PREFACE

Introduction to Wildland Fire Behavior, S-190, is identified training in the National Wildfire Coordination Group's (NWCG), Wildland and Prescribed Fire Curriculum. This course has been developed by an interagency development group with guidance from the National Interagency Fire Center (NIFC), Fire Training Group under authority of the NWCG, with coordination and assistance of personnel from the following agencies:

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The NWCG appreciates the efforts of these personnel, and all those who have contributed to the development of this training product.

CONTENTS

Introduction to Wildland Fire Behavior, S-190

Unit 0 – Introduction

OBJECTIVES:

During this unit the instructor will:

1. Introduce instructors and students.
2. Discuss administrative concerns.
3. Explain the purpose of the course.
4. Explain the course objectives.
5. Discuss expectations.
6. Explain course evaluation methods.
7. Explain where the course fits in the wildland fire behavior curriculum.

I. INTRODUCTIONS

II. ADMINISTRATIVE CONCERNS

III. PURPOSE OF COURSE

To provide the student with wildland fire behavior knowledge applicable for safe and effective fire management activities (wildfires, prescribed fire, and fire use).

This course introduces students to characteristics and interactions of the wildland fire environment (fuels, weather, and topography) that affect wildland fire behavior for safety purposes.

The materials in this course are elements of the wildland fire behavior curriculum.

This is the first formal wildland fire behavior training course the students will receive.

IV. COURSE OBJECTIVES

- Identify and discuss the three sides of the fire triangle.
- Identify the environmental factors of fuels, weather, and topography that affect the start and spread of wildland fire.
- Describe the contributing factors that indicate the potential for increased fire behavior that may compromise safety.

V. EXPECTATIONS

A. Student Expectations

What are your expectations for the course?

B. Instructor Expectations

- Attendance at all sessions
- Be prepared to start on time
- Participate and share ideas

VI. EVALUATIONS

A. Student Evaluations

Students must obtain 70% or higher on the final exam to receive a certificate of completion for this course.

B. Course Evaluations

This is an opportunity for students to comment on the course and instructors for the purpose of improving future courses.

VII. WHERE DOES THIS COURSE FIT IN THE WILDLAND FIRE BEHAVIOR CURRICULUM?

A. Introduction to Wildland Fire Behavior, S-190

Entry-level course designed around the basics of fuel, weather, and topography.

B. Intermediate Wildland Fire Behavior, S-290

Provides a better basis for analyzing variables and understanding how they interact and affect wildland fire behavior. Introduces the Fireline Assessment Method (FLAME); a practical fireline tool used for predicting significant short term changes in wildland fire behavior.

C. Introduction to Wildland Fire Behavior Calculations, S-390

Introduces wildland fire behavior calculations by manual methods such as tables and nomograms.

D. Advanced Wildland Fire Behavior Calculations, S-490

Teaches students to use state of the art computer models to project fire perimeter growth based on weather predictions and knowledge of fuels and topography.

Introduction to Wildland Fire Behavior, S-190

Unit 1 – Basic Concepts of Wildland Fire

OBJECTIVES:

Upon completion of this unit, students will be able to:

1. Define basic terminology used in wildland fire.

2. Identify the elements of the fire triangle.

3. Describe three methods of heat transfer.

I. BASIC TERMINOLOGY USED IN WILDLAND FIRE

A. Parts of the Fire

1. Point of origin

The precise location where a competent ignition source came into contact with the material first ignited and sustained combustion occurred.

2. Head of a fire

The side of the fire having the fastest rate of spread.

3. Flank of a fire

The part of a fire's perimeter that is roughly parallel to the main direction of spread.

4. Rear of a fire

- That portion of a fire spreading directly into the wind or down slope.
- That portion of a fire edge opposite the head.
- Slowest spreading portion of a fire edge. Also called heel of a fire.

5. Fire perimeter

   The entire outer edge or boundary of a fire.

6. Fingers of a fire

   The long narrow extensions of a fire projecting from the main body

7. Pockets of a fire

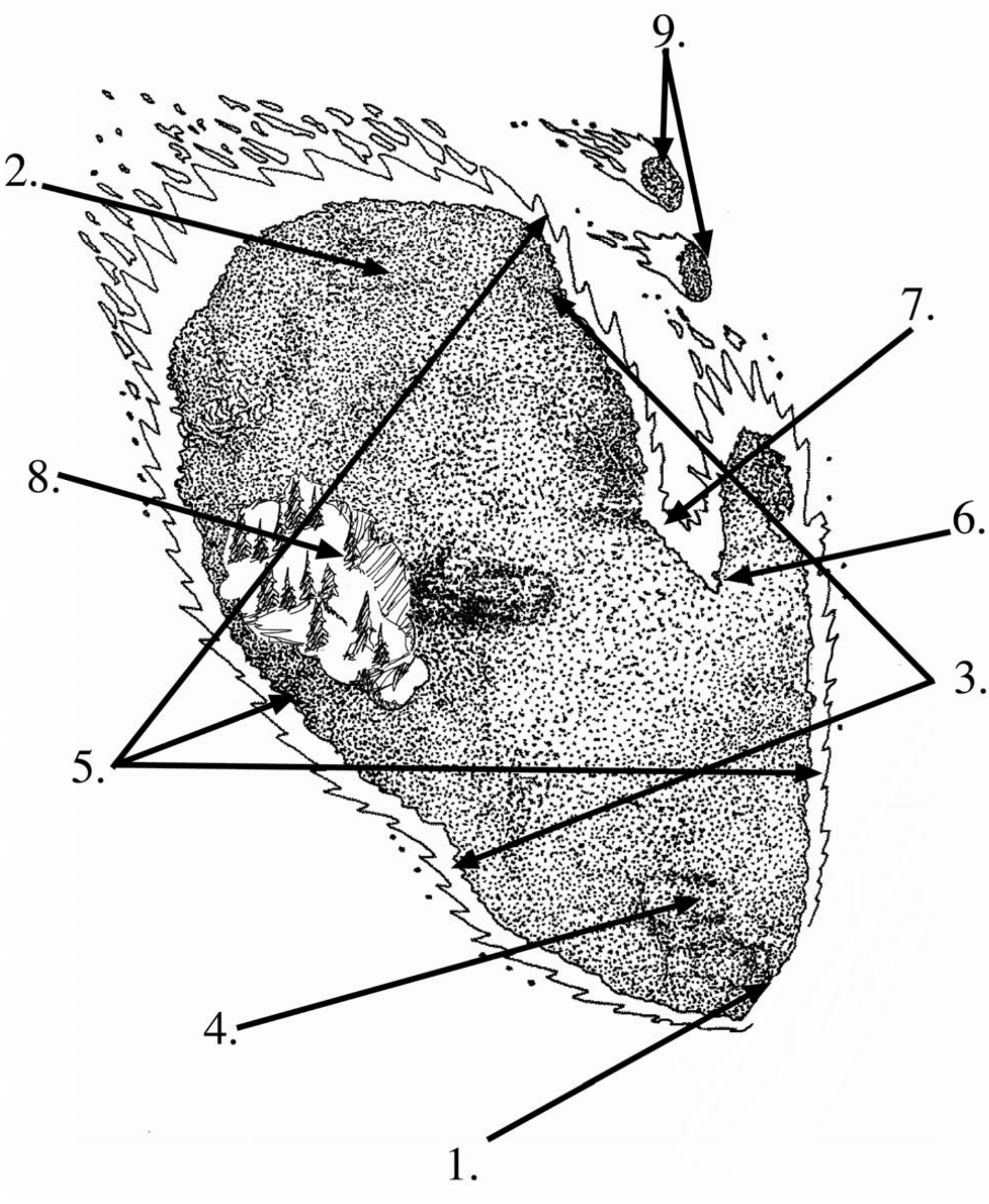
   Unburned indentations in the fire edge formed by fingers or slow burning areas.

8. Island

   Area of unburned fuel inside the fire perimeter.

9. Spot fire

   Fire ignited outside the perimeter of the main fire by a firebrand.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B. Fire Behavior Terms

1. Smoldering

   Fire burning without flame and barely spreading.

2. Creeping fire

   Fire burning with a low flame and spreading slowly.

3. Running fire

   Behavior of a fire spreading rapidly with a well defined head.

4. Spotting

   Behavior of a fire producing sparks or embers that are carried by the wind and which start new fires beyond the zone of direct ignition by the main fire.

5. Torching

   The burning of the foliage of a single tree or a small group of trees, from the bottom up.

6. Crown fire

   A fire that advances from top to top of trees or shrubs more or less independent of a surface fire. Crown fires are sometimes classed as running or dependent to distinguish the degree of independence from the surface fire.

7. Flare up

Any sudden acceleration in the rate of spread or intensification of the fire. Unlike blowup, a flare-up is of relativity short duration and does not change existing control plans.

8. Firewhirl

Spinning vortex column of ascending hot air and gases rising from a fire and carrying aloft smoke, debris, and flame. Fire whirls range in size from less than one foot to over 500 feet in diameter. Large fire whirls have the intensity of a small tornado.

9. Backing fire

That portion of the fire with slower rates of fire spread and lower intensity, normally moving into the wind and/or down slope. Also called heel fire.

10. Flaming front

That zone of a moving fire where the combustion is primarily flaming.

Behind this flaming zone combustion is primarily glowing or involves the burning out of larger fuels (greater than about 3 inches in diameter).

Light fuels typically have a shallow flaming front, whereas heavy fuels have a deeper front.

C. Other Useful Firefighting Terms

1. Anchor point

   An advantageous location, usually a barrier to fire spread, from which to start constructing a fireline. The anchor point is used to minimize the chance of being flanked by the fire while the line is being constructed.

2. Control line

   An inclusive term for all constructed or natural barriers and treated fire edges used to contain a fire.

3. Fireline

   The part of a containment or control line that is scraped or dug to mineral soil.

4. Mop-up

   Extinguishing or removing burning material near control lines, felling snags, and trenching logs to prevent rolling after an area has burned, to make a fire safe, or to reduce residual smoke.

5. Contained

   The status of a wildfire suppression action signifying that a control line has been completed around the fire, and any associated spot fires, which can reasonably be expected to stop the fire's spread.

6. Controlled

The completion of control line around a fire, any spot fires, and any interior islands to be saved.

Burn out any unburned area adjacent to the fire side of the control lines.

Cool down all hot spots that are immediate threats to the control line, until the lines can reasonably be expected to hold under the foreseeable conditions.

7. Chain

Unit of measure in land survey, equal to 66 feet (20 M)
(80 chains equal 1 mile).

Commonly used to report fire perimeters and other fireline distances.

Popular in fire management because of its convenience in calculating acreage (example: 10 square chains equal one acre).

II. ELEMENTS OF THE FIRE TRIANGLE

Three elements must be present and combined before combustion can occur and continue. There must be:

- Fuel to burn

- Air to supply oxygen for the flame

- Heat to start and continue the combustion process

These three elements or sides compose what we call the “fire triangle.” Remove any single one, and there can be no fire.

III. THREE METHODS OF HEAT TRANSFER

We have learned that heat is a necessary condition for combustion, and part of the fire triangle. There are many methods by which heat can be supplied to a fuel to start a fire. Examples:

- Matches
- Lightning
- Cigarettes

More importantly, we must know how the fire spreads once it has started.

Heat must be able to move from one burning piece to another, or the fire triangle will be broken. This movement is called heat transfer. Heat is transferred by three processes:

- Radiation
- Convection
- Conduction

A. Radiation

Think of radiant heat as a ray or wave. Radiant heat warms you as you stand close to a campfire, or stand in the sunlight. Radiant heat can dry surrounding fuels and sometimes ignite them.

B. Convection

Think of convection as a smoke column above the fire. Convection occurs when lighter warm air moves upward. The hot gases and embers which compose the smoke column can dry and ignite other fuels.

C. Conduction

Think of conduction as a spoon in a hot drink. Heat is conducted from one fuel particle to another in the same way, through direct contact.

Since wood is a poor conductor (meaning heat will not travel through it easily), this process is the least important of the three to fire behavior.

OPEN BOOK EXERCISE.

1. What are the three methods of heat transfer?

2. The fire triangle consists of oxygen, heat, and ____________________?

3. When is a fire controlled?

4. Should you fight fire without an anchor point?

   Why?

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Unit 2 – Principles of Wildland Fire Behavior

Lesson A – Topographic Influences

OBJECTIVE:

Upon completion of this lesson, students will be able to:

- List the basic characteristics of topography and describe how they affect wildland fire behavior.

I. TOPOGRAPHY

Topography is the configuration of the earth's surface including its relief and the position of its natural and man-made features.

It is much easier to predict the influences which topography will have on a wildfire than the influences of fuel and weather.

Following are topographic terms and how they affect wildland fire behavior.

A. Aspect

Aspect is the direction a slope is facing (its exposure in relation of the sun).

The aspect of a slope generally determines the amount of heating it gets from the sun; therefore, determines the amount, condition, and type of fuels present.

1. South and southwest slopes are normally more exposed to sunlight and generally have:

- lighter and sparser fuels
- higher temperatures
- lower humidity
- lower fuel moisture

They are the most critical in terms of start and spread of wildland fires.

2. North facing slopes have more shade which causes:

- heavier fuels
- lower temperatures
- higher humidity
- higher fuel moistures

A north facing aspect will have less fire activity than a south facing slope.

B. Slope

The amount or degree of incline of a hillside (a steep slope).

Fires burn more rapidly uphill than downhill. The steeper the slope, the faster the fire burns.

This is because the fuels above the fire are brought into closer contact with the upward moving flames.

Convection and radiant heat help the fuel catch fire more easily.

Another concern about steep slopes is the possibility of burning material rolling down the hill and igniting fuel below the main fire.

The position of the fire in relation to the topography is a major factor in the resulting fire behavior.

A fire on level ground is primarily influenced by fuels and wind.

A fire which starts near the bottom of a slope during normal upslope daytime wind conditions will normally spread faster and has more area to spread upslope than a fire that starts near the top of the slope.

C. Shape of the Country – Terrain

Certain topographic features can influence the wind speed and direction for small areas, independent of general weather conditions for an area.

The shape of the country can also influence the direction of fire spread, rate of spread, and the intensity.

D. Box Canyons

Fires starting near the base of box canyons and narrow canyons may react similar to a fire in a wood burning stove or fireplace.

Air will be drawn in from the canyon bottom creating very strong upslope drafts. These upslope drafts create rapid fire spread up the canyon, also referred to as the chimney affect. This affect can result in extreme fire behavior and can be very dangerous.

E. Narrow Canyons

Fire in a steep narrow canyon can easily spread to fuels on the opposite side by radiation and spotting. Wind eddies and strong upslope air movement may be expected at sharp bends in canyon.

F. Wide Canyons

Prevailing wind direction can be altered by the direction of the canyon. Cross-canyon spotting of fires is not common except in high winds. Strong differences in fire behavior will occur on north and south aspects.

G. Ridges

Fire burning along lateral ridges may change direction when they reach a point where the ridge drops off into a canyon. This change of direction is caused by the flow of air in the canyon.

H. Saddle

Wind blowing through a saddle or pass in a mountain range can increase in speed as it passes through the constricted area and spreads out on the downwind side with possible eddy action.

I. Elevation

The height of the terrain above mean sea level, usually expressed in feet (ASL - Above Sea Level).

Elevation plays a large role in determining the conditions and amount of fuel.

Because of higher temperatures, fuels at lower elevations dry out earlier in the year than those at higher elevations.

In extremely high elevations there may be no fuel.

Elevation affects fire behavior in several other ways like the amount of precipitation received, wind exposure, and its relationship to the surrounding terrain.

J. Barriers

Any obstruction to the spread of fire, typically an area or strip lacking any flammable fuel.

Barriers to fire include many things, both natural and man-made.

1. Natural barriers:

   - rivers
   - lakes
   - rock
   - slides

   Fuels which have a high moisture content do not burn as well as others in the same area.

2. Man-made barriers:

   - roads
   - highways
   - reservoirs
   - fireline constructed by fire resources

OPEN BOOK EXERCISE.

1. A barrier is:

2. Under normal conditions, a north facing aspect will have more fire activity than a south facing aspect.

   a. True
   b. False

3. A box canyon is dangerous because:

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Unit 2 – The Principles of Wildland Fire Behavior

Lesson B – Fuels

OBJECTIVES:

Upon completion of this lesson, students will be able to:

1. Identify the basic fuel types.

2. Identify the fuel characteristics that influence the behavior of the fire.

I. THE SIX BASIC FUEL TYPES

A. Definition of Fuel

A simple definition of fuel is any burnable material.

- Wildland fuels are basically live and/or dead plant material.

- Houses, sheds, etc., can also be fuels

Fuels are the source of energy that drives the fire.

Regardless of the area of the country, fire behavior is dependent on certain fuel characteristics:

- Fuel type
- Fuel loading
- Fuel availability

B. Fuel Types

Wildland fuels are grouped into fuel types based on the primary fuel that carries the fire. There are six major fuel types:

- Grass
- Grass – Shrub
- Shrub
- Timber – Understory
- Timber litter
- Slash - Blowdown

Fuels vary in type from one area of the country to another and within the same area.

Differences in the amount of water in the soil is one reason that types of fuels vary and elevation changes is another.

1. Grass

   - Found in most areas.
   - More dominant as a fuel in desert and range areas.
   - Can become prevalent after a fire in timber areas.
   - Burns hottest and fastest.

2. Grass – Shrub

   - Found in the plains regions and high deserts.
   - A significant contributor to fire spread due to the fine fuels mixed with the aerial/shrub fuel.

3. Shrub

   - Found throughout most areas.
   - Some highly flammable shrub fuels are:
     – Palmetto/gallberry in the southeast
     – Sagebrush in the Great Basin
     – Chaparral in the southwest and California

4. Timber - Understory

   - Found throughout most areas
   - Provides ladder to aerial crown fuels

5. Timber litter

- Most dominant in mountainous topography, especially in the Northwest.

- Provides fuel for ground fire.

6. Slash - Blowdown

- Debris left after natural events or human activities:

  - Logging
  - Road building
  - Pruning
  - Thinning
  - Shrub cutting
  - Wind
  - Fire
  - Snow

- Debris may include:

  - Logs
  - Chunks of wood
  - Bark
  - Branches
  - Stumps
  - Broken understory trees
  - Shrubs

- Provides fuel for fire spread

EXERCISE 1.

For your assigned fuel type, answer the following questions on a flip chart:

1. List examples, near your area, where this fuel type occurs.

2. Why is this fuel type a possible concern to firefighters?

II. FUEL CHARACTERISTICS THAT INFLUENCE THE BEHAVIOR OF THE FIRE

A. Fuel Type

B. Fuel Loading

The amount of fuel present expressed quantitatively in terms of weight of fuel per unit area (tons per acre).

- This may be available fuel (consumable fuel) or total fuel and is usually dry weight.
- The loading of the fuels in any given area does not necessarily mean the fire will burn with great intensity.
- What is more important is the quantity of fuels available for combustion.

C. Fuel Availability (for combustion)

Many factors are involved when talking about the availability of a fuel for combustion.

1. Fuel size classes and shape

   The physical characteristics of fuels, divided into four categories on the basis of their size:

   a. 1-hour fuels: 0 – ¼ inch in diameter

   b. 10-hour fuels: ¼ – 1 inch in diameter

   c. 100-hour fuels: 1 – 3 inches in diameter

   d. 1000-hour fuels: 3 – 8 inches in diameter

2. Surface area to volume ratio

   - Relates to the amount of the outer surface of the fuel that is exposed to the air.

   - The more surface exposed, the more easily the fuel will dry and burn.

   - Smaller (fine) fuels have a higher surface area to volume ratio than larger (heavy) fuels.

An example to illustrate surface-area-to-volume ratio concepts is the process of building a campfire:

- Start with small fuels (such as dry grass, pine needles, and small twigs), then add larger fuels (such as larger twigs and sticks), and finally add the largest fuel – the logs.

  The smaller fuels (grass, needles, etc.) have a larger surface area to volume ratio than the logs, and therefore ignite more readily than the logs.

D. Fuel Arrangement

The manner in which fuels are spread over a certain area.

1. Horizontal continuity

Horizontal continuity affects fire's rate of spread.

a. Uniform fuels

Include all fuels distributed continuously over the area.

- Areas containing a network of fuels which connect with each other to provide a continuous path for a fire to spread are included in this category.

b. Patchy fuels

Include all fuels distributed unevenly over the area, or areas of fuel with definite breaks or barriers present.

Examples:

- Patches of rock outcroppings.

- Bare ground.

- Areas where another dominant type of fuel is much less flammable.

2. Vertical arrangement

a. Ground fuels

All combustible materials lying beneath the surface:

- Deep duff
- Tree roots
- Rotten buried logs
- Other organic material

Ground fire consumes the organic and combustible materials beneath the surface, such as a smoldering duff or peat fire.

b. Surface fuels

All combustible materials lying on or immediately above the ground:

- Needles or leaves
- Duff
- Grass
- Small dead wood
- Downed logs
- Stumps
- Large limbs
- Low shrubs

Surface fire burns surface litter, debris, small shrubs, and other vegetation.

c. Ladder fuels

Combustible materials that aid the spread of fire from the surface to the upper canopy.

- Ladder fuels can include surface litter, shrubs, and other moderate height vegetation that provides a pathway from the surface to the canopy.

d. Aerial fuels

All green and dead materials located in the upper canopy:

- Tree branches and crowns
- Snags
- Hanging moss
- Tall shrubs

Crown fire burns through the tops of trees or shrubs and can advance in conjunction with or be independent of the surface fire.

3. Fuel moisture

The amount of water in a fuel, expressed as a percentage of the oven-dry weight of that fuel.

- Fuel moisture is expressed as a percent of total weight.

- How well a fuel will ignite and burn is dependent, to a large extent, on its moisture content.

- Dry fuels will ignite and burn much more easily than the same fuels when they are wet.

  – You don't use wet wood to make a campfire!

- Before a wet fuel can burn, the moisture it contains must evaporate.

  – This process requires more heat. As fuel moisture increases, the amount of heat required to ignite and burn that fuel also increases.

- Because of their various sizes and characteristics, different fuels in the same area will have various moisture levels.

- Likewise a similar type of fuel, across a broad area, will have different moisture levels based on the amount of precipitation received and period of warm, dry weather.

Remember, light (small) fuels take on and lose moisture faster than heavier (larger) fuels.

4. Wet fuels

Fuels that have a high moisture content because of exposure to precipitation or high relative humidity.

5. Dry fuels

Fuels that have low moisture content because of prolonged exposure to sunshine, dry winds, drought, or low relative humidity.

6. Timelag

The rate at which dead fuel gains or loses moisture.

Time needed under specified conditions for a fuel particle to lose about 63 percent of the difference between its initial moisture content and its equilibrium moisture content.

If conditions remain unchanged, a fuel will reach 95 percent of its equilibrium moisture content after four timelag periods.

Firefighters use a concept of "Timelag" to identify the different sizes of dead fuels as they relate to increasing moisture or drying-out over time.

Smaller fuels can dry out in an hour larger fuels may take ten to a thousand hours to dry.

One-hour timelag fuels react to changes in relative humidity much faster than 100-hour timelag fuels.

The timelag categories are:

1-hour	0 - ¼ inch in diameter
10-hour	¼ - 1 inch in diameter
100-hour	1 - 3 inches in diameter
1000-hour	3 - 8 inches in diameter

EXERCISE 2.

Part 1

View each photo and match it to the correct description.

Photo #1: ____	a. These are patchy fuels.
Photo #2: ____	b. This is a large volume of fuel.
Photo #3: ____	c. These are 1-hr timelag fuels.
Photo #4: ____	d. This is a shrub fuel type.

Part 2

Match the definitions to the correct descriptions.

Uniform Fuels	____	A. The amount of water in a fuel, expressed as a percentage of the oven-dry weight of that fuel.
Ladder Fuels	____	B. Grasses, leaves, pine needles
Fuel Timelag	____	C. Fuels distributed continuously over the area.
Light Fuels	____	D. All combustible materials lying on or immediately above the ground.
Fuel Moisture	____	E. The rate at which dead fuel gains or loses moisture.
Surface Fuels	____	F. Combustible materials that aid the spread of fire from the surface to the upper canopy.

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Unit 2 – Principles of Wildland Fire Behavior

Lesson C – Weather

OBJECTIVES:

Upon completion of this lesson, students will be able to:

1. Describe the effect temperature and relative humidity have on wildland fire behavior.

2. Describe the effect of precipitation on wildland fire behavior.

3. Describe the differences between a stable and unstable atmosphere.

4. Describe general and local winds.

5. Describe critical fire weather conditions.

6. List the different types of fire weather forecasts and outlooks available.

I. WEATHER

Short-term variations in the atmosphere are what we call weather. Weather is one of three components of the fire environment.

Weather conditions can result in the ignition of fire by lightning from thunderstorms and the rapid spread of fires as a result of strong winds. On the other hand, an increase in humidity or precipitation can slow or extinguish fires.

Of the three fire environment components, weather is the most variable over time, and at times, difficult to predict.

Firefighters conducting fire suppression must monitor the weather at all times to make safe and effective firefighting decisions.

The importance of monitoring weather and predicting the resultant fire behavior cannot be overstressed. It is one of the 10 Fire Orders and three of 18 Watchout Situations that all firefighters must obey.

The risk involved in fire suppression can be reduced if firefighters and fire managers pay attention and understand weather conditions that impact fire behavior.

The basic principles and concepts of fire weather as they relate to wildland fire behavior include:

- Air Temperature and Relative Humidity (RH)
- Precipitation
- Atmospheric Stability
- Wind

II. THE EFFECT TEMPERATURE AND RELATIVE HUMIDITY HAVE ON WILDLAND FIRE BEHAVIOR

A. Air Temperature

Air temperature is the degree of hotness or coldness of the air.

1. Air temperature varies with:

   - Time
   - Location
   - Height above the earth's surface

2. Changes in air temperature near the surface of the earth are caused by:

   - Changing seasons
   - Alternations of night and day
   - Migrating weather systems

3. Seasonal and diurnal temperature changes can be large or small, depending on:

   - Latitude
   - Elevation
   - Topography
   - Proximity to the moderating influences of nearby oceans or lakes

Abrupt changes in temperatures can occur when migrating weather systems transport colder or warmer air into a region.

Heating of the earth's surface and the atmosphere is primarily a result of solar radiation from the sun; however, on a smaller scale, heat may be caused by a large fire.

In the wildland fire environment, direct sunlight and hot temperatures can preheat fuels and bring them closer to their ignition point, whereas cooler temperatures have the opposite affect.

Above average temperatures are common on large fires. Many firefighter fatalities have occurred on fires where record high temperatures were set.

Temperature is measured with a thermometer calibrated either to the Fahrenheit scale or the Celsius scale.

B. Relative Humidity

Relative humidity is the amount of moisture in the air divided by the amount the air could hold when saturated at the same air temperature; usually expressed in percent.

Relative humidity can range from 1% (very dry) to 100% (very moist). Low relative humidity is an indicator of high fire danger.

Moisture in the atmosphere, whether in the form of water vapor, cloud droplets, or precipitation, is the primary weather element that affects fuel moisture content and the resulting flammability of wildland fuels.

The amount of moisture that fuels can absorb from or release to the air depends largely on relative humidity. Light fuels, such as grass, gain and lose moisture quickly with changes in relative humidity. Heavy fuels respond to humidity changes much more slowly.

Firefighters can usually see or feel most of the elements of weather such as:

- Wind
- Rain
- Increasing temperatures

Small changes in relative humidity that cannot be felt or seen can have a significant impact on wildland fire behavior.

Relative humidity values for extreme wildland fire behavior vary over time and location, and are different for different fuels types.

Fuels in the southeast part of the United States and Alaska typically burn with considerably higher relative humidities than fuels in the western U.S.

C. Temperature and Relative Humidity Relationships

Temperature and relative humidity have an inverse relationship.

- When temperature **increases**, relative humidity **decreases**.
- When temperature **decreases**, relative humidity **increases**.

In the early morning hours, temperature typically reaches its lowest point and relative humidity reaches its highest point. As the sun rises and the temperature increases, relative humidity decreases.

When the temperature reaches its maximum for the day (usually mid to late afternoon) relative humidity decreases to a minimum. This is the time when fine fuel moisture reaches its minimum. As the sun sets the temperature drops and the relative humidity increases.

There can be a large fluctuation of temperature and relative humidity in time and location. However, the majority of large fire outbreaks occur when air temperature is high and relative humidity is low.

It is very important for firefighters to routinely monitor temperature and relative humidity trends. The most common field instrument used to measure and determine these two important weather elements is a sling psychrometer, which is part of the belt weather kit.

Exercise 1. Temperature and Relative Humidity

1. Temperature is:

   A. The degree of hotness or coldness of a substance.

   B. The amount of moisture in the air.

   C. The amount of moisture in the air divided by the amount the air could hold when saturated at the same air temperature.

2. Relative humidity is:

   A. The degree of hotness or coldness of a substance.

   B. The amount of moisture in the air divided by the amount the air could hold when saturated at the same air temperature.

   C. Expressed in degrees Fahrenheit.

   D. Expressed as a percentage.

   E. B and D

3. As temperature increases, relative humidity:

   A. Increases

   B. Decreases

III. THE EFFECT OF PRECIPITATION ON WILDLAND FIRE BEHAVIOR

A. Precipitation

Precipitation is liquid or solid water particles that originate in the atmosphere, and become large enough to fall to the earth's surface.

B. Precipitation Amount vs. Duration

Fuel moisture is affected by the amount and also the duration of the precipitation.

Fine fuels react quite rapidly by precipitation since they gain or lose moisture usually within one hour.

Heavy fuels are not affected as drastically since they gain or lose moisture more slowly.

A large amount of precipitation in a short time will not raise the fuel moisture as much as less rainfall over a longer period of time where the fuels can absorb more moisture before it runs off.

IV. THE DIFFERENCES BETWEEN A STABLE AND UNSTABLE ATMOSPHERE

A. Atmospheric Stability

Wildfires are greatly affected by atmospheric motion and the properties of the atmosphere that affect its motion.

Surface winds, temperature, and relative humidity are most commonly considered and easy to measure in the fire environment.

Less obvious, but equally important, is atmospheric stability and related vertical air movements that influence wildfire.

Atmospheric stability is the degree to which vertical motion in the atmosphere is enhanced or suppressed. Stability is directly related to the temperature distribution of the atmosphere.

The temperature and stability of the atmosphere is constantly changing with variations over time (day-to-day or season-to-season), location, and from one layer of the atmosphere to the next.

B. Stable Atmosphere

A stable atmosphere is defined as an atmosphere that resists upward motion.

In a stable atmosphere, the extensive heat of the fire generates vertical motion near the surface, but the vertical motion above the surface is weakened, thus limiting indrafts into the fire at low levels and fire intensity.

C. Visual Indicators of a Stable Atmosphere

In the fire environment, visual indicators can give clues about the stability of the atmosphere. Keeping in mind that stable air resists upward vertical motion, the following are visual indicators of a stable atmosphere:

- Clouds in layers
- Stratus type clouds
- Smoke column drifts apart after limited rise
- Poor visibility due to smoke or haze
- Fog layers
- Steady winds

D. Inversions

The usual temperature structure of the lower atmosphere is characterized by a decrease in temperature with altitude. However, a layer where temperature increases with altitude (warm air over cold air) may exist. This layer is referred to as an inversion.

Warm air
------------- = Inversion (stable condition)
Cold air

Under an inversion, fuel moisture content is usually higher, thus decreasing fire spread rates and intensities.

Updrafts containing smoke and warm gases generated by a fire are typically weak and will only rise until their temperature equals that of the surrounding air. Once this occurs, the smoke flattens out and spreads horizontally.

When inversions break or lift, as a result of heating the lower atmosphere by the sun or a fire, increased wildland fire behavior is almost certain.

1. Watch for the following indicators when an inversion breaks:

   - Increase in temperature
   - Decrease in relative humidity
   - Increase and/or shift in wind

2. There are four types of inversions that may be encountered in the wildland fire environment:

   - Nighttime (radiation)
   - Subsidence
   - Frontal
   - Marine

   Though all inversions are important, nighttime and subsidence inversions are most common in the wildland fire environment.

E. Nighttime (Radiation) Inversions

Air cooled at night, primarily by contact with cold surfaces, gradually deepens as the night progresses and forms a surface inversion. Inversions forming at night near the earth's surface are commonly referred to as a radiation or nighttime inversion.

Nighttime inversions develop on calm, clear nights when radiational cooling of the earth's surface is greatest, and can differ in strength depending on time of year. Inversions in the winter are typically stronger than inversions that develop in the summer.

Nighttime inversions are easy to identify because they trap smoke and gases resulting in poor visibilities in valleys or drainages.

F. Thermal Belts

Nighttime inversions in mountainous regions increase in depth during the night. They form early in the evening at the canyon bottom or valley floor and at first are quite shallow. The cold layer gradually deepens, with the nighttime inversion coming in contact with and reaching farther up the slope below the main ridges.

The warmest nighttime air temperatures in valleys are often found at the inversion top. The height of the warmest air temperature, at the top of the inversion, can be found by measuring temperature along the slope. From the top of the inversion, temperature decreases as one goes farther up or down the slope. This region of warmer air, typically found on the middle third of the slope, is called the THERMAL BELT.

The thermal belt is characterized by the highest minimum temperature and the lowest nighttime relative humidity. Within the thermal belt, wildland fires can remain rather active throughout the night. Below the thermal belt, fires are in cool, humid, and stable air.

G. Subsidence Inversion

Subsidence is the large-scale sinking of air associated with high pressure systems. As air from higher elevations in high pressure systems descends to lower elevations, it warms and dries.

The warming and drying of air sinking is so pronounced that saturated air (air with 100% RH), can produce relative humidity less than 5 percent in a very short period of time. If a high pressure system persists for a period of days, the subsidence inversion may reach the surface with only very little external modification or addition of moisture.

Skies are typically clear or cloudless under these high pressure systems, and extended periods of above average temperatures and below average relative humidities can dry out fuels to the point that burning conditions become severe. Subsidence is usually a contributor in the development of foehn winds.

H. Unstable Atmosphere

An unstable atmosphere is defined as an atmosphere that encourages upward motion.

When the atmosphere is unstable, vertical motions increase, contributing to increased fire activity by:

- Allowing convection columns to reach greater heights, producing stronger indrafts and convective updrafts.
- Increasing the lofting of firebrands by updrafts.
- Increasing the occurrence of dust devils and fire whirls.
- Increasing the potential for gusty surface winds.

Wildland fires burn hotter and with more intensity when the air is unstable. Cold air over warm air represents an unstable condition.

Cold air
------------- = Unstable condition
Warm air

I. Visual Indicators of an Unstable Atmosphere

- Clouds grow vertically and smoke rises to great heights
- Cumulus clouds
- Good visibility
- Gusty winds
- Dust devils and firewhirls

Exercise 2. Atmospheric Stability

1. A stable atmosphere:

   A. Encourages upward vertical motion

   B. Resists upward motion

2. An unstable atmosphere:

   A. Encourages upward vertical motion

   B. Resists upward motion

3. An inversion is:

   A. A layer of air where temperature increases with altitude.

   B. A layer of air where temperature decreases with altitude.

   C. A layer of air where there is no temperature change with altitude.

V. GENERAL AND LOCAL WINDS

A. Wind and Wind Direction

Wind is the horizontal movement of air relative to the surface of the earth. Wind direction is the direction **from** which the wind is blowing (a north wind means the wind is blowing from the north).

Wind is the most critical weather element affecting wildland fire behavior, the most difficult to predict, and the most variable in both time and location.

This variability (especially in rough terrain) can pose safety and fire control problems, which can result in firefighter fatalities. Wind direction and wind speed must be constantly monitored by all firefighters.

B. Characteristics of Wind and its Effect on Wildland Fire

Wind impacts the fire environment by:

- Increasing the supply of oxygen to the fire.
- Determining the direction of fire spread.
- Increasing the drying of the fuels.
- Carrying sparks and firebrands ahead of the main fire causing new spot fires.
- Bending flames results in the preheating of fuels ahead of the fire.
- Influencing the amount of fuel consumed by affecting the residence time of the flaming front of the fire. The stronger the wind, the shorter the residence time and the less fuel is consumed.

C. Wind Systems

1. General wind

General winds are large scale upper level winds caused by high and low pressure systems.

If strong enough, these winds can influence wildland fire behavior, but are generally modified in the lower atmosphere by terrain.

2. Local wind

Local winds are found at lower levels of the atmosphere.

Local winds are induced by small-scale (local) differences in air temperature and pressure, and are best developed when skies are clear and general winds are weak.

Terrain also has a very strong influence on local winds; the more varied the terrain, the greater the influence.

Local winds can be as important to wildland fire behavior as the winds produced by the large-scale pressure patterns. In many areas, especially in rough terrain or near large bodies of water, local winds can be the prevailing daily winds.

The different types of local winds include:

a. Slope winds

Slope winds are local winds that develop in mountainous terrain where the differences in heating and cooling occur.

During the day, the typical local wind pattern is upslope and downslope during the night. There will be cases where this rule does not apply.

Local personnel are usually aware of prevailing wind conditions.

(1) Upslope wind characteristics

The air in the valleys becomes warmer than the air on the mountain top and thus rises, producing the upslope wind.

- The greatest upslope wind speed occurs about mid-afternoon.

- Speeds generally range between 3 and 8 mph and can be gusty.

- East facing slopes receive solar energy at sunrise, thus the downslope to upslope change takes place first on east aspects.

  This change can be gradual and may be characterized by a relative calm for an hour or more as the slope heats.

- South and west facing slopes receive heat later in the morning; therefore, the downslope to upslope takes place usually by late morning.

(2) Downslope wind characteristics

The air along the mountain tops at night cools faster than the air in the valley. The cool air sinks, producing the downslope wind.

- The greatest downslope flow occurs after midnight.
- Speeds generally range between 2 and 5 mph.
- Relative calm takes place before the downslope wind begins.
- Because east aspects lose solar energy first, the change from upslope to downslope occurs on east aspects early in the afternoon.
- Southwest and west facing slopes receive solar energy through much of the afternoon, thus downslope wind typically begins just after sunset.
- The change in wind from downslope to upslope can rapidly change wildland fire behavior from inactive to active in a matter of minutes.
- Though the steepness of slope also plays a role, stronger upslope winds lead to faster uphill fire spread.
- Downslope winds seldom produce dangerous conditions; however, strong downslope winds, increased by the steepness of the terrain, can result in downhill runs.

b. Valley winds

Valley winds are produced by local temperature and pressure differences within the valley or between a valley and a nearby plain.

Though there are exceptions, valley winds flow up-valley during the day and downvalley at night.

(1) Up-valley wind characteristics

As air in the valley warms, temperature and pressure differences within the valley or valley to adjacent plains results in an up-valley wind flow.

- The greatest up-valley winds occur mid to late afternoon.
- Up-valley wind speeds typically range between 10 and 15 mph.
- Because of the large amount of air heated in the valley, up-valley winds develop after the upslope winds.
- Up-valley winds typically continue after sunset.

(2) Down-valley wind characteristics

As the valley loses solar heating, the air in the valley cools. The cool air drains down-valley, resulting in the down-valley wind.

- The greatest down-valley winds occur after midnight.
- Down-valley wind speeds typically range between 5 and 10 mph.
- Because of the large amount of air cooling in the valley, down-valley winds typically do not develop until a few hours after dark, and well after the development of the downslope winds.

c. Sea and land breezes

(1) Sea breeze

A daytime breeze in which cooler air from high pressure over the coastal waters moves onshore to replace heated air rising above the warmer land mass.

Typical wind speed is between 10 and 20 mph. However, wind speed can attain 20 to 30 mph along the California, Oregon, and Washington coasts.

(2) Land breeze

A light nighttime breeze which originates over the relatively cool land, flows out over the warmer coastal waters. Typical wind speed is between 3 and 10 mph.

Exercise 3. Winds

1. General winds are:

   A. Found at lower levels of the atmosphere and are induced by small-scale (local) differences in air temperature and pressure.

   B. Large scale upper level winds caused by high and low pressure systems.

   C. Local winds that develop in mountainous terrain where the differences in heating and cooling occur.

2. The different types of local winds include (circle all that apply):

   A. upslope wind
   B. downslope wind
   C. upvalley wind
   D. jet stream
   E. sea-breeze

VI. CRITICAL FIRE WEATHER CONDITIONS

Fire seasons occur at different times of the year in different regions of the country, depending on seasonal variations in weather.

The typical fire season at any given location has numerous hot and dry days, yet wildfires are usually clustered within relatively short periods.

These periods are characterized by one (or a combination of) critical fire weather conditions:

- Strong and shifting wind
- Very low relative humidity
- High temperature
- Unstable atmosphere
- Dry lightning

Examples of weather phenomena in which one or more of these critical fire weather conditions may occur:

- Cold fronts
- Foehn winds
- Thunderstorms
- Dust devils
- Firewhirls

A. Cold Fronts

A cold front is the boundary line between two different air masses, with cooler air behind the front and warmer air ahead of the front. The two differing air masses result in pressure differences that can lead to moderate or strong wind speed.

Frontal winds associated with frontal passages are particularly dangerous, not only for the strength of the wind, but also the shift in direction as the front approaches and passes through the area.

Along with the shifting winds, atmospheric stability ahead of and behind the front also impacts the fire environment. Unstable conditions encouraging upward motion are typically found ahead and along the frontal boundary. Stable conditions discouraging upward motion are typical behind the front.

Historically, firefighter fatalities have occurred in the pre-frontal environment where winds are strong and shifting, and the atmosphere is unstable.

1. Potentially dangerous cold front characteristics:

   - Light southeasterly winds are common several hundred miles ahead of the front.

     – Just ahead or along the front, moderate to strong southwesterly winds are common. The strong southwesterly flow ahead of the front will drive the fire head to the northeast.

   - The air mass ahead of the front is typically very warm and unstable, resulting in an increase in fire behavior.

- Relative humidities can be low or high depending on the origin or location of the system.
  - High relative humidities ahead of the front are more common over the eastern U.S. than the western U.S.
- As the front pushes through, the wind can abruptly shift from southwest to northwest, driving the fire head to the southeast.
  - This can be a great concern to firefighters due to the increased fire behavior on the south flank of the fire as the winds shift.
- The air mass behind the front is cooler, more stable, and relative humidities are higher, thus fire activity typically decreases.
- Wind speeds just ahead, along, and behind the front typically range from 15 to 30 mph, and can be gusty.

2. Cold front indicators:
   - A line of cumulus clouds may be seen approaching from the west or northwest.
   - Large clouds of dust can precede the arrival of a cold front.
   - Winds normally shift from the southeast to the south, to the southwest, and increase in velocity before the arrival of the front.
   - Winds will be strongest and gusty as the front reaches you.
   - Winds will continue to shift as the front passes, generally resulting in strong, gusty, cool wind out of the northwest.

B. Foehn Winds

Foehn winds are strong, dry winds caused by the compression of air as it flows down the lee side of a mountain range. It is usually, but not always, warm for the season.

Foehn winds can persists for days and frequently reach speeds of 40-60 mph but can be as high as 90 mph. The relative humidity will usually drop with the onset of foehn winds.

The combination of high wind speeds and low relative humidity can cause high rates of fire spread. When a foehn wind occurs after a long period of dry weather, wildland fire behavior can be extreme.

Common foehn winds in the western U.S. are:

1. Chinook wind: Found along the east side of the Rockies and east side of the Sierra Nevada.

2. Wasatch wind: Found on the west side of the Wasatch Range in Utah.

3. Santa Ana and Sundowner: Southern California.

4. Mono and North wind: Central and Northern California.

5. East wind: Western Washington and Western Oregon.

C. Thunderstorms

A storm is produced by a cumulonimbus cloud and always accompanied by lightning and thunder.

1. Thunderstorms can also produce:

    - Strong gust winds
    - Heavy rain
    - Hail (sometimes)

    Thunderstorms are usually of short duration, seldom over 2 to 3 hours for any one storm.

2. The direction of thunderstorm movement is generally in the direction of the winds aloft.

    - The direction of thunderstorm movement can be determined by the direction the anvil shaped top is pointing.

3. Downdraft winds from thunderstorms that reach the ground usually spread radially in all directions.

    - These wind velocities will often be 25 to 35 mph and can reach as high as 70 mph.

    - Surface winds from a thunderstorm will be the strongest in the direction the thunderstorm is moving.

    - Thunderstorm wind speed and direction can be altered by topography and vegetation.

4. Thunderstorms are potentially dangerous to firefighters because:

- Wind associated with thunderstorms, whether indrafts or downdrafts, can change direction and speed, **resulting in sudden changes in the rate and direction of a fire, as well as fire intensity.**

- Heat rising from a fire can form a convection column strong enough to trigger the development of a thunderstorm, even on an otherwise cloudless day.

- Thunderstorms, as a result of a convection column, can produce dangerous downdrafts.

- Thunderstorms produce dangerous lightning that results in new starts. Lightning is also a safety problem and can result in death.

D. Dust Devils and Firewhirls

Dust devils are one of the most common indicators of unstable air. They occur on hot days over dry ground when skies are clear and the winds are light.

Under intense heating, air near the ground rises in upward-spiraling motions in columns or chimneys.

Firewhirls, generated by intense fires, have been known to twist off trees more than 3 feet in diameter.

They can pick up large burning embers and spew them far across the fireline causing numerous spot fires.

In some extreme cases, firewhirls and dust devils have moved across safe zones, and burned and turned over vehicles.

- The size of dust devils can range from 10 feet to over 100 feet in diameter with heights from 10 feet to 3,000 or 4,000 feet.

- Wind speeds in dust devils are often more than 20 mph and in some extreme cases have exceeded 70 mph.

- A favorite area for firewhirl development is on the wind sheltered (leeward) side of ridges.

Exercise 4. Critical Fire Weather

1. Chinook and Santa Ana winds are examples of:

   A. A foehn wind

   B. A cold front wind

   C. A thunderstorm wind

   D. A sea-breeze

2. Cold front winds:

   A. Are strong, dry winds caused by the compression of air as it flows down the lee side of a mountain range.

   B. Are winds associated with a boundary between two dissimilar air masses.

   C. A and B.

VII. DIFFERENT TYPES OF FIRE WEATHER FORECASTS AND OUTLOOKS AVAILABLE

A. Predictive Services

Predictive Services is a combined group of Interagency Land Management Fire Intelligence Coordinators or Fire Behavior Analysts (FBAN), and Fire Meteorologists.

1. Predictive Services monitors, analyzes, and predicts:

- Fire weather
- Fire danger
- Interagency fire management resource impact

2. Predictive Service products and services:

- Seasonal assessments
- 7 Day Significant Fire Potential
- Monthly Fire Weather/Fire Danger Outlook
- Weather briefings
- Daily summaries of National Weather Service fire weather forecasts, both graphical and text.
- Long term precipitation monitoring
- Smoke management summaries

B. National Weather Service (NWS)

There are over 120 National Weather Service offices nationwide that provide a variety of different types of forecasts.

Another major NWS program includes the fire weather program.

NWS standardized products include:

1. Fire Weather Planning Forecasts (FWF)

   These forecasts can be in tabular or narrative format.

   They include a discussion of the upcoming weather and highlights of any critical fire weather events, as well as many different forecasted elements including:

   - Sky/weather
   - Temperature
   - Relative humidity
   - Wind

2. Spot forecasts

   A spot forecast is a site specific 24- to 36-hour forecast issued to fit time, topography, and weather of a specific location.

3. Fire Weather Watches / Red Flag Warnings

A fire weather watch or red flag warning is issued when the combination of dry fuels and weather conditions support extreme fire behavior or ignition is occurring or expected to occur.

a. Fire Weather Watch

Issued when there is a high potential for the development of a Red Flag Event.

A Fire Weather Watch is normally issued 24 to 72 hours in advance of the expected onset of criteria.

b. Red Flag Warning

Is used to warn of an impending or occurring Red Flag event.

Its issuance denotes a high degree of confidence that a Red Flag event will occur in 24 hours or less.

Exercise 5. Types of Fire Weather Products

1. The seasonal assessment product is issued by:

   A. The National Weather Service
   B. Predictive Services
   C. Both A and B

2. Red Flag Warnings are issued by:

   A. The National Weather Service
   B. Predictive Services
   C. Incident Management Teams

Introduction to Wildland Fire Behavior, S-190

Unit 3 – Wildland Fire Behavior and Safety

OBJECTIVES:

Upon completion of this unit, students will be able to:

1. Identify indications that fire behavior may be increasing.

2. Describe combined influences that may cause extreme fire behavior and safety concerns.

3. List seven fire environment factors to be aware of while monitoring fire behavior.

I. MONITORING FIRE BEHAVIOR

A. Large Fire Indicators

Fires rarely just go from small fires to extreme "blow ups." There are indicators that, if monitored, will show when a fire is starting to transition from problem fire behavior to extreme fire behavior.

B. Problem vs. Extreme Fire Behavior

1. Problem fire behavior

Fire activity that presents potential hazard to fireline personnel if the tactics being used are not adjusted. The prediction or anticipation of fire behavior is the key to good tactical decisions and safety.

2. Extreme fire behavior

The highest level of problem fire behavior can be described with specific elements:

- Rapid rate of spread
- Intense burning
- Spotting
- Crowning

C. Incident Response Pocket Guide

Use the Incident Response Pocket (IRPG) as a field reference to help monitor changing conditions. The pages of the Operational section are green and placed in the front for quick reference in the field.

The Operational section is where the seven fire environment factors of Look Up, Down and Around are located. Each factor lists indicators to help individuals monitor the fire environment and become more aware of changes that are occurring.

II. THE SEVEN FIRE ENVIRONMENT FACTORS OF LOOK UP, DOWN AND AROUND

The fire environment is the conditions, influences, and modifying forces that control fire behavior. The fire environment has been described with a triangle showing weather, fuels, and topography (terrain).

There are seven factors within this fire environment that fireline personnel must monitor:

- Fuel Characteristics
- Fuel Moisture
- Fuel Temperature
- Topography (Terrain)
- Wind
- Atmospheric Stability
- Fire Behavior

These seven factors and their corresponding indicators help provide clues when monitoring the fire and anticipating what might happen.

A. Fuel Characteristics

1. Continuous fine fuels

Fire is able to change and spread rapidly in these fuels, especially when combined with slope and/or wind.

2. Heavy loading of dead and down

Large amounts of readily available fuel.

3. Ladder fuels

Allow the fire to readily spread into the canopy, launching firebrands (spots) into the air.

4. Tight crown spacing

   Allows fire to move from bush to bush (or tree to tree) easier.

5. Special conditions

   a. Firebrand sources

      Burning material that is carried by the wind ahead of the fire or outside of control lines.

      Potential firebrand sources are:

      - pine bark plates
      - manzanita leaves
      - eucalyptus leaves
      - maple leaves
      - oak leaves

   b. Numerous snags

      Fire can become established in these dead or partially dead trees, making them very hazardous. These can launch firebrands into the air as well as fall across control lines.

   c. Frost and bug kill

      More available fuel to be consumed by the fire.

   d. Preheated canopy

      Caused by a lower intensity fire burning the fuels near the ground. Heat from the fire dries the fuels above it, making those fuels available to burn.

e. Unusual fine fuels

Light flashy fuels mixed with high energy fuels, such as continuous grass mixed with sage.

f. High dead to live ratio

Greater amounts of potentially available fuel.

B. Fuel Moisture

1. Low RH (<25%)

The lower the humidity, generally, the more available the fine fuels are to carry fire.

The 25% RH indicator is a general threshold for much of the U.S. In the East, Alaska, and Hawaii, the threshold is generally higher.

2. Low 10 hr FMC (< 6%)

10 hour fuels are just one good indicator of how available fuels are to burn.

3. Drought conditions and seasonal drying

Both are indicators that fuels are more receptive to ignition and carrying the spread of fire.

C. Fuel Temperature

1. High temps (> 85° F)

Increasing the temperature of the fuels closer to the point of ignition.

2. High percent of fuels with direct sun

On any given slope, are a majority of the fuels in the sun or the shade?

3. Aspect fuel temperature increasing

Which slopes tend to have higher fuel temperatures in the morning? Which are higher in the afternoon? Why is this important?

a. South and southwest slopes:

- Are normally more exposed to sunlight.

- Generally have lighter and sparser fuels.

- Have higher temperatures, lower humidity, and lower fuel moisture.

- Are the most critical in terms of start and spread of fire.

b. North facing slopes have more shade, which causes:

- Heavier fuels
- Lower temperatures
- Higher humidity
- Higher fuel moistures

Being aware of which slopes are "hotter" throughout the day allows firefighters to monitor where the potential for the greatest fire behavior is.

D. Topography (Terrain)

1. Steep slopes (>50%)

Provides for rapid rates of fire spread due to convective heating and increased potential for rollouts below the fire.

2. Chutes – Chimneys

Provides potential for rapid rates of fire spread by combining steep terrain with updrafts of air.

3. Saddles

Fire is pushed faster through these during uphill runs.

4. Box canyons

All provide for rapid rates of fire spread due to the channeling of wind and heat.

5. Narrow canyons

a. Radiant and convective heating could increase spotting across the canyon.

b. Fire can burn down to the bottom of the canyon and then crossover to the other side. This is known as “slope reversal.”

E. Wind

Wind is the primary factor that influences fire spread.

1. Surface winds above 10 mph

These winds help determine the direction of fire spread, help to carry firebrands ahead of the fire, and increase the supply of oxygen to the fire.

2. Lenticular clouds

Indicates high winds aloft with the potential to surface.

3. High, fast moving clouds

Indicates a potential for wind shifts.

4. Approaching cold fronts

Wind will increase in speed and change direction with the advance of a cold front.

5. Cumulonimbus development

Indicates possible wind speed and direction and potential for erratic winds.

6. Sudden calm

Be alert for a wind change.

7. **Battling or shifting winds**

   Winds that change direction and go back to the original direction are battling. This is an indication of a probable change in wind speed and direction.

   Changes in wind speed and direction affect everyone on the fire from individual firefighters to fire managers on many portions of the fire.

   A sudden change in wind direction can cause firebrands to cross control lines. Increasing winds could cause previously quiet parts of the fire to increase in intensity.

F. Atmospheric Stability

Indicators of an **unstable atmosphere** and the potential for large fire growth:

1. Good visibility

2. Gusty winds and dust devils

3. Cumulus clouds

4. Castellatus clouds in the a.m.

5. Smoke rises straight up

6. Inversion beginning to lift

   This is an indication of a transition from a stable to an unstable atmosphere and the potential for fire growth.

7. Thermal belt

   An area of lower nighttime relative humidity and higher temperatures. Fires will generally burn more actively in these areas at night.

G. Fire Behavior

Indicators of a rapidly changing, wind-driven fire with intense burning:

1. Leaning column

2. Sheared column

3. Well-developed column

4. Changing column

   Fire behavior is usually increasing.

5. Trees torching

   The fire is beginning to transition from a surface fire to a crown fire. Observe if just one tree is torching or small groups of trees are catching fire. Note if there is wind present and how fast it is blowing.

6. Smoldering fires picking up

   Fire behavior is increasing. What else might be occurring to cause this? It is possible that the:

   - Inversion is lifting
   - Wind is increasing
   - Shading has decreased on that aspect and temperature is increasing
   - Relative humidity has decreased

7. Small firewhirls beginning

   The fire is increasing in intensity.

8. Frequent spot fires

   The fire is spreading and increasing in complexity

H. Review the Seven Fire Environment Factors

- Important to not just monitor one or two factors but all of them.
- Equally important to monitor the trends of each indicator as well.

EXERCISE.

List the seven fire environment factors.

1.

2.

3.

4.

5.

6.

7.