1; supplementary material). Frequency distributions of each total score for incidents exceeding the statewide 80th (a), 95th (b), and 97th (c) percentile of daily maximum rate of spread for all states 1999-2014 shows a well-defined score value of 11 as a well-defined marker for potential RFW issuance (Figure 2; supplementary material). This technique allowed for the development of the decision matrix.
The decision matrix (Figure 3; supplementary material) was formed by classifying percentiles into six categories for each variable and assigning a score from 0 to 5 dependent on the category. An attached supplemental document provides a table showing this scoring system.
An objective of this project was to understand how current red flag warnings and fire weather watch products are currently used by the fire management community. Working with the National Weather Service Fire Weather team, we explored several areas of interest, including:

- issuance frequency
- primary purpose of the products
- confusion over the purpose and differences between the two products
- management actions/responses taken based on product issuance
- the role of potential event severity in use and response by users
- perceived relationship between local Weather Forecast Offices and the fire management community
- value of fire detection products for users

From these discussions, the research team developed a preliminary survey instrument that was initially reviewed by the NWS Fire Weather Team personnel and a Storm Prediction staff member. The preliminary survey instrument was then tested using cognitive interviewing techniques in three separate rounds with a confirmatory final round with the final survey instrument. The final instrument contained 11 topical questions and 6 demographic questions.

31. Inventions, patent applications, and/or licenses

Nothing to report.

PRODUCTS *(cont'd)*

32. Other products

Nothing to report.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

33. What individuals have worked on this project?

Dr. Tim Brown, PI
Dr. Tamara Wall, co-PI
Sarah Jakober, Graduate student

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS *(cont'd)*

34. Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

No

35. What other organizations have been involved as partners?

NWS
USFS

Attach a separate document if more space is needed for #6-10, or #24-50.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS *(cont'd)*

36. Have other collaborators or contacts been involved?

Input from several fire agencies in California, Oklahoma, Texas, Utah.

IMPACT

37. What was the impact on the development of the principal discipline(s) of the project?

Established guidance criteria for potential issuance of a Red Flag Warning. This also includes potential issuance of a Particularly Dangerous Situation (PDS) forecast.

Attach a separate document if more space is needed for #6-10, or #24-50.

IMPACT *(cont'd)*

38. What was the impact on other disciplines?

Nothing to report.

39. What was the impact on the development of human resources?

Allowed for student educational and career advancement. Expanded the research team's professional network.

Attach a separate document if more space is needed for #6-10, or #24-50.

IMPACT *(cont'd)*

40. What was the impact on teaching and educational experiences?

Allowing the graduate student to learn new computer programming and analysis skills; people network building.

41. What was the impact on physical, institutional, and information resources that form infrastructure?

Allowed for software code development and ability to monitor decision matrix test forecasts at the Storm Prediction Center.

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IMPACT *(cont'd)*

42. What was the impact on technology transfer?

This will likely occur during phase 2 of the project which will establish assessment, validation, and evaluation procedures.

43. What was the impact on society beyond science and technology?

This project provided a first step of improving the RFW NWS warning product that is utilized for firefighter and public safety.

Attach a separate document if more space is needed for #6-10, or #24-50.

IMPACT *(cont'd)*

44. What percentage of the award's budget was spent in foreign country(ies)?

0 , Nothing to report.

CHANGES/PROBLEMS

45. Changes in approach and reasons for change

Noting to report.

Attach a separate document if more space is needed for #6-10, or #24-50.

CHANGES/PROBLEMS *(cont'd)*

46. Actual or anticipated problems or delays and actions or plans to resolve them

Nothing to report.

47. Changes that had a significant impact on expenditures

Nothing to report.

Attach a separate document if more space is needed for #6-10, or #24-50.

CHANGES/PROBLEMS *(cont'd)*

48. Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Nothing to report.

49. Change of primary performance site location from that originally proposed

Nothing to report.

Attach a separate document if more space is needed for #6-10, or #24-50.

PROJECT OUTCOMES

50. What were the outcomes of the award?

1. Provided a national standardized methodology for RFW forecast guidance.
2. Project success that has led to phase 2 DSRA funding support.
3. Improved understanding of fire management uses and viewpoints of RFW.
4. Allowed for the development of 20 recommendations for improving the RFW product.

DEMOGRAPHIC INFORMATION FOR SIGNIFICANT CONTRIBUTORS (VOLUNTARY)

Gender:

- ◯ Male
- ◯ Female
- ◯ Do not wish to provide

Ethnicity:

- ◯ Hispanic or Latina/o Not
- ◯ Hispanic or Latina/o Do not
- ◯ wish to provide

Race:

- ◯ American Indian or Alaska Native Asian
- ◯ Black or African American
- ◯ Native Hawaiian or other Pacific Islander
- ◯ White
- ◯ Do not wish to provide

Disability Status:

- ◯ Yes
  - [ ] Deaf or serious difficulty hearing
  - [ ] Blind or serious difficulty seeing even when wearing glasses
  - [ ] Serious difficulty walking or climbing stairs
  - [ ] Other serious disability related to a physical, mental, or emotional condition
- ◯ No
- ◯ Do not wish to provide

Attach a separate document if more space is needed for #6-10, or #24-50.

CSTAR Red Flag final report 2022 supplementary material

Figure 1. Formulation of the decision matrix.

ERC Percentile	RH Percentile	Wind Percentile	Score
0-50th	100-51st		0
50-59th	50-41st	0-20th	1
60-69th	40-31st	20-40th	2
70-79th	30-21st	40-60th	3
80-89th	20-11th	60-80th	4
>90th	<11th	>80th	5

Figure 2. Frequency distributions of each total score for incidents exceeding the statewide 80th (a), 95th (b), and 97th (c) percentile of daily maximum rate of spread for all states 1999-2014.

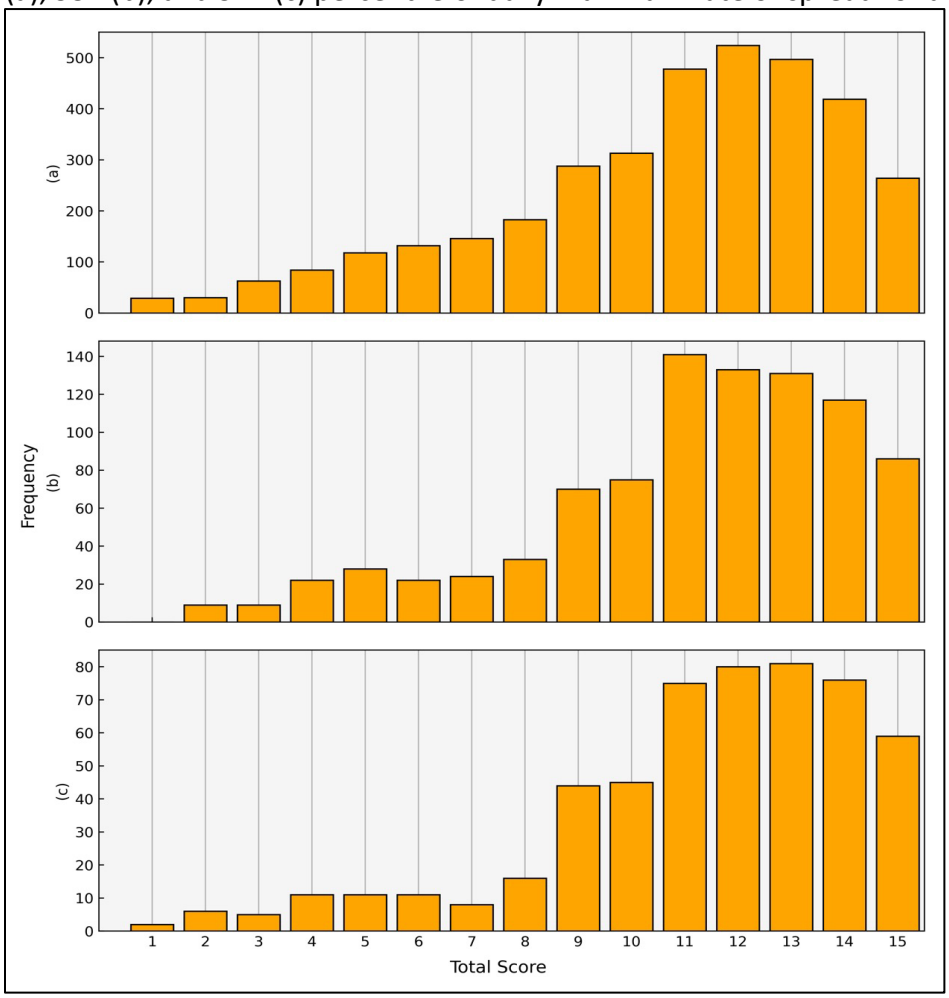

Figure 3. Final decision matrix product.

		RH Percentile:				
		50-41st	40-31st	30-21st	20-11th	<11th
ERC Percentile:	50-59th	2	3	4	5	6
	60-69th	3	4	5	6	7
	70-79th	4	5	6	7	8
	80-89th	5	6	7	8	9
	90th+	6	7	8	9	10

		Combined ERC and RH Percentile Score:								
		2	3	4	5	6	7	8	9	10
Wind Percentile	0-20th	3	4	5	6	7	8	9	10	11
	20-39th	4	5	6	7	8	9	10	11	12
	40-59th	5	6	7	8	9	10	11	12	13
	60-79th	6	7	8	9	10	11	12	13	14
	80th+	7	8	9	10	11	12	13	14	15

Figure 4. Example survey result showing how RFW is used in different conditions.

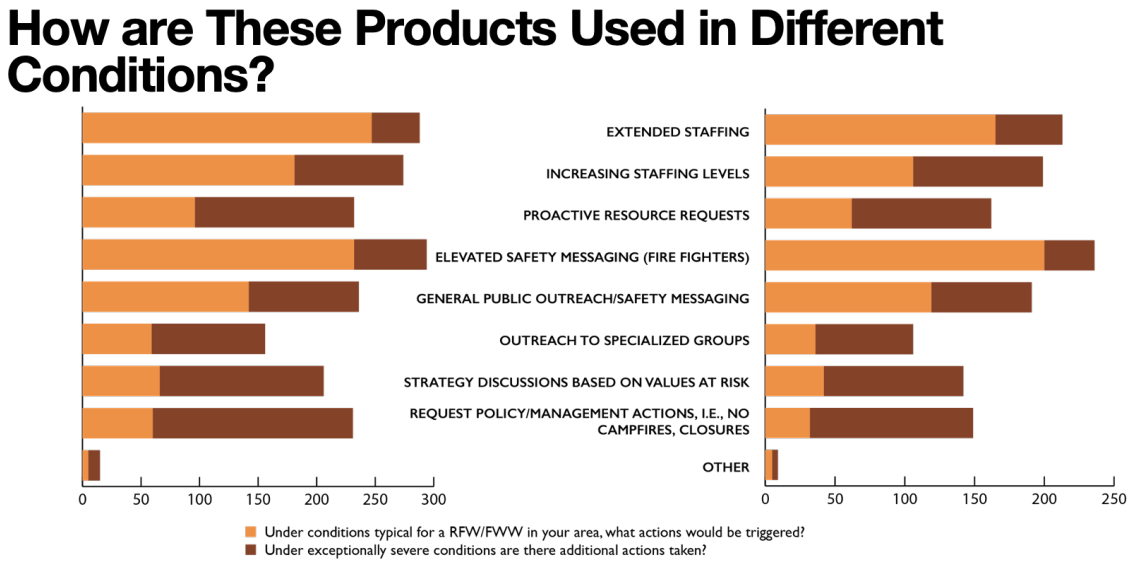

Figure 4: Thinking about different conditions when Red Flag Warnings (RFW)/ Fire Weather Watches (FWW) are issued, what actions would you take dependent on the severity of conditions?

Recommendations developed from the project:

Red Flag recommendations for the reports

Red Flag warning is defined as environmental conditions that could lead to extreme fire behavior, defined by the National Wildfire Coordination Group (NWCG) as "implies a level of fire behavior characteristics that ordinarily precludes methods of direct control action. One or more of the following is usually involved: high rate of spread, prolific crowning and/or spotting, presence of fire whirls, strong convection column."

1. NWS should nationally utilize a consistent methodology for assisting in the determination of Red Flag Warning criteria. Currently there are 524 variants of RFW criteria.

2. Relative humidity and wind speed are common criteria inputs to all RFWs. However, most RFWs lack indication of fuel conditions. The Energy Release Component from the National Fire Danger Rating System (NFDRS) has been shown to be good indicator of fuel status in relation to potential extreme fire potential conditions and should be utilized as part of RFW criteria.

3. Current RFW criteria utilize actual magnitude values of indicator elements (e.g., RH less than 25%). Instead, RFW criteria should utilize historical percentiles of ERC, RH, and wind speed gust. A percentile statistical indicator allows for common comparison across all fire weather zones and more easily highlights potential extreme conditions (e.g., 99^{th} percentile).

4. The decision matrix formulated in this project is recommended for use as a standardized guidance for all WFOs. The matrix utilizes historical gridded percentiles of ERC, RH, and wind speed gust as related to days of large fire growth. These percentiles should be scored according to the categories depicted in the decision matrix table. Days exceeding a score of ≥ 11 should be considered as having elevated potential for extreme fire behavior. Days with highest percentile rankings (e.g., 99^{th} or 100^{th} percentile) may be candidates for Particularly Dangerous Situation (PDS) forecasts.

5. Numerical percentile values for relative humidity, wind speed gust, and ERC will need to be calculated from historical data and made available in the operational environment. While daily wind and humidity data are readily available, an operational ERC product needs to be implemented. NWS and USFS should coordinate and implement an operational gridded ERC product.

6. The decision matrix should be implemented on the NDFD grid. This will provide forecasters with a tool based on weather forecast data already provided in the operational environment.

7. Some RFWs incorporate lightning as a factor for RFW issuance. However, no standardized national methodology has been established for determining when lightning should be included. Utilizing the NWCG definition of extreme fire behavior, lightning, while an obvious potential safety issue, is an ignition source and not a factor that influences rapid fire spread (gusty outflow winds would be a factor). It is recommended to include lightning concerns as part of RFW decision and discussion, but not the primary factor in a RFW issuance.

8. While the current definition of RFW is based on extreme fire behavior, fire management has expressed a need to know if dry or abundant lightning will be a concern. Further exploration should be undertaken to examine if there should be a lightning specific RFW (historically for some regions this has been the case), or the development of national consistent guidance if lightning is used as a factor in RFW issuance, or if headline messaging alone would be sufficient to depict lightning concerns. It is recommended as part of this exploration effort to examine the utilization of a matrix approach that combines factors such as lightning occurrence and probability of ignition.

9. If a local office adds any factors to the primary decision matrix these factors should be justified through science, SME statements, or regulatory needs.

10. When issuing a RFW the larger meteorological cause and suspect duration of the watch/warning should be communicated to fire management, along with an indication of associated uncertainty and forecaster confidence.

11. Similar with other NWS watches/warnings, RWW/RFW should be issued based on polygon type boundaries versus Fire Weather Zones. This will allow for highlighting areas most likely to be impacted rather than including unnecessary geographic area.

12. Descriptive information regarding historical and seasonal severity should be included with each FWW/RFW. This would provide the user community with historical context of the event and partially address concerns regarding too many issuances of the RFW.

13. WFOs should frequently and freely communicate with fire management to ascertain forecast effectiveness (including fuels conditions) and discuss potential impacts of the forecast.

14. This project analysis focused exclusively on fire management as the intended audience. Since FWW/RFWs are also being used by the public, further work should be undertaken to determine appropriate messaging for public use.

15. It is recommended using a two-tiered (watch and warning with special provision for PDS) set of fire weather products for clarity. Survey results indicate that more than a two-tiered product may introduce additional confusion regarding the meaning and use of the products. As all fire weather products indicate critical fire weather/conditions, the

top-most tier should indicate only the most exceptionally extreme conditions and be used in both the warning and watch products.

16. In context of NWS hazard simplification, it is recommended keeping both FWW and RFW tiers and utilizing the warning/watch system. The RFW product is used to make decisions and drive actions during extreme critical weather and fuel conditions.

17. Anecdotal comments suggest the need for radio clarity as underlying the current difference between “red flag” and “fire weather.” In this context, it is recommended that an increased educational outreach program be undertaken for fire practitioners to ensure understanding that fire weather watch ***does not*** indicate less severe conditions but indicates additional preparation time.

18. Plain language headlines should be developed for the public from the RFW and FWW tiered products that can be disseminated via social media, media outlets, and by fire/emergency management agencies in alignment with the hazard simplification program that increases understanding of the warning and watch terms.

19. Matrix output should be properly messaged to the public, using expertise with local WFO knowledge, NWS Office Communication expertise, and social science expertise.

20. The results of this CSTAR project should be utilized into a next phase of, assessment, validation, and evaluation. This includes refinement of the RFW decision matrix, comparison with existing RFW issuances, testing and evaluating the decision matrix with WFOs, assessment in potential utilization for extreme conditions related to Particularly Dangerous Situation (PDS) forecasts, a usability assessment of the decision matrix, and developing a verification process.

24. What were the major goals and objectives of this project?

The purpose of this project was to scientifically define weather and environmental criteria that drives extreme fire behavior and develop a standardized methodology to provide guidance for issuing a Red Flag Warning (RFW). When this project began there were 524 variants of RFW criteria across the country. This project attempts to align RFW with the goals of the Hazard Simplification Program. By providing a scientifically verifiable and actionable link between fire danger and fire behavior, more meaningful warnings will be available to fire managers and the public, increasing the salience and reliability of these forecasts. The primary issues defining the project are:

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31. Inventions, patent applications, and/or licenses

None

32. Other products

None

33. What individuals have worked on this project?

Dr. Tim Brown, PI
Dr. Tamara Wall, co-PI
Sarah Jakober, Graduate student

34. Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

No

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None.

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None.

46. Actual or anticipated problems or delays and actions or plans to resolve them

None

47. Changes that had a significant impact on expenditures

None

48. Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

None

49. Change of primary performance site location from that originally proposed

None

50.What were the outcomes of the award?

1. Provided a national standardized methodology for RFW forecast guidance.
2. Project success that has led to phase 2 DSRA funding support.
3. Improved understanding of fire management uses and viewpoints of RFW.
4. Allowed for the development of 20 recommendations for improving the RFW product.