Railroads and Weather

From Fogs to Floods and Heat to Hurricanes, the **Impacts** of Weather and Climate on American Railroading

Stanley A. Changnon

American Meteorological Society

Railroads and Weather

Railroads and Weather

From Fogs to Floods and Heat to Hurricanes, the Impacts of Weather and Climate on American Railroading

Stanley A. Changnon

American Meteorological Society
Boston, Massachusetts

Railroads and Weather: From Fogs to Floods and Heat to Hurricanes, Impacts of Weather and Climate on American Railroading

Published by the American Meteorological Society
45 Beacon Street, Boston, Massachusetts 02108

For a catalog of AMS Books and Monographs, see www.ametsoc.org/pubs/books. To order this and other AMS Books or Monographs, call (617) 227-2425, or email amsorder@ametsoc.org.

ISBN 978-1-87220-73-8
ISBN 1-878220-73-X

Library of Congress Cataloging-in-Publication Data

Changnon, Stanley Alcide.
  Railroads and weather / Stanley A. Changnon.—1st ed.
    p. cm.
  Includes index.
  ISBN 978-1-878220-73-8
  ISBN 1-878220-73-X
  1. Railroads—Maintenance and repair. I. Title.

  TF530.C475 2006
  385'.2042—dc22
2006005332

CONTENTS

PREFACE

MUCH OF MY WEATHER and climate research over the past 50 years has focused on how atmospheric conditions impact the environment, the economy, and human activities/health. These studies have led to several scientific papers and two books, one about the great floods of 1993 and the other about El Niño, 1997/98. Coupled with this scientific career orientation was a lifelong interest in railroads. This avocation led me to write six books and numerous articles about many facets of railroads. The coupling of these two central intellectual interests led to the preparation of this book.

Prior to the 1980 deregulation of the industry, there were many more railroads in operation. This text focuses on weather impacts and railroad adjustments since the 1940s. It covers decades when the challenges of weather and climate were faced by a larger number of companies, and this is well emphasized in the wide variety of photographs, which show trains belonging to companies that have now been absorbed or otherwise relegated to the halls of history. Most of the photographs were taken by me and two of my sons, David and Marc. Several friends supplied other photographs.

This book has been made possible by several persons and institutions. The concept of a book about how weather and climate affect railroads and their operations was first suggested to me by Michael Glantz; and my wife, Joyce Changnon, encouraged me to do it. The Intelligent Transportation Systems Committee of the American Meteorological Society responded very favorably to my proposal to prepare a book on this topic. In particular, I thank committee members Rich Wagoner and Mike Rossetti for their encouragement and suggestions to make the book a publication of the American Meteorological Society. Mike also provided insightful comments that improved the book's content.

The support of the Illinois State Water Survey, as part of its program of assessing impacts of weather and climate, was instrumental in getting the book written and assembled. I am indebted to Derek Winstanley, survey chief; Kevin Merrifield, computer graphics expert; and Ken Kunkel, head of atmospheric sciences, for their support and assistance.

Many railroad personnel also helped with advice and information. During my emerging career as an atmospheric scientist in the 1950s, I got to know Bill Hay, who got me interested in assessing weather and railroad relationships.

I am also indebted to Ken Heideman, Director of Publications, and Sarah Jane Shangraw, Books and Monographs Manager at the AMS. They graciously and skillfully handled the book and prepared it for publication.

CHAPTER

1

Dealing with the Weather

WEATHER AFFECTS every kind of outdoor activity. For as long as they have been in existence, railroads have been impacted by weather conditions 24 hours a day, 7 days a week, and in all seasons. Railroads have designed structures and right-of-ways to minimize weather problems, built refrigerated freight cars and air-conditioned passenger trains to reduce weather stress, and found ways to function in all forms of adverse weather, ranging from floods to snowstorms.

Railroad maintenance and operations have always been locked in a continuing battle against the forces of weather, which almost always affect railroads adversely. Temperature extremes, ice, fog, snowfall, wind, and precipitation influence the design of plants and equipment, maintenance and operating practices, train movements, capital and operating costs, and revenue. It is not easy to establish absolute cause-and-effect relationships between individual weather conditions and railroad operations. Usually the worst weather effects on rail operations occur when two or more factors combine, such as when snowfall, wind, and low temperatures combine to form blizzards. The tremendous diversity of climate in the United States presents numerous challenges to railroads, as they must address the particular climatic extremes in the regions they serve. We find tropical climates in Florida and southern California, desert climates in the Southwest, a moist maritime climate in the Northwest, humid coastal climates along the West and East Coasts, mountain climates in much of the West, and a continental-type climate in the central and eastern sections of the nation. Continental climates, in particular, are known for their extremes, with hot, humid summers and cold, snowy winters. Some railroad companies operate lines in several of these different climate regions, and these lines must be designed to handle the variety of weather-induced problems found in each zone.

The story of railroads and weather is one of unusual conflicts and benefits to society and the development of the United States. As railroads developed during the nineteenth century, they offered the world's first means of transportation that was largely weatherproof and able to function throughout the year. The development of the nation's rail network from 1840 through the 1890s brought safe and reliable movement of people and goods throughout the nation, with many fewer seasonal impacts than befell other existing forms of transportation, all of which suffered greatly with the weather's capriciousness. Railroads now enabled farmers to get their harvested crops to market in a matter of days, whether they were shipped in July or January (Fig. 1.1). Prior to the advent of the railroads, shipments of anything could not be accomplished during many months of the year, and other forms of moving goods were extremely slow and apt to be inexplicably halted for days and weeks by conditions such as low water, muddy roads, and storms. By contrast, except in extreme weather conditions, trains could be counted on to reach their destinations on time. Even today, fog, heavy precipitation, and low ceilings stop commercial aircraft operations and slow vehicular traffic, often causing multiple accidents. But trains continue to operate in such conditions.

Over the past 150 years, with ever-newer technologies, the railroads have constantly worked to minimize their weather problems. They have buried cables and employed radios for communication to escape the major losses that snowstorms and freezing rain once caused to their exposed wire-

Fig. 1.1. Railroads enabled the widespread development of farming by delivering grain crops to market, an important service as illustrated by this Indiana grain train passing maturing corn crops. The train is led by an Alco RS11, built in 1956, a rare breed still operating in 1998 on the Kankakee, Beaverville & Southern.

based communication systems. They built snow sheds in mountainous areas where heavy snow caused trouble. They installed gas-fired heaters to keep their switches from freezing. Diesel engines and their operating needs are much less weather-sensitive than were steam engines and their more extensive support and maintenance. Taller and stronger bridges have reduced many flood-related problems.

The railroads of the past, and to some extent those of today, suffered from certain vagaries of the weather. Despite huge improvements in building rail lines and bridges, every year brings forth stories of how railroad service in some areas has been temporarily delayed or stopped by weather extremes (Figs. 1.2–1.12). Trains and their facilities suffer, sometimes severely, from major weather extremes, such as massive snowdrifts, flood washouts of roadbeds, and rails broken by extremely low temperatures.

Fig. 1.2. Heavy rain reduces visibility and traction. Here a CSX train moves cautiously through heavy rain, which blurs the illumination from the headlight, at a junction in southern Ohio.

Fig. 1.3. Sometimes locally heavy rains produce 6 to 10 inches of rain in a few hours, resulting in flash flooding that causes sudden washouts of roadbeds and bridges, as seen in this Missouri branch line. A May rainstorm produced 11 inches of rain in 6 hours, resulting in these massive damages, with vehicles swept off a highway that paralleled the line.

Fig. 1.4. Prolonged heavy rains and spring snowmelt can produce massive deep flooding over large areas. Such a flood in the 1950s immersed the Mississippi River Valley and swept around this CB&Q depot at McPaul, Iowa.

Fig. 1.5. Snowfall is a curse for railroads, bringing reduced visibility, slippery rails, and frozen switches. Here an IC train moves slowly along the main line during a heavy snowfall.

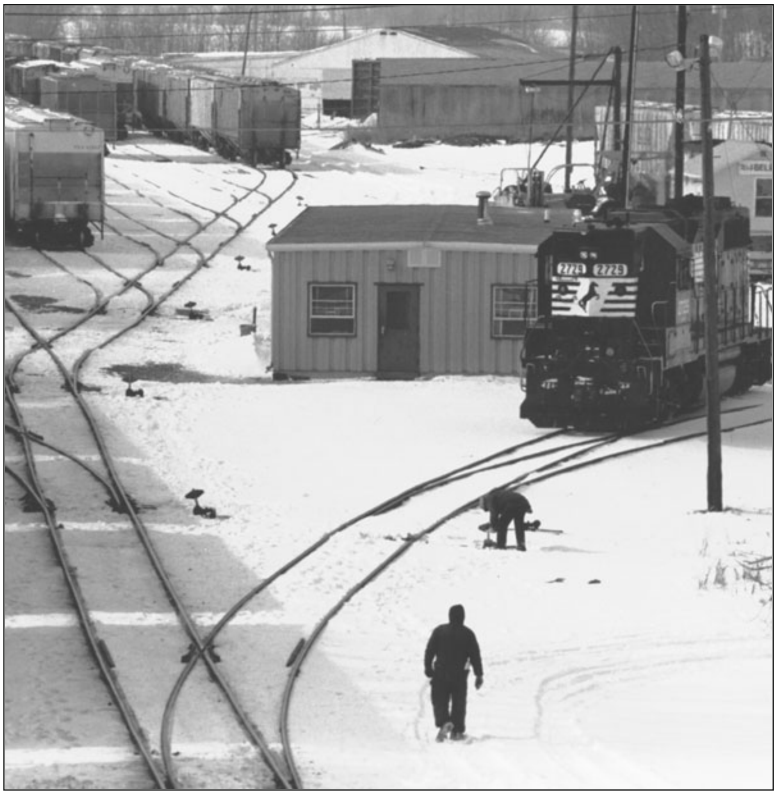

Fig. 1.6. Snowfall in rail yards brings a multitude of problems including frozen switches, frozen couplers, and discomfort and danger to work crews. Here, two heavily clad yard workers are trying dig out the frozen, snow-clogged switches so the yard's switcher can move out and go to work.

Fig. 1.7. Deep snow impedes train movement. Here an IC grain train struggles through a 15-inch snowfall with heavy drifts on the rail line in northern Illinois.

Fig. 1.8. Fogs can dangerously limit visibility, making signals, and anything else on the tracks ahead, hard to see. Here the northbound "City of New Orleans" bursts out of a thick summer morning fog.

Fig. 1.9. A heavy Louisiana fog has made the lights of this junction signal nearly indistinguishable as a freight train penetrates the fog.

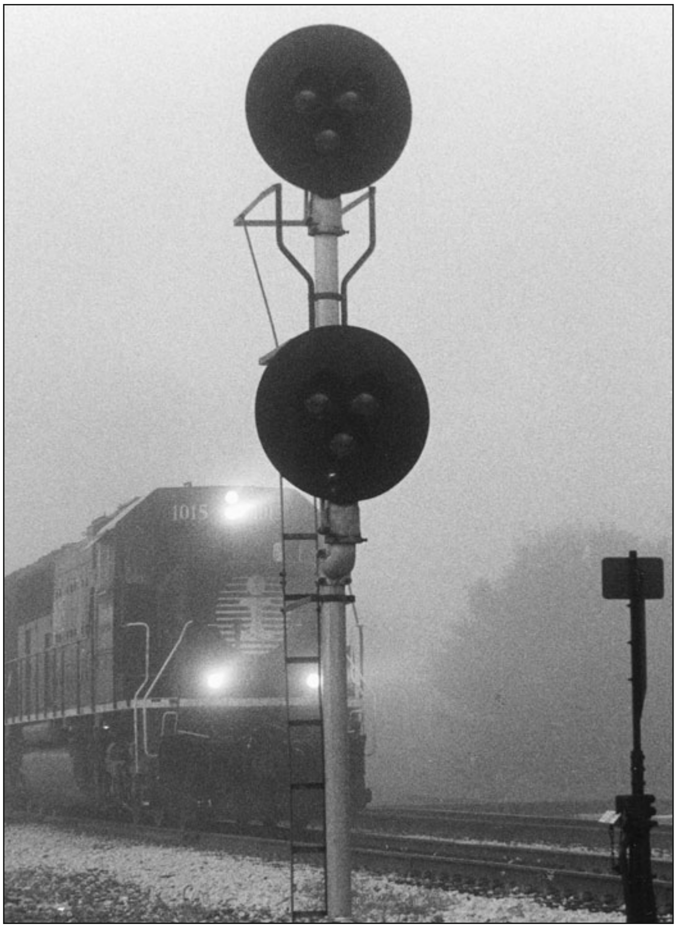

Fig. 1.10. High temperatures, typically 100°F or higher, can produce "sun kinks" in rails, leading to derailments. Here a Conrail train on a branch line in New York state cautiously pulls upgrade on a hot, 99°F, hazy August day with the rails ahead showing many disconcerting oscillations.

Fig. 1.11. A combination of high winds, blowing snow, severe cold, and a temperature of 10°F have clogged the engines on this Wisconsin train, which stalled in this blizzard.

Fig. 1.12. A combination of snow and extremely cold temperatures left icing on the rails leading to the derailment of the leading wheels of this Conrail SD60 engine sitting in a rail yard in western Pennsylvania.

CHAPTER

2

Weather Impacts: The Good and the Bad

SCIENTISTS WHO have studied how weather impacts our economy have learned that almost any extreme event produces some financial losers and some winners (Changnon 2003a). Furthermore, financial impacts come in two classes. Some impacts are labeled *direct.* For railroading, these include physical damages to infrastructure, delayed trains, and rerouting of trains. Other weather effects are classed as *indirect*—they cause more or less traffic and alter a railroad's income. For example, a drought does not directly affect the rail facilities or halt train movements. If it is severe and lasts long enough to reduce crop yields for a year or more, however, a drought decreases the number of trains hauling grain to market and reduces the income of railroads that rely on hauling grain (see Figs. 2.1, 2.2a, and 2.2b).

In a general context, weather affects railroads in eight ways: 1) design of plants and equipment; 2) maintenance and operating practices; 3) train movements, including carrying hazardous materials through urban areas; 4) planning for allocation of seasonal resources; 5) capital and operating costs; 6) safety of staff and passengers; 7) homeland security and response; and 8) amount of revenue received by the railroad company.

Benefits of Weather

Floods and droughts in the central United States curtail the use of barges and enhance rail shipments. The extensive 1988 drought caused wheat yields to decrease by 45% and corn yields to drop to 60% of average. As a result, the incomes of the grain-hauling lines like the Burlington Northern and the Chicago & North Western fell by 34% in 1988. However, the drought also caused low flows on the major navigable rivers, such as the Mississippi and Missouri rivers, and barges could not move for many months (Changnon 1989). The inability of barges to move grain and other bulk commodities led to increased shipments and profits for railroads like the Illinois Central (IC) and Kansas City Southern (KCS). Some weather benefits experienced by railroads are due to extremes that hurt their competitors (Fig. 2.3).

Fig. 2.1. In droughts, as well as good crop seasons, much of the Midwestern grain is picked up at small-town elevators by local freights like this train, powered by a Conrail GP38, which is picking up newly loaded cars at a small town in Indiana.

Figs. 2.2a and 2.2b. After the many locals service on-line elevators to get grain, the loaded cars are assembled in yards to either form grain trains to go to southern port cities or to deliver cars to riverside barge-loading facilities. In Fig. 2.2a (left), two SD40-2s of the Soo line at the Dubuque, Iowa yards are assembling a grain train for movement south. The Soo served many hundreds of grain elevators in the upper Midwest. Fig. 2.2b (right) shows an elevated view of the Dubuque yards, which are filled with loaded grain cars in October.

Fig. 2.3. The 1987–1989 drought led to increased grain train traffic on the IC. Here, a southbound grain train heading for Louisiana moves down the main line in Illinois in the fall of 1988.

For example, a 1993 flood curtailed freight shipments on several Midwestern railroads, but others not flooded, such as the IC, inherited the business of the rail competitors. A cold winter causes a greater need for coal by utilities, and unusually hot summers do the same, as power plants attempt to meet large air-conditioning demands. Both of these scenarios substantially increase coal-train traffic (Figs. 2.4 and 2.5). A year with good crop-season weather brings high crop yields, so rail traffic booms. The unusually warm and snow-free winter of 2001/02 brought record automotive sales across the

Fig. 2.4. A BN coal train hauling 105 cars of Wyoming coal to a barge-loading facility on the Ohio River moves through the winter woods of southern Illinois. An abnormally cold winter in 1990/91 led to increased coal train operations, a benefit to several railroads.

Fig. 2.5. The unusually hot summer of 1997 in the Midwest led to increased coal usage by power plants attempting to meet large air-conditioning demands. Here an empty UP coal train led by a new AC44/60CW heads west from Chicago on the ex-C&NW main for refilling in Wyoming.

nation (Changnon 2002), and this, in turn, led to great increases in business for railroads, both for hauling parts to auto assembly plants and for hauling new vehicles to auto distribution centers.

Problems Caused by Weather

Railroads function well within the normal range of weather conditions, be it winter or summer. This is a result of many adjustments in the fixed plant and train equipment made over the past 150 years. Railroads have been designed and configured to function well typically nine years out of any decade.

However, weather occasionally causes problems for both equipment and staff when it becomes extreme. Every form of weather that becomes extreme at some level has its own often-unique impact on rail operations. This includes thick fog, heavy snow, high winds, intense rain, severe icing, high and low temperature extremes, and severe storms. Some extremes, such as snowstorms, occur only in certain parts of the nation.

Assessment of the weather factors producing various problems and costs to the railroads led to the identification of the two most costly weather situations: flooding and heavy snowfall. Flooding can be caused by any one of four weather conditions: 1) very heavy rainfall in 24 hours or less that causes flash floods; 2) massive and rapid snowmelt caused by unseasonably warm temperatures; 3) frequent rains over many days or weeks; 4) hurricanes that are capable of producing 12 or more inches of rain in 24 to 48 hours. Floods occur in all parts of the United States, but heavy snows that slow or stop rail operations occur largely in the northern half of the nation and in the eastern and western mountains. Deep snow requires specialized equipment for removal, and the entire effort is very costly.

Capital costs to address flooding include bridges and earthen fill to ensure trackage is located above maximum flood levels. Washouts of fill and/or bridges in major floods become complex problems and represent significant recovery expenses. Operating costs involve train delays and reroutings, such as those that occurred during and after the record 1993 flood in the Midwest (Changnon 1994).

Assessment of train accidents during 1943–52 (Hay 1957) showed there were a total of 695 accidents, of which 94 (13.5%) were caused by weather. The weather factors causing the accidents broke down as follows:

1. Poor visibility—60 accidents, with 40 due to fog, 13 to snow, and 7 to rain;
2. Washouts or sinking trackage from flooding—19 accidents;
3. Slippery rails from ice or rain—8 accidents;
4. Hot weather bending rails—3 accidents;
5. Debris washed onto tracks—4 accidents.

Rail accidents during a recent 10-year period, 1993–2002, were also analyzed (Rossetti 2003). Accidents due to problems with track, roadbed, and/or structures included 46 with roadbed settling, 18 with washouts or damage to track, and 67 due to irregular track alignment due to thermal misalignment commonly known as sun kinks. These were much higher counts than those for 1943–52. The problem with sun kinks is related to the use of welded rail. The reported cause of all other accidents during 1993–2002 from weather included the following:

1. Snow, ice, or mud on track—22 accidents;
2. Tornadoes—4 accidents;
3. Floods—44 accidents;
4. Fog—0 accidents;
5. High winds—26 accidents;
6. Other environmental conditions (such as extreme temperatures)—8 accidents; and
7. Highway user inability to stop at crossing due to weather conditions—2 accidents.

Figure 2.6 presents the number of weather-related accidents in each month during 1993–2002. Accidents peaked in the winter months, as might be expected, and a peak in April reflects many flood-related problems. Weather-related accidents were also examined on a state basis: Illinois led with 88, followed by Texas with 79. These two states have more trackage than any other states. Other states with high accident counts were Arizona (55), Washington (40), California (30), Montana (28), Tennessee (27), Louisiana (26), and Alabama (26). All other states had fewer than 20 rail accidents. Arkansas, with 2, had the fewest.

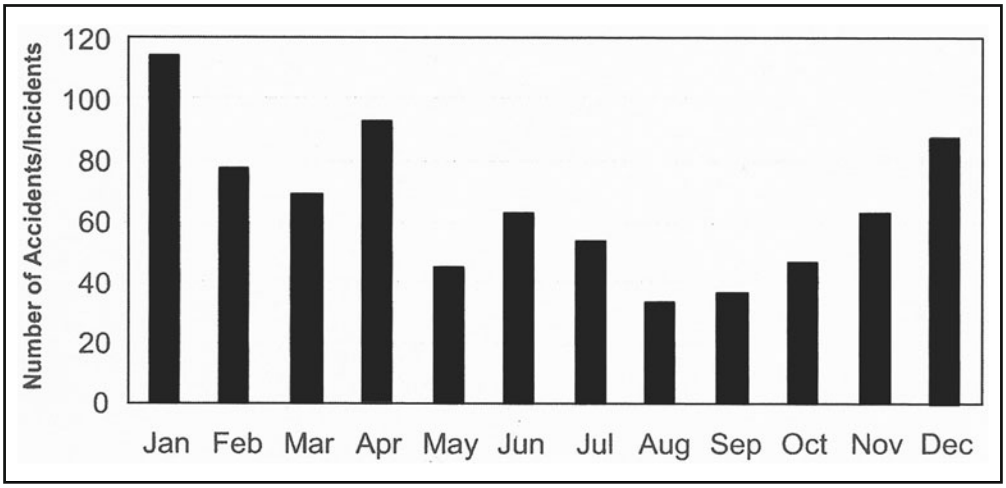

Fig. 2.6. Monthly frequencies of weather-related rail accidents, 1993–2002 (Rossetti 2003).

Table 2.1 documents the types of problems created by various weather conditions. Inspection of the causes further reinforces the idea that excessive snowfall and flooding from too much precipitation make up the bulk of problems (Fig. 2.7). The worst effects happen when various detrimental weather conditions occur together, such as heavy snow, high winds, and very low temperatures.

Table 2.1. Types of weather problems affecting rail operations and crews.

Weather conditions	**Resulting problems**
Fog, heavy snowfall, heavy rain, or sand/dust storms	Visibility restricted
Extreme heat or cold, snow, or ice	Slippage of traction, sun kinks, derailments
Extensive snow, ice, fogs, high winds, or cold	Trains slowed
Wind, snowstorms, ice storms, floods, and fogs	Wrecks
Floods–rainstorms or snowmelt	Roadbed washouts
Snow, downed trees (ice, wind), floods, or rock slides (rain or freeze–thaw)	Blocked rail lines
Ice, snow, high winds, lightning, or space-weather disruptions	Communication failures
Floods, frost heaving	Weakened tracks and bridges
Severe cold	Equipment problems: couplers, engines, switches, Centralized Traffic Control (CTC) systems
All weather extremes	Added maintenance costs/repairs
Droughts or floods	Loss of business

Fig. 2.7. A massive flash flood that originated in the Black Hills of South Dakota in July 1972 led to washouts of local rail lines, such as this one west of Rapid City.

Fig. 2.8. Cold weather brings discomfort and danger to crews who must work outdoors. Here two heavily bundled NW yard workers hang onto a tank car being switched in Virginia on a February day with temperatures at 11°F above zero.

In discussing the negative effects of weather extremes, it is important to consider the problems experienced by railroad workers as a result of these extremes (Fig. 2.8). These problems include discomfort, injuries, exhaustion, frostbite, sunstroke—even danger to life and limb. At a minimum, work efficiency is greatly reduced. In bad snowstorm or flood conditions, work crews are often temporarily shifted from regular duties to repair work.

Even with modern technologies, many of which are designed specifically to minimize weather problems, railroads still suffer from weather extremes. For example, a flash flood at Kingman, Arizona, in 1997 weakened a wooden trestle, derailing an Amtrak train. The accident injured 183 passengers and caused damages amounting to $7.2 million. This accident led the Federal Railroad Administration (FRA) to issue a special safety advisory about the need to use official weather watches and warnings by all railroads.

The current era's pressure to deliver high-speed freight and tight schedules for intermodal traffic makes operations more vulnerable to weather. These examples are from 2003:

- The 2002/03 winter brought two major snowstorms, called Nor'easters, to the East Coast. These delayed both freight and passenger traffic (commuters and Amtrak) into the busy cities of the Northeast including New York, Philadelphia, Baltimore, and Washington, D.C.

- High Midwestern winter winds blew 18 cars of a 105-car freight Burlington Northern Santa Fe (BNSF) off the tracks near Streator, Illinois.
- The spring brought heavy rains and major flooding in the southeastern United States. CSX and Norfolk Southern (NS) both suffered. Lines were closed and trains were rerouted over much longer lines. Concern over bridges led to the use of an age-old technique—having someone walk a bridge in advance of a slow-moving train to make sure of its safety.
- Spring 2003 had record numbers of tornadoes. In attempting to avoid these storms, both the BNSF and Union Pacific (UP) railroads at times had to stop trains.

Costs of Weather

Dealing with weather extremes often produces sizable costs to a railroad as well as dangers to trains and human lives. Costs include the following:

- *Capital costs*—investments in facilities (including modifications to rail cars) to overcome various weather hazards; also, costs to rebuild infrastructure when weather has caused serious damages.
- *Operating costs*—train delays, accidents, damages, and repairs from a wide variety of weather hazards.
- *Loss of revenue*—train delays or cancellations mean reduced income; also, massive droughts or floods reduce crop yields and cause rail shipments to be shifted to other modes of transportation.
- *Reduced market value of the company*—significant weather-related losses to a railroad already in a questionable credit position can lead to major financial problems, and in a few cases, have led to bankruptcy.
- *Intermodal effects*—delayed shipments and missed connections.

The record 1993 flood across the central United States was one of the most costly weather hazards on record (Fig. 2.9). Lost revenue to the railroads was $197.8 million, and costs to repair washed-out facilities totaled $282.3 million. This was one of the most expensive natural disasters in the history of American railroads, costing railroad companies $480 million and regional shippers another $527 million.*

---

* All amounts are expressed in 2005 dollars.

Fig. 2.9. The massive floods of the summer of 1993 in the Midwest caused huge damages. Here we see the Santa Fe's yards at Ft. Madison, Iowa, about to go under water as a train passes slowly on 2 July. Three days later the line here was closed. Note the sandbags around the control shed.

Capital costs are investments to the rail plant (right-of-ways, tracks, signals, communications, facilities, cars, and engines). Some capital costs are unrelated to weather; some are partly related to weather; and some are directly weather-related. An analysis of what American railroads spent on items directly related to weather during 1952 appears in Table 2.2. This reveals a total of over $19 billion in 2005 dollars. Costs for communication systems, both radio and underground cabling, were $8,608 per mile on the Southern Pacific and $3,135 per mile on the Chicago, Rock Island and Pacific Railroad.

Tables 2.3 and 2.4 show the results of an extensive nationwide inventory of capital and operating costs on all railroads existing in the 1950s (Hay 1957). In some instances, the average national costs, based on all railroads, are presented, and in other cases, the range of costs is presented. Costs were not obtained for a few items, or were considered so variable that numbers could not be provided.

Table 2.2. What American railroads spent on weather-related facilities (Hay 1957).

Facility	Expenditure (in millions, 2005 dollars)
Snowsheds and fences	$156.1
Underground cabling	$233.8
Grading	$5,214.0
Bridges and trestles	$3,135.0
Ore and coal wharves	$179.9
Roadway machines	$181.9
Freight cars (refrigerated)	$8,415.0
Passenger cars (air conditioned)	$1,980.2
Work equipment	$355.7
TOTAL	$19,581.6

Table 2.3. Sources of capital expenditures due to severe weather and typical costs.

Item	Cost (in 2005 dollars)
Refrigerator cars	$13,700 average cost per car
Icing stations and cooling plants	$650,000–$6,850,000 per installation
Air conditioning of passenger cars	$8,560–$17,120 per car
Snow removal equipment	$83–$217 per mile in heavy snow areas $20–$55 per mile in intermediate areas
Snow melting equipment	$2–$412 per mile, based on climate
Snow fences	$0.5–$3.4 per foot (depends on type)
Cut widening	No value
Communication facilities	
microwave	$2,054–$9,416 per mile
radio	$171–$2,054 per mile
buried cable	$1,712–$3,530 per mile
GPS	No value
Increased wire size and supports	Varies widely
Platform canopies	Variable with size and design
Heavier roof designs for snow	Varies with roof design
Snow sheds	
timber	$517,925 per mile
concrete	$1,966,206 per mile
Stronger bridges, signal masts, etc.	Variable due to wind loadings
Bridges	Variable
Raising of track, bridges, etc.	$171,200–$1,331,930 per mile

Table 2.4. Sources of operating expenses and typical costs from severe weather conditions.

Item	Cost (in 2005 dollars)
Operation of refrigerator cars	$13.4 per mile
Operating icing/cooling facilities	Unknown
Air conditioning of cars	Unknown
Ice storm damages (wires, track, etc.)	$1,030–$1,766 per mile
Excess rail breakage	$0.59–$18.78 per mile
Snow & ice removal (track miles)	$178–$353 per mile for heavy snow areas $17–$240 per mile in intermediate areas
Sand removal	$1,300–$8,680 mile
Flood costs—major events Long-term average	$7,297–$10,443 per mile $1,616–$1,728 per mile
Corrosion removal	$1,198 per mile
Train delays	$3.83–$7.09 per train mile

Fig. 2.10. Snow, high winds, and cold collectively are a major problem for railroads. Here a westbound NS train that had entered an Indiana siding to meet with an eastbound train has become stalled by drifts and cold temperatures on a morning with temperatures of −2°F and winds of 35 mph.

Extremely bad weather has led to severe economic stresses on certain regional railroads. For example, the severe damages to the Western Maryland Railway (WMR) resulting from Hurricane Agnes in June 1972 led to its financial collapse, and in turn, its sale to the Chessie System in 1973. Hurricane Agnes caused record floods in Pennsylvania, Maryland, and Virginia, with property damage amounting to $4.25 billion (2005 dollars).

The flooding also created extensive damages to the Erie Lackawanna (EL), and as a result the line was forced into bankruptcy (Shafer 2000). Four years later the EL became part of Conrail. Figures 2.10–2.20 provide more examples of weather impacts.

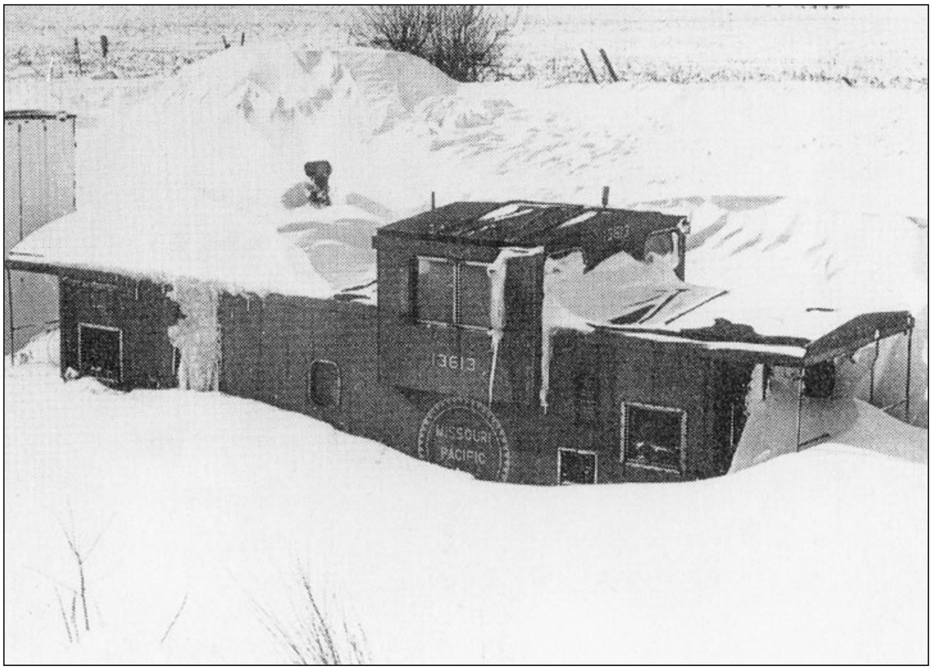

Fig. 2.11. The winter of 1977/78 was one of the worst on record in the central and eastern U.S. The Midwest experienced a record number of 23 major winter storms. Some drifts in late January were 20 feet high. This Missouri Pacific train was trapped in deep snow: the top of the caboose is even with the top of the snow.

Fig. 2.12. Reduced visibility, always a problem for train operations, is caused by three different weather conditions—snow, fog, and rain. Here a Gateway Western train is moving through heavy snow in eastern Missouri.

Fig. 2.13. Heavy rains obscure an approaching junction as a UP train heads past the dimmed caution signal.

Fig. 2.14. An IC SD40 leads a southbound train through a dense fog near Fulton, Kentucky.

Accidents, whether they are weather-related or not, can be seriously problematic events. Not only are they costly, but also they can hurt or kill rail employees, others riding on the trains, and bystanders. In addition, many chemicals classed as toxic-if-inhaled (TIH) are carried in bulk by rail cars. Weather conditions may play a critical role in the dispersion of such substances, and also factor importantly into models used to predict the dispersion path. If an accident occurs to freight trains carrying various hazardous TIH chemicals like chlorine, anhydrous ammonia, or fuming sulfuric acid, these can be spilled and cause dangerous plumes and intense fires that expose nearby populations to great risk. Costly lawsuits can develop if the railroad is deemed at fault for such an accident.

Fig. 2.15. Freezing rain brings several problems to railroads, including slippery rails and loss of traction. Here an NS train behind an SD40 and a GP38 heads slowly across southern Indiana after an ice storm ended. Note the ice on the wires, poles, and weeds.

Fig. 2.16. Slippery rails result when it rains. The power wheels on this UP C36-7 are slipping as it tries to lug a heavy TOFC train.

Fig. 2.17. Electrical storms also cause problems. Lightning strikes can cause power outages and loss of communications. Here a lightning strike hits just west of a Wabash signal bridge.

Fig. 2.18. Twin tornado funnels approach a rural Missouri rail line.

Fig. 2.19. Snow, ice, and cold weather freeze switches closed, unless heaters have been installed. Here two crew members of a grain train in a small Iowa town need to dig out a switch to an elevator service siding on a cold December day.

Fig. 2.20. Flooding leads to washouts of roadbeds like this one in Arkansas. The major activity in the following days involved restoring the earthen fill and rebuilding the small bridge (left) that was enlarged to better handle future high waters.

CHAPTER

3

Examples of Weather Problems in Different Climatic Regions

THIS CHAPTER presents seven examples of how various weather extremes have created critical problems for railroads and allied forms of transportation in different climatic regions. These examples illustrate in detail how problems have developed and how they have been handled. When one thinks of problems created by the abnormal weather conditions in the central United States (High Plains or Midwest), agricultural issues typically come to mind. However, weather aberrations in that area drastically impede all the highly weather-sensitive transportation systems that serve not only the region, but the entire nation. Chicago is the nation's rail hub, and nearly 90% of all freight traffic going east–west or north–south across the nation passes though Chicago. Barges operating on the Mississippi River system, which includes the Ohio, Illinois, and Missouri rivers, handle 73% of all bulk commodities (grain, coal, lumber, oil, and chemicals) moved in an area covering 60% of the United States.

The Drought of 1987–89

In late 1987, a drought developed over several parts of the United States, and it continued to expand nationally the following year. By July 1988, 39% of the nation was experiencing severe drought. The drought continued into 1989. Figures 3.1 and 3.2 show the percent of the nation and the regional extent of areas affected by severe and extreme drought, which include the northern Rockies, northern High Plains, Midwest, and Southeast. The severe drought conditions with little rain created low flows on the region's major rivers (Riebsame et al. 1991). By May 1988, river flows were so low they impeded the movement of the thousands of tows and barges that ply the Mississippi, Missouri, and Illinois rivers. In the area where all the rivers converge near St. Louis and from there flow south to New Orleans, there are no dams to help manage river flows and keep levels needed for barges.

By early June 1988, hundreds of barges became grounded at Cairo, Vicksburg, and Memphis. The Corps of Engineers closed the river system, trapping 700 barges at a daily cost of $400 million (Changnon 1989). In one Illinois port, more than $1 million of grain was poured on city streets because of the lack of storage and no barge movement, and there the grain ultimately rotted. By late June, 3,900 barges were stranded, representing a loss of $2.6 million daily. Grain and other bulk commodities hauled by barges were being shifted to railroads for movement to ports.

Dredging was attempted, along with reduced loads on barges, but little improvement occurred. Desperate barge owners and shippers united and asked their state governors and congressional members to get permission to triple the amount of water diverted from the Great Lakes system into the Mississippi system through an existing diversion outlet at Chicago (Changnon 1989). There, the diverted flow is controlled by a U.S. Supreme

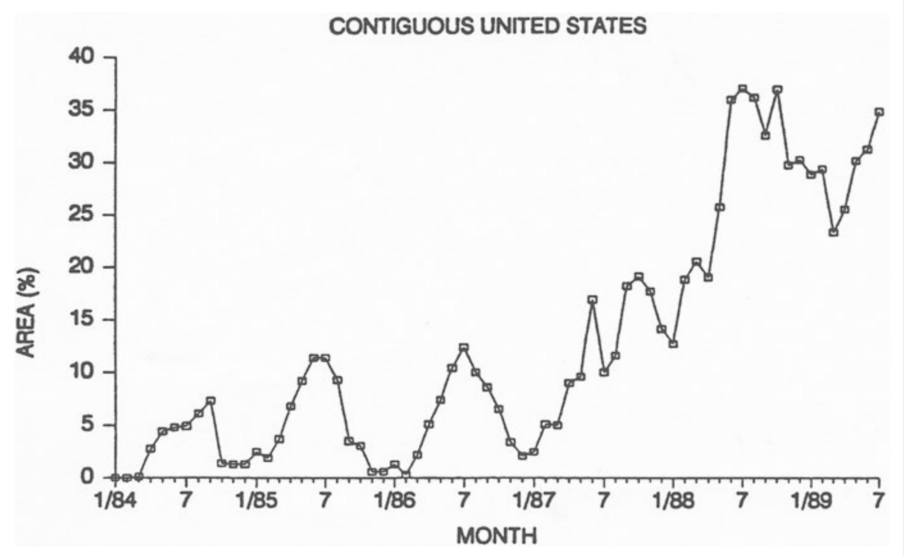

Fig. 3.1. Percent of the nation experiencing severe or extreme drought in each year from 1984 through July 1989 (Riebsame et al. 1991).

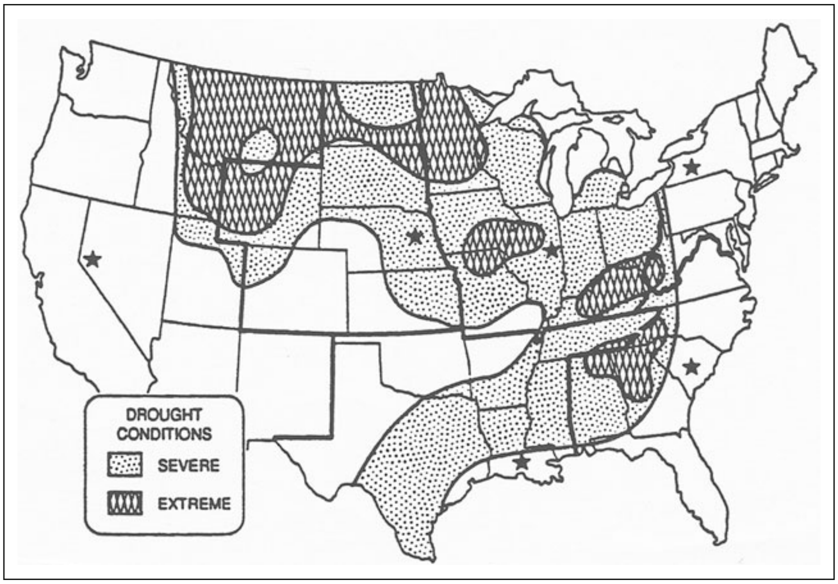

Fig. 3.2. The areal extent and locations with severe or extreme drought conditions in June 1988 (Riebsame et al. 1991).

Court decree resulting from prior interstate battles over the amount of the diversion (the limiting decree resulted from low lake levels due to persistent dryness and the severe drought of the 1930s). However, members of Congress from states around the lakes resisted, fearing additional lowering of the lakes and ensuing problems for lake shippers. Canada also objected, and in July its ambassador took a formal objection to President Reagan. Thirteen senators from states along the river countered and asked President Reagan to approve their requested diversion increase. After several weeks, the Secretary of the Army formally declined the request, claiming the added diversion would be of little use. Increased rainfall in September and ensuing months alleviated the barge problems by October. The total cost to the barge industry was $1 billion (for 5 months), plus another $1.2 billion in losses to shippers and ports along the rivers.

However, the very dry summer of 1988 led to benefits for several railroads. Traffic usually shipped by barges was shifted to the railroads. In particular, north–south–oriented lines that compete for the Midwest/Gulf coal and grain traffic like the IC, CSX (former L&N), UP (former MP lines), NS, and KCS experienced sizable increases in freight shipments.

The Archer Daniels Midland Company, a major grain processor based in Decatur, Illinois, owned 1,400 barges and 19 towboats. It faced the problem and recognized its great need for shipments on the IC. As a result of the flood, this huge company bought 25% of the IC's stock in January 1989 to ensure its current and future rail shipments (*Trains*, January 1989).

The drought had negative impacts on other railroads. The low crop yields in the upper Midwest greatly reduced grain shipments on the Soo and the Chicago and North Western (C&NW) railroads. The financial situation of the Soo, already not in good shape, led the Soo's owner, the Canadian Pacific Railroad, to consider selling it (*Trains*, June 1989).

The Floods of 1993

Record floods that were concentrated in the center of the nation's rail system and embraced the heart of the Mississippi waterway navigation system occurred in 1993. Heavy and prolonged summer rains and ensuing floods on the Mississippi and Missouri river systems enveloped a triangle of the nation's three major rail hubs of surface transportation: Chicago, Kansas City, and St. Louis. About 25% of all U.S. freight either originates or terminates in the flooded area. The flood stopped river navigation for two months, and also produced a huge traffic jam on the region's railroads during June through August 1993 (Changnon 1996).

From April through August 1993, more than 2 feet of rain fell in an enormous area (Fig. 3.3) encompassing parts of nine states and centered in Iowa, which experienced rainfall totals of up to 3 feet compared to the state's normal rainfall of 16 inches. The resulting floods were most extreme in western Illinois, throughout Iowa, in the northern half of Missouri, and in eastern Kansas. These floods broke all-time records for the Mississippi River from Rock Island, Illinois, south to Cairo where the Mississippi meets the Ohio, and the floods on the Missouri River broke flood records from St. Louis west to Kansas City and north to near Omaha. Numerous major tributaries to these

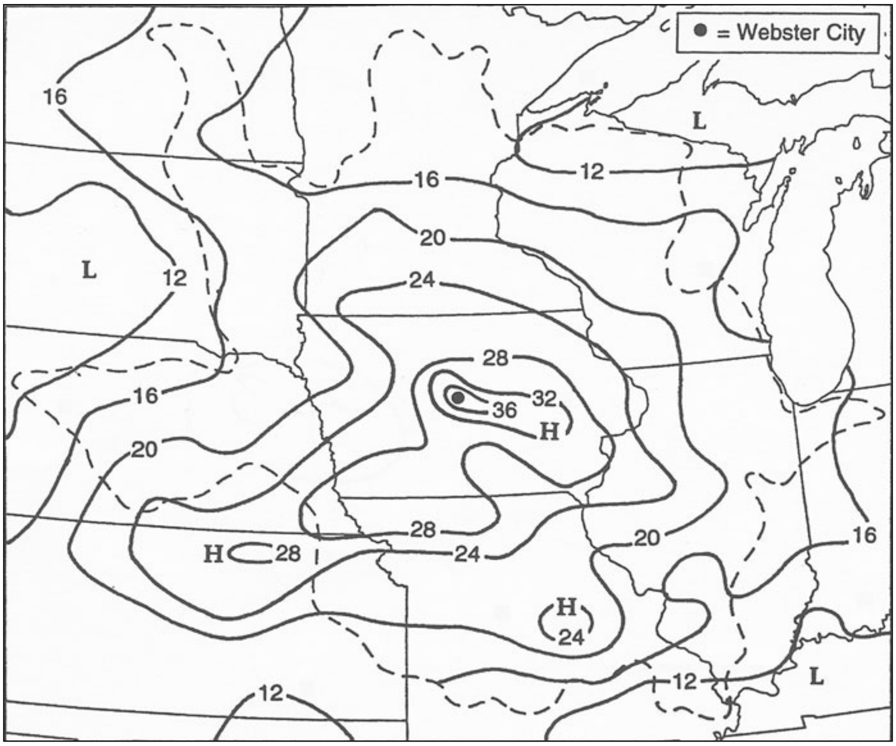

Fig. 3.3. The rainfall pattern (in inches) for June–August 1993. The dashed line defines the boundary of the Upper Mississippi River basin.

rivers, including the Des Moines, Kansas, Iowa, and Illinois rivers, also had record floods. The nation's major east–west railroads converge at three hubs, all in the flood zone, and cross all of these rivers, which are also prime waterways for the nation's inland commercial navigation system.

The flood was unique for three reasons: 1) it occurred in summer (most Midwestern floods of consequence are partly due to rapid snowmelt and occur in the spring); 2) it covered 260,000 square miles, an immense area; and 3) it lasted months, not weeks as do most floods. Figure 3.4 shows how heavy rainfall began in the Upper Mississippi basin in April and persisted week after week into late August. These last two factors—the huge area covered and the flood's exceptionally long duration—are what really produced severe impacts on the transportation systems and the movement of people and goods, both within and through the huge flooded area. It became a much larger flood problem than one that occurred three years earlier in May 1990, when heavy rains in east Texas, Oklahoma, and parts of Arkansas produced several washouts and bridge closures for the SP, UP, and Kiamichi railroads.

By late June, the worsening flood led the U.S. Coast Guard to order stoppage of all barge traffic on the Mississippi, Missouri, and Illinois rivers. One might initially predict that a severe flood on the big rivers would create a major economic victory for the railroads. The barge industry is a major competitor with the rail industry for hauling bulk commodities including grain, coal, petroleum, and chemical products. These were shipments the railroads gladly would have moved, but once again the flood prevailed. Rail traffic also began to cease within a few days after all barge traffic had ceased on 26 June. The oblate-shaped, badly flooded area (with Kansas City at one end and

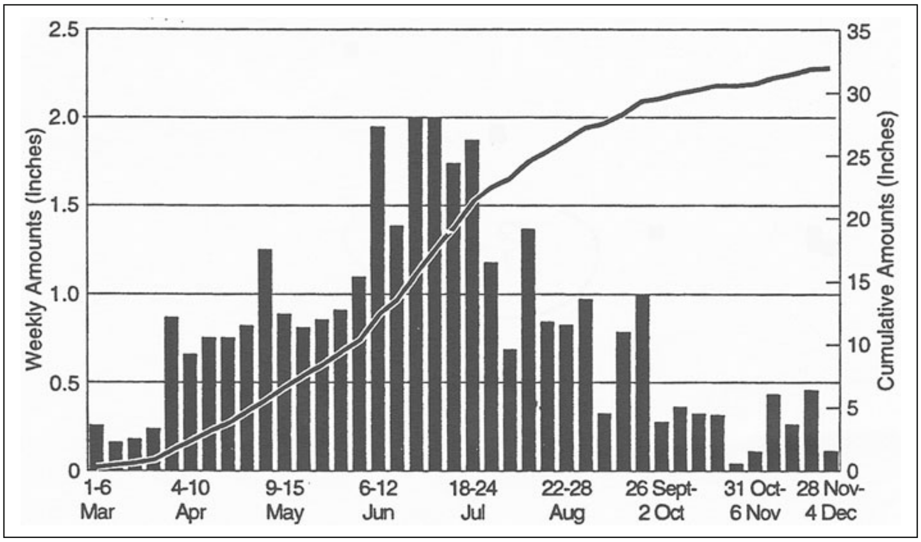

Fig. 3.4. The weekly amount of precipitation across the Upper Mississippi River basin and lower Missouri River basin for March–October 1993. The curve depicts the accumulated rainfall across this huge area.

Chicago at the other) occurred over the main lines of the nation's major east–west railroads, as shown in Fig. 3.5.

Rail troubles began on 19 June when a portion of the Green Bay & Western line in Wisconsin was washed out, and then on 24 June the Canadian Pacific (CP) removed all its cars from the St. Paul rail yards before the flood submerged them (*Pacific Rail News*, August 1993). By early July, high waters along the Mississippi Valley had inundated low-lying rail lines built

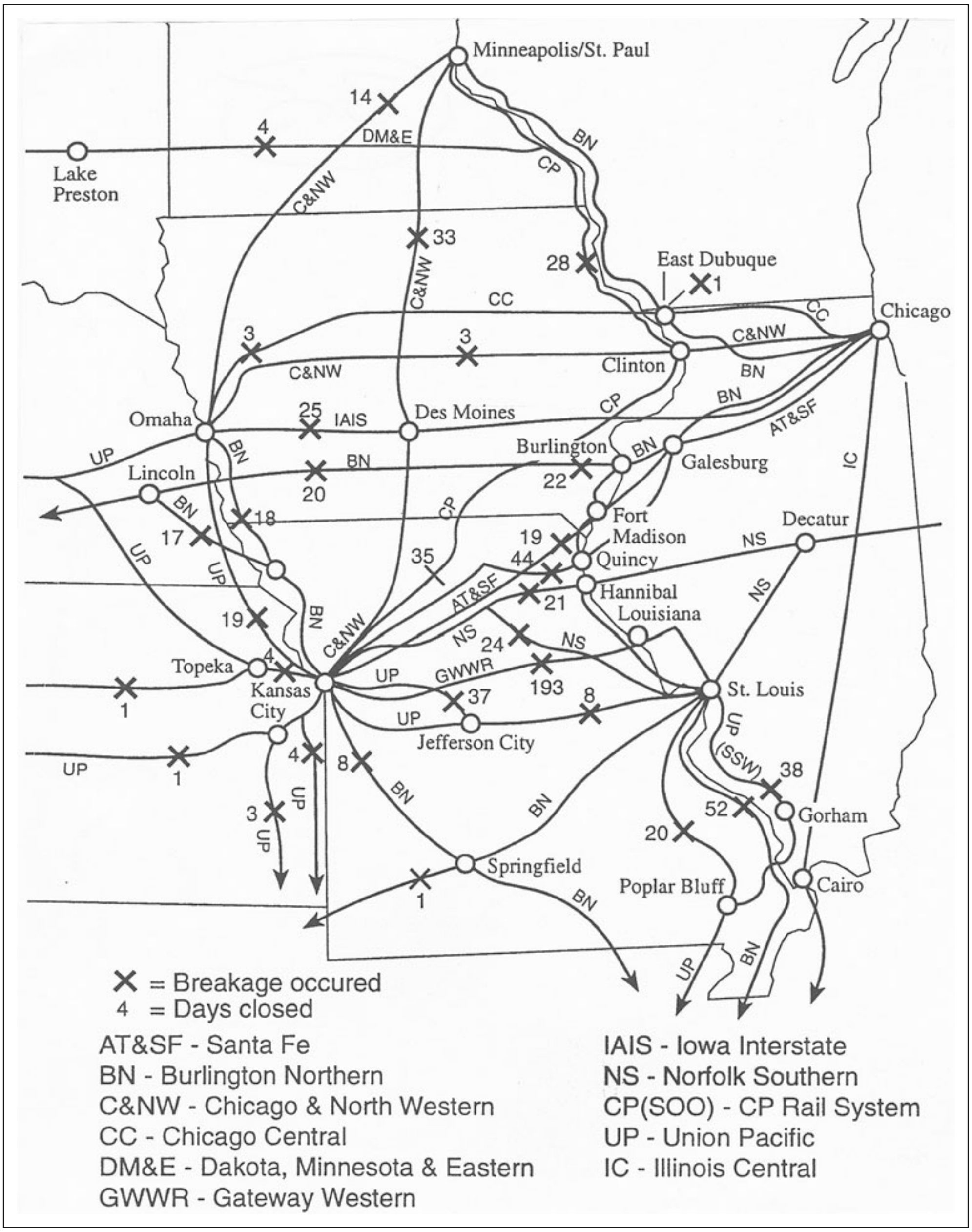

Fig. 3.5. Locations where rail lines were closed by the massive 1993 flood. Shown are the number of days each line was closed.

parallel to the river valley and the approaches to certain rail bridges across the Mississippi. Bridge problems slowed or stopped trains at seven major crossings (Fig. 3.5):

1. The Iowa Interstate (IAIS) bridge at the Quad Cities, Illinois–Iowa;
2. Canadian Pacific (CP) at Savanna, Illinois;
3. Atchison, Topeka & Santa Fe (AT&SF) at Ft. Madison, Iowa (Fig. 3.6);
4. and 5. Burlington Northern (BN) at Quincy, Illinois, and at Burlington, Iowa (Fig. 3.7);
6. Gateway Western (GWWR) at Louisiana, Missouri; and
7. The Norfolk Southern (NS) Decatur–Kansas City line at Hannibal, Missouri.

Train stoppages and reroutings were occurring by 6 July on the BN, CP, and Southern Pacific (SP). On 7 July, the Union Pacific main line between St. Louis and Kansas City went under water; two days later the NS east–west main line at Hannibal was flooded, and on 10 July the AT&SF main line and yards at Ft. Madison were flooded (see Fig. 3.6) and a bridge had washed out near Marcelline, Missouri. The UP line between Kansas City and Omaha went out on 13 July. The situation had become deadly serious for all railroads in the Midwest.

Fig. 3.6. An AT&SF train moves on the nearly flooded mainline near the Mississippi River on 5 July 1993. The next day the line was closed here.

Continued record heavy rains in northern Missouri, eastern Kansas, and southern Iowa during mid-to-late July created a series of new flood crests, which resulted in several major washouts and a few "bridge-outs" in those three states. One major result was the washout of the Santa Fe's bridge near Marcelline on 10 July (*Traffic World*, 19 July 1993).

These new floods severed several major lines for periods of two weeks or longer. This massive halting of rail traffic occurred on seven main lines (including six major railroads) crossing the Midwest:

1. The BN main line between Galesburg, Illinois, and Kansas City (across northern Missouri), also home to SP trains operating between Kansas City and Chicago;
2. The BN double-track main line between Galesburg and Omaha (across southern Iowa);
3. The AT&SF double-track main line between Ft. Madison and Kansas City (across northern Missouri);
4. The NS Decatur, Illinois–Kansas City main line (in central Missouri), which remained closed until October, and the NS's St. Louis–Kansas City main line;
5. The GWWR St. Louis–Kansas City main line (in north-central Missouri), a line that remained closed until November;
6. The UP main line from St. Louis to Kansas City; and
7. The CP main line between Chicago and Kansas City.

The flood's impact on the GWWR was especially severe. In mid-July the Missouri River broke through levees and washed out two segments of track, one 1,000 feet long and another 500 feet long. Then on 30 July, a surging new flood crest wiped out the GWWR rail bridge at Glasgow, Missouri, closing the railroad for many months. When barge operations were allowed to resume in August, the rivers were still in flood, and the GWWR was further damaged when a barge struck a rail bridge across the Mississippi River at Louisiana, Missouri.

Lines parallel to the big rivers were threatened (Fig. 3.7), and four were closed for prolonged periods. Those included:

1. The UP–Cotton Belt (SLSW) shared railroad line from East St. Louis south along the Mississippi's east shore to Gorham, Illinois;
2. The parallel BN river lines along the Mississippi's west shore north of St. Louis to Burlington and south of St. Louis to Cape Girardeau, Missouri;
3. The BN and UP lines along the Missouri River between Kansas City and Omaha; and
4. The CP line along the Mississippi between Dubuque and LaCrosse, Wisconsin.

The Battle at Marcelline

By early July, leaders of the AT&SF (Santa Fe) railroad were fearful of the flood. They situated cars loaded with rock to be placed on threatened bridges, hoping these would keep the bridges stable against the force of floodwaters (*Trains*, October 1993). At a 96-ft-long bridge built over a small creek located 17 miles west of Marcelline, Missouri, two such "ballast cars" sat. However, in the early morning of 10 July, an 8-ft-high wall of water, resulting from a levee break on the nearby Grand River, swept away the bridge and the two heavily loaded cars (two weeks later the remnants of the Marcelline bridge and the two cars had still not been found).

The Santa Fe mobilized to restore the bridge and get their heavily used line (40 trains a day) open. A new bridge designed to be 280 feet long and built of concrete beams and steel pilings was an enormous logistical challenge for the railroad. One hundred workers, construction materials scrounged from everywhere possible, and four huge pile drivers were brought to this isolated location, and a command headquarters was established in a passenger car brought to the scene. Work began around the clock. Through rain and sunshine, trucks with rock for fill and other materials and vehicles for the workers, which had to detour 55 miles to reach the bridge site, came and went. The enormous effort paid off. At 2 a.m. on 24 July, just 14 days after the washout, the new bridge was completed (at a cost of $2 million), and trains were again operating along the Santa Fe's main line.

Fig. 3.7. A BN coal train, diverted north to Minneapolis because of a bridge closure at Burlington, Iowa, crawls alongside the flooded Mississippi River on 12 July 1993. Note the light-colored rock alongside the track close to the encroaching river, new gravel brought to protect the track from the flood.

TABLE 3.1. Financial outcomes for individual railroads from the 1993 flood (in millions, 2005 dollars).

Railroad	Damages	Revenue lost
Amtrak	$0	$8.2
Atchison Topeka & Santa Fe	$43.3	$23.4
Burlington Northern	$102.9	$51.5
Canadian Pacific	$17.6	$14.0
Chicago & North Western	$5.9	$14.0
Dakota, Minnesota & Eastern	$2.3	$1.2
Gateway Western	$11.7	$8.2
Illinois Central	$0	$21.1
Iowa Interstate	$4.9	$3.5
Norfolk Western	$15.2	$8.2
Southern Pacific	$19.9	$29.3
Union Pacific	$58.5	$15.2
TOTALS	$282.2	$197.8

The BN line along the west shore of Mississippi between Burlington and St. Louis was closed on 30 June and was not reopened until October. The flooding seriously affected Kansas City, where floods closed several rail yards and approaches to the city for two periods in July, altering train movements in and around this key hub, which is the nation's second busiest rail center behind Chicago. During 27–30 July, most rail traffic was halted at Kansas City. St. Louis was spared flooding of its major yards, as was Chicago.

The physical damage to the railroads was massive. Best estimates indicate losses amounting to $282 million.* This figure includes $112 million for damage to track (60 miles were washed out at a replacement cost of $300,000 per mile, and 820 miles of track were under water, with repair costs at $117,000 per mile; *Traffic World*, August 23). The loss total also includes $17.6 million for bridge replacement and repair, $16.4 million for signals, $10.5 million for train cars and engines, and $64.4 million for labor and fuel costs associated with train detours. Table 3.1 itemizes the losses experienced by individual railroads.

Revenue losses were sizable. For example, the AT&SF estimated a loss of $875,000 per day during the days its tracks were blocked and trains rerouted (*Traffic World*, 30 July) for a total loss of $23.4 million. Delays of 1 to 5 days occurred on AT&SF, BN, and SP trains, which created major

---

*All amounts are expressed in 2005 dollars.

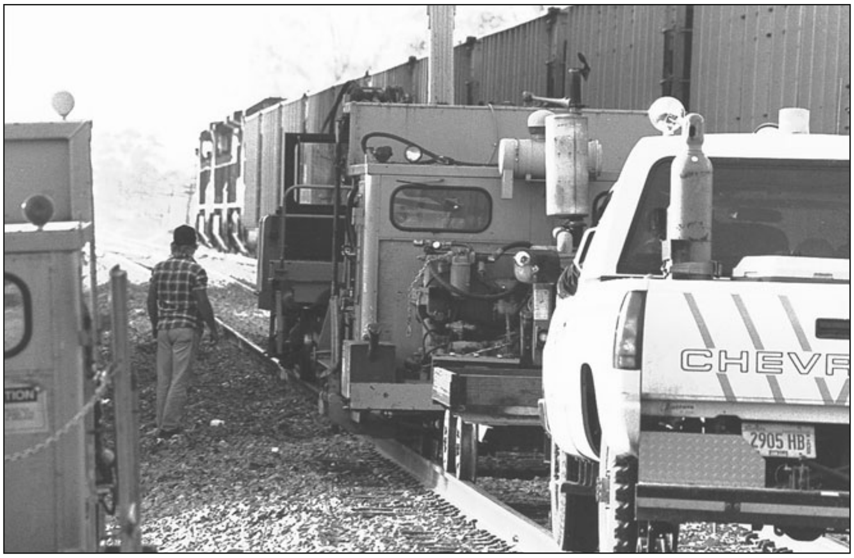

Fig. 3.8. More than 500 UP workmen from all over the nation were called to flood duty in the Midwest. Here a crew involved in rebuilding the main line near the Mississippi River is waiting for a freight train to slowly pass. It is 15 October 1993, more than a month since local flood waters had receded here south of St. Louis.

problems for speed-oriented shippers such as United Parcel Service. The loss in revenue to BN was $51.5 million (*Transportation and Distribution*, January 1994). With an estimated $197.8 million of revenue losses due to delayed trains and shipments lost to other carriers, the actual losses from the flood totaled $480 million, the greatest flood loss ever experienced by railroads. The amount was more than 20 percent greater than the previous high losses to railroads, which was $393 million to 6 railroads as a result of Hurricane Agnes in 1972.*

Two major responses occurred as the flood developed, persisted, and began incurring damages: plans and action. Affected railroads established “situation rooms” to deal with their emerging problems. By 11 July, the situation room of the AT&SF was routing 50 trains a day over various other railroad lines to try to maintain service.

The railroads worked feverishly to elevate nearly flooded rail lines, to rebuild washouts and bridges, and to restore operations. For example, the NS raised a mile of threatened track in Missouri by 6 feet with imported rock. During most of July, 500 UP workers labored to keep their Sedalia Subdivision line in Missouri open, and UP crews drawn from all over the nation were still working to restore damaged lines as late as October (Fig. 3.8). To protect its line along the Mississippi’s threatened west shore, CP carried 6,000 carloads of rock. Ironically, an abandoned but intact NS rail line across parts of Missouri and Iowa became a highly useful detour when the main lines were flooded (American Railway Engineering Association, January 1994).

---

*All amounts are expressed in 2005 dollars.

Although their lines went out in July, the NS line across Missouri (Decatur–Kansas City) and the GWWR line (East St. Louis–Kansas City) were closed until October to repair damaged bridges, eroded bridge approaches, and major on-line washouts. Of GWWR's 250-person staff, 20% were furloughed, and its Missouri bridge that collapsed in July was not rebuilt until February 1994. The NS line across Missouri was the line most damaged during the flood (*Railway Track & Structures*, September 1993).

After washouts and bridge losses were repaired on the BN's Omaha–Galesburg main line and on four UP lines, all were reopened by late July or in early August. However, the BN's Galesburg–Kansas City main line was blocked at West Quincy, Missouri, until late October. SP's Chicago–Kansas City trains normally operated on this BN line, but they were shifted from mid-July until the end of September, and either used the CP (Soo) line or the SP line south from Chicago to St. Louis and west over the BN line to Oklahoma.

The railroads also helped others fight the flood. For example, in 10 days during mid-July, the NS carried 250 carloads of sand (enough to fill 6 million sandbags) and 50 carloads of rock from a quarry to Hannibal to help strengthen local levees. UP hauled large quantities of drinking water in 10 special tanks to Des Moines during the 12 days when the city's flooded water plant was inoperative. The devotion and heroism of thousands of individual employees of the railroads are evident in their outstanding efforts to quickly rebuild and to maintain a semblance of normal operations. Countless employees worked around the clock, and their story ranks among the finest hours in the history of railroad service.

While the lines were closed, the other major activity was the rerouting of trains. The alternative routes found and used by Amtrak passenger trains and the freight trains of the AT&SF, BN, NS, SP, and UP were truly amazing. More than 2,870 trains were rerouted during the flood at costs ranging from \$10.5 to \$23.4 per train mile. One train was rerouted 1,000 miles at a cost to the parent railroad of \$23,400. The total cost of these reroutings was \$64 million (Harper 1993).* The railroads solved their blockage problems largely by doing "end runs" around the huge flooded area (Changnon 1994). However, some of the overload traffic continued to move across the Mississippi at St. Louis (on a single bridge) and from there westward to Kansas City on the lone, open, direct line: the badly congested UP Sedalia Subdivision line. Some trains were diverted over longer BN alternative lines via Springfield, Missouri (Fig. 3.5). Various options were used when the flooding hit rail yards at Kansas City.

The diversions of the high-speed east–west trains run by the AT&SF, BN, SP, and Amtrak began with the use of the "north end" alternative. Although the flood was very serious during June in the upper reaches of

---

*These amounts have been adjusted to 2005 dollars.

the Mississippi River basin, it stopped rail traffic only briefly from East Dubuque, Illinois, northward to Minneapolis (Fig. 3.5). The Chicago & North Western (C&NW) crosses the Mississippi River at Clinton, Iowa (see Fig. 3.9). It remained open throughout the flood except on two flooded-out days (9–10 July) in central Iowa. Lines of the C&NW became a major thoroughfare for Amtrak trains and the freights of more severely flooded Midwestern railroads. Other railroads crossing the two large river basins and located farther north also remained open: the CP, which crosses the Mississippi at Savanna, the Chicago Central & Pacific at East Dubuque (see Fig. 3.10); and the BN lines north along the Big River to the Twin Cities (see Fig. 3.7). Many diverted BN trains rode the BN rails north to Minneapolis and circumvented the flood.

After the flood severed its main line on 10 July, the AT&SF used every device known to its management personnel to move its 50 daily high-speed trains between Chicago and the West Coast. Some trains were routed to the SP line from Chicago to St. Louis and then on the BN line to rejoin the AT&SF main line in Oklahoma. Other AT&SF trains took the BN line from Chicago north and west through Minneapolis, then on to the West Coast. Others got on the C&NW line at Chicago, went west to Omaha, and wound south to the AT&SF main line or continued west on the UP line. And some trains used the IC line and went 500 miles south from Chicago to Memphis, then west on BN lines to Oklahoma. By 13 July, 25% of all rail traffic in the

Fig. 3.9. A diverted UP train slowly crosses the still-operating bridge of the C&NW at Clinton, Iowa. Note the many barges anchored alongside the Mississippi River.

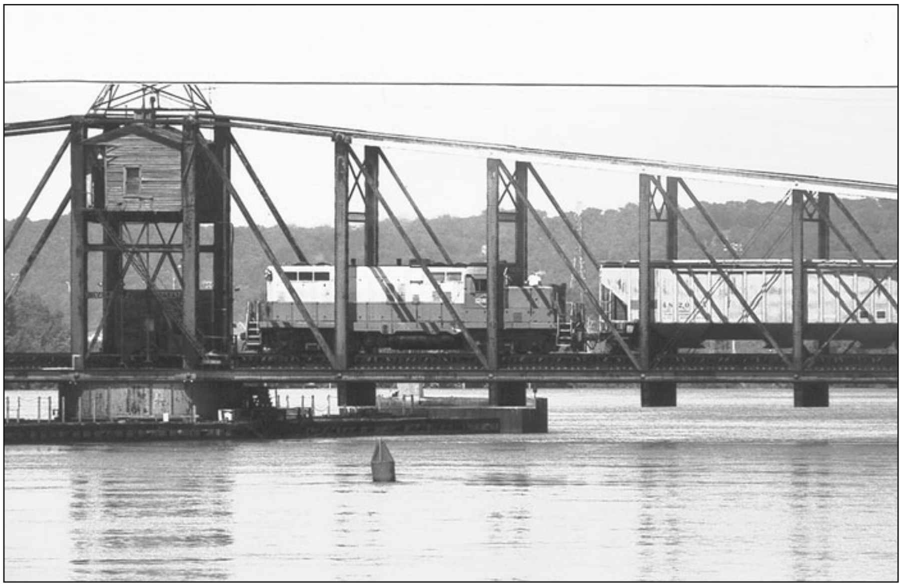

Fig. 3.10. A CC&P train cautiously eases across the aged Mississippi River bridge at Dubuque, Iowa, with the swirling waters just 2.5 feet below the bridge.

United States was affected, and massive reroutings resulted in 120 trains moving daily across the open bridge at St. Louis. Traffic tripled during July and much of August on the IC's north–south main line, the UP's Chicago Subdivision, and on the SP main between Chicago and East St. Louis.

Amtrak's trains underwent numerous shifts. The Texas Eagle, which normally operated among several Texas cities and from Chicago through St. Louis, was rerouted for several weeks. First it crossed the Mississippi at St. Louis and used the UP line south along the Mississippi, crossed back over the Big River at the famed Thebes Bridge, which joins southern Illinois and Missouri, and returned to its normal route in Arkansas. When parts of that UP line were flooded south of St. Louis, the Texas Eagle was shifted to another route, going from Little Rock to Memphis and then north on the IC main line to Chicago (Fig. 3.11). The California Zephyr, which normally operated on the BN main line between Chicago and Omaha, was stopped for a few days in early July, and was rerouted over the C&NW line between Chicago and Omaha for three weeks beginning on 9 July. The Southwest Chief normally operated on the AT&SF line between Chicago and Los Angeles, but simply stopped all operations between Kansas City and Chicago for several weeks beginning on 13 July.

Certain railroads such as the IC benefited from the flood (*Traffic World*, 19 July 1993). Not only did the IC receive revenue from operating 160 rerouted AT&SF, SP, and Amtrak trains (see Fig. 3.11) for several weeks, but it also got additional grain and coal shipments that could not be handled by the thousands of barges moored to the shores of the major rivers for 8 weeks. It was the second time in 5 years that nature provided the IC with such a benefit, the first time being during the great drought of 1988 when the rivers

Fig. 3.11. Amtrak's "Texas Eagle" comes to a stop at Champaign, Illinois, on 27 July 1993, traveling across foreign territory, the IC's main line from Memphis to Chicago. The train had been rerouted by nearly 900 miles to bypass the flooded areas.

were too low to allow barge traffic. Major shippers such as the APL Land Transport Services, which had standing contracts using the open and operating C&NW line, received increased business and revenues because other shippers' major east–west rail lines were blocked (*Traffic World*, 19 July).

Government aid to the damaged railroads was relatively small. Of the $21 million in federal funds allotted, most went to the GWWR and other regional short lines. The major railroads received no federal or state aid and rebuilt their damaged lines with their own capital.

Hurricane Diane in August 1955

On 17 August 1955, a major hurricane came ashore along the coasts of North and South Carolina with 125 mph winds and heavy rains. The giant storm's center was at Wilmington, North Carolina, at 9 a.m. on the 17th. The center of Hurricane Diane moved quickly over western North Carolina in 12 hours (Fig. 3.12), turned, and crossed western Virginia. It then moved more slowly across the southeastern portion of Pennsylvania, lower New York State, and southern New England. Many areas along the storm's track had 10 to 12 inches of rain in 24 hours or less, and some places in southern New England had 20 inches of rain, creating 1-day record amounts in Connecticut, Rhode Island, and lower New York state. As a result, immense

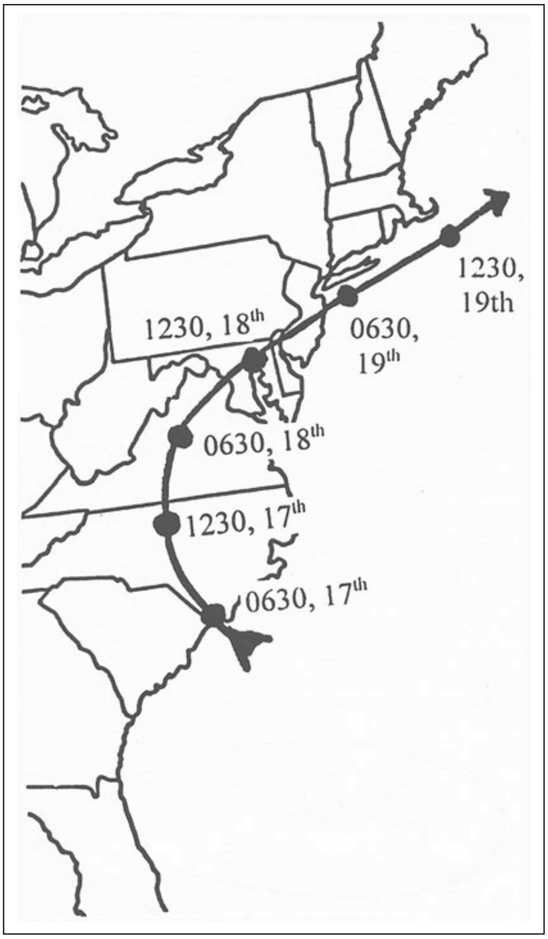

Fig. 3.12. The path of the center of Hurricane Diane in August 1955. Times are local, Eastern Standard Time.

flash floods occurred everywhere. The National Weather Service's assessment of Hurricane Diane's effect on New England was "the greatest disaster of record in the Northeast." The slow-moving storm produced huge amounts of rainfall in these areas, causing hundreds of millions of flood damages to property, and more than $7.9 million in crop damages. The storm was labeled as the nation's first "billion-dollar storm" with more than $940 million in damages in New England.* When the storm moved into the North Atlantic on 19 August, it left 194 persons dead and huge damages to the railroads.

Table 3.2 itemizes the recorded damages to 11 railroads (Hay 1957). This does not include railroads that sustained less damage in Virginia and the Carolinas. In 2005 dollars, the total losses were $141 million; the repair costs were equivalent to $1,986 per mile of track. The maximum time that one of the railroad's main lines was out of service due to damages is also shown in Table 3.2. These periods varied from a few days to five weeks on the New Haven line.

---

*All amounts are expressed in 2005 dollars.

Table 3.2. Impacts of Hurricane Diane in August 1955 on selected railroads.

Railroad	Maximum days portion of main line was out of service	Storm-related repair expenses (in 2005 dollars)
Boston & Maine	28	$78,500,000
Central of New Jersey	10	$3,140,000
Central Vermont	14	Not available
Lackawanna	21	$12,560,000
Erie	13	$20,410,000
Lehigh & New England	8	$157,000
Lehigh Valley	7	$785,000
New Haven	35	$21,980,000
New York, Ontario & Western	9	$196,250
Pennsylvania	4	$2,355,000
Reading	14	$879,200
TOTAL		$140,962,450

The 1951 Mississippi Ice Storm

The IC in the 1950s had a maze of main and branch lines in Mississippi with considerable train operations. In late January 1951, freezing air covered the region. An ice storm stretching from east Texas to Virginia began on 30 January and covered much of the northern half of Mississippi. The ice layers covered trees and structures with a half-inch of ice. On 31 January, a passing strong cold front brought high winds, adding to the ice damages.

By the end of 30 January, communication failures began to occur on the IC as the ice broke wires and poles in three of its rail districts. Train delays became numerous. The ensuing high winds on the morning of 31 January disrupted all wire service south of Memphis (see Fig. 3.13). The area impacted by the storm included the Mississippi towns of Clarksdale, Grenada, and Corinth to the north of Vicksburg and Jackson. Extra linemen were brought to the storm as fast as possible. Jackson was cut off from all communications by the end of 31 January; by then the storm had been in progress there for 41 hours.

Shortwave radios were utilized to try to keep the railroad operating. All available signal crews, extra crews, linemen, and work trains worked overtime during the first two weeks of February making emergency repairs. A generator from a tie tamper was used to furnish power to the IC's office in Vicksburg, where all power had been lost. Winds, snow, and some icing continued on 1 February, keeping line-based communications closed to Jackson. As an example of the severity of the ice damage, the IC's main line from

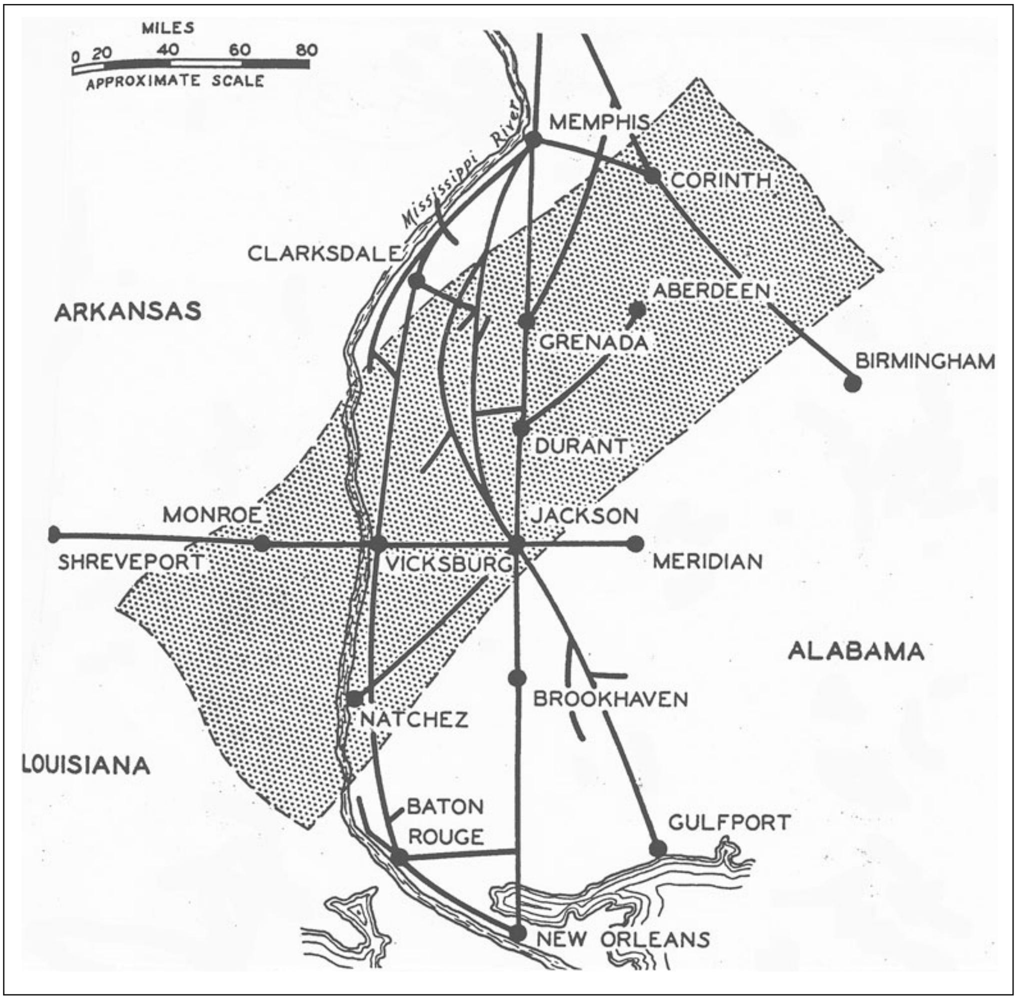

Fig. 3.13. Map of the 1951 ice storm in Mississippi and surrounding states. Shown are the rail lines of the IC, and the shaded area is where the ice occurred (Hay 1957).

Grenada to Jackson, a distance of 111 miles, had 614 poles down (75% required replacement), 35,000 wire breaks, and 200 trees on wires.

In addition to the massive communication problems, coal chutes and water tanks were frozen and many steam engines were halted. Switches were frozen and packed with ice and snow, causing further train delays. Ice and frozen debris on the tracks had caused several train derailments, and ensuing meltwaters caused some major washouts.

By 3 February the IC had brought three work trains, four signal crews, two extra crews, and seven extra linemen to work with the local track and section forces throughout the storm area shown in Fig. 3.13. Many work crews were brought from all parts of the IC's system in the Midwest. A total of 1,097 miles of line had to be repaired at a cost of $932,000 ($1.5 million in 2005 dollars) before communications were able to regulate traffic movement.

Trains were continually late for over two weeks after the storm. Many freight trains were annulled for over a week after the storm. During the first two weeks of February, passenger train delays ranged from 30 minutes up to 13 hours and 30 minutes. In total, 45 trains were delayed an average of 4 hours and 5 minutes. During the first four days after the storm, the average delay was 5 hours and 45 minutes.

Emergency repairs were completed by 15 February. Full, permanent restoration of all signal lines was not complete for over two years. Estimates of costs of all delays and repairs from the 1951 ice storm were in excess of $1.5 million, which would be $2.5 million in 2005 dollars.

A Windblown Runaway Train in 1997

Freight cars were being switched in the IC's large rail yards on the north side of Champaign, Illinois, on 30 April 1997. One switching move left 18 empty grain hopper cars near the north end of the yards. It was a warm spring day with mid-afternoon thunderstorms and strong southwest winds that averaged 17 mph for the day, 10 mph above average. By 5 p.m., gusts had reached 49 mph with steady winds of 36–40 mph.

Suddenly the strong winds began pushing the string of cars northward onto the main line. The orientation of the tracks was south-southwest by north-northeast, nearly aligned with the wind's direction. The cars kept rolling. They passed a grain elevator 3 miles north of the yards whose operator estimated their speed as 20 mph. The land was nearly flat. The ground elevation at the yards is 737 feet above sea level. It gradually decreases to the north, becoming 728 feet 3 miles north of the yards, a slight downward condition that likely aided the windborne movement of the "grain train." The elevator staff who spotted the passing cars called IC yard controllers. Now aware of the runaway cars, the IC yard staff sought permission from the IC dispatcher in Homewood to chase and catch the runaway cars. The dispatcher first radioed Amtrak's southbound Illini, warning it of the approaching runaway. The Illini was put on a siding near Thomasboro, eight miles north of the Champaign yards, to avoid a head-on collision.

When the moving cars reached the small town of Thomasboro (Fig. 3.14), the town's mayor, Tony Grilo, noticed their uncontrolled passage. Being knowledgeable about railroads, he ran and caught the grab iron of the last car, managing to climb on board the runaway as it rolled by. He reached the brake wheel and turned it, but it did not stop the runaway. He then moved to the next two cars and turned their brake wheels, finally

Fig. 3.14. Some of the grain cars of the runaway train alongside the grain elevator in Thomasboro, Illinois.

bringing the runaway train to a stop by the grain elevator in Thomasboro. An IC switch engine soon arrived and took the cars back to Champaign.

A Fog-Induced Accident in 1991

A method of train movement frequently used on busy single-tracked main lines involves the organization of a series of trains going in the same direction. This caravan of trains is labeled a block of trains, each separated from others in the block by a few miles of track.

The NS inherited such a single-track main when it acquired the former Wabash railroad. The east–west main from Kansas City to Detroit was almost entirely single track, and in the 1990s the line was extremely busy carrying many auto-related parts and finished vehicles.

On the morning of 5 April 1991, the NS had a block of three westbound trains moving from Frankfort, Indiana, to Decatur, Illinois. The trains encountered a region of heavy fog in eastern Illinois, and by 7:30 a.m. the visibility had dropped to zero. The advection fog had developed as a result

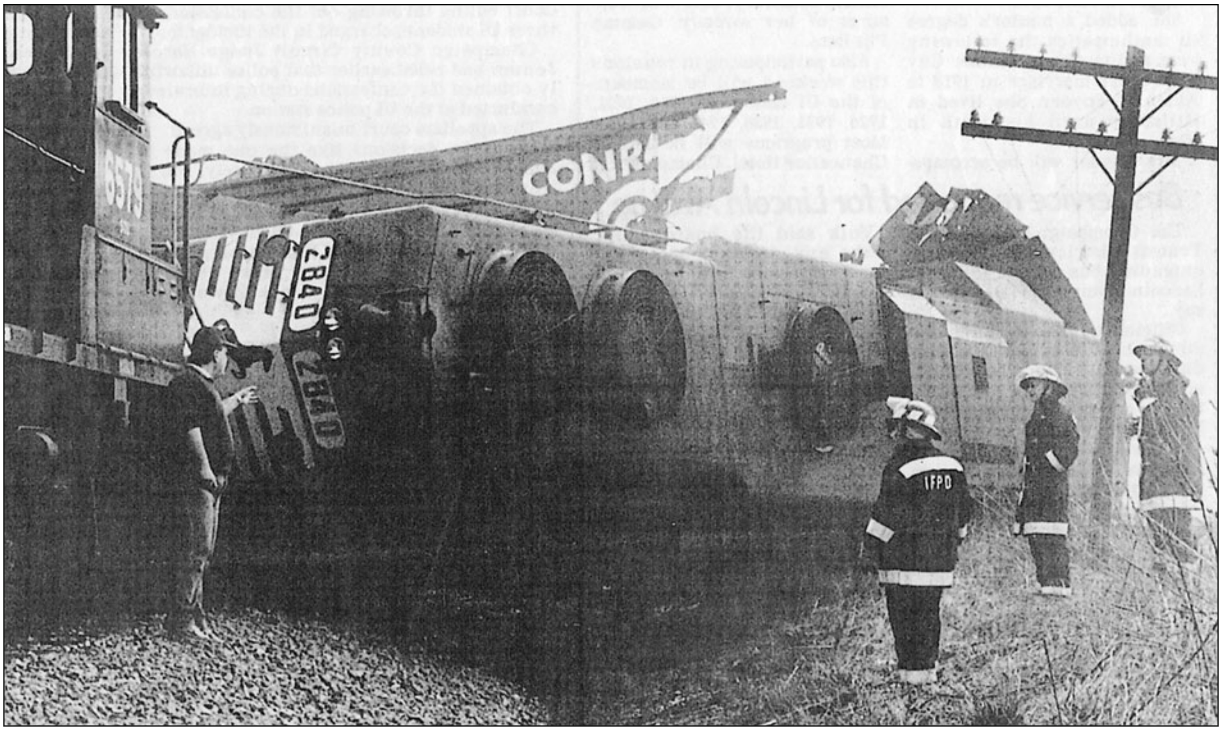

Fig. 3.15. A fog-caused accident scene with the overturned lead engine of an NS train, which crashed into another slower-moving train. Conditions were still quite foggy later, when this photograph was taken.

of rainfall the evening before, and once dewpoint temperatures matched the morning's air temperature of 45°F, dense fog had rapidly developed.

The leading train, with its speed reduced to 15 mph, stopped when its crew noted a defective equipment detector. The second train stopped two miles behind the first, but the third train, going 15 mph, ran into the rear of the second train. The third train's engineer reported that his visibility was totally obscured and his train had not passed any visible block signal for several miles. The impact caused the third train's two engines to derail; one turned over (Fig. 3.15). Four of its cars were also derailed, as were several cars at the end of the stopped second train. Five crewmen were injured, and NS estimated the damages to be $211,000 (2005 dollars).

West Coast Storms, December 1996–January 1997

Most of the precipitation along the nation's West Coast occurs during the November–March period as a result of storm systems generated in the Pacific. As these systems move inland, they typically produce rain in the low hills and valleys and snow in the higher elevations of the Cascades and the Sierra Nevada mountains.

In late December 1996, a series of strong Pacific storm systems began invading the West Coast from central California northward to Washington state. This series of strong storm systems persisted from 25 December until the end of January 1997, producing near-record amounts of rainfall and heavy snows in the higher elevations. Between 25 December and 3 January, the Sierra Nevadas received between 28 and 82 inches of snow. Figure 3.16 shows the snowfall at Donner Memorial weather station located along the Donner Pass. The storm on 21–23 December produced 83 inches, nearly double the average snowfall for all of December.

A storm system in late December brought unusually warm air with temperatures of 60° to the northwestern United States, plus moderate snows and more rain, and this led to rapid melting of the mountain snows. This situation, coupled with 3–6 inches of rain in the lower elevations, brought massive flooding in the northern half of California. Conditions were similar in Oregon and western Washington, which also experienced heavy precipitation, 5–7 inches of rain, and winds of 50–70 mph, from the same storm systems during the 25–31 December period. By 1 January, flooding was widespread in the lowlands and valleys of the three states, and many mud slides had occurred.

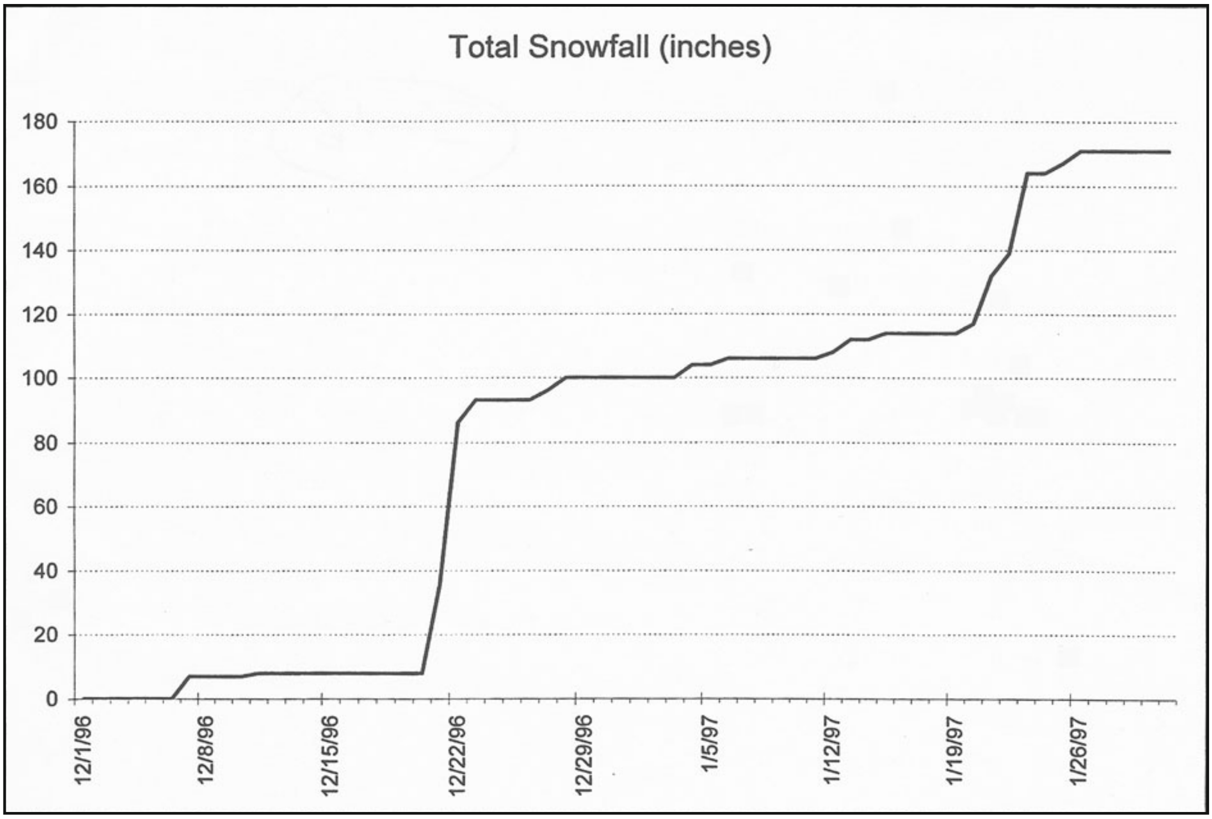

Fig. 3.16. The accumulated snowfall for 1 December 1996 – 31 January 1997 at the Donner Memorial weather station in the Sierra Nevada Mountains.

How railroads tackled freezing rainstorms

One of the most serious long-term problems facing the nation's railroads has been freezing rain. Layers of ice build up on wires, rails, and railroad cars and structures, causing excessive damages. Before the advent of radios for train control, ice storms were super-devastating—they took out the power for signals, and worse, they took down the telegraph and telephone lines needed to sustain communications for train operations. The freezing-rain problem was so serious that the railroads decided to gather systematic data on ice storms so as to better plan operations and maintenance. Unfortunately, the U.S. Weather Bureau collected freezing rain occurrence data at only a few locations—two to three weather stations in most states—and these data did not indicate whether there had been damages. These data were insufficient to meet the needs of the railroads, and today are insufficient to measure the spatial aspects of ice storms in the nation.

Under the auspices of the Association of American Railroad (AAR), the railroads decided in 1927 to launch a major nationwide program to collect data on ice storms. Each station agent was asked to report when damaging ice occurred at his station. The reports consisted of the date of the storm and the radial thickness of the ice on low-lying telegraph wires. Because of the uniformity in wire sizes used, this presented a uniform basis for ice measurement. This is important because the amount of freezing rain accumulating depends on the size of the surface on which it falls.

The AAR organized this unique nationwide project to collect data on damaging freezing rain occurrences to permit better planning and design. All railroads cooperated in this massive data collection effort, and their station agents located in every U.S. community served as observers of freezing rain occurrences when ice occurred. When ice accumulated on local telegraph wires, stations agents reported the date and radial thickness of ice that had accumulated on the wires. The data collection began in the winter of 1928/29 and continued through the 1936/37 winter, a 9-year period. All data were sent to AAR. In the area east of the Rockies, most stations were 5 to 10 miles apart, providing a massively dense set of observers and ice measurements in the area where most freezing rain occurs in the United States.

The results of this great sampling effort represented by these data can be illustrated by comparing their counts of glaze reports with those of the Weather Bureau, as published in the *Monthly Weather Review*. For example, during the 1932–37 period, the Weather Bureau reported damaging glaze events on 113 dates, whereas the railroad sample had damaging glaze events recorded on 243 dates, more than twice as many.

These findings along with many others have provided information on ice storms heretofore unavailable. From a climatological standpoint, the data are priceless. The nation owes a huge debt of gratitude to the railroads for this unique data collection effort. Now, more than 65 years after they were collected, the railroad data serve as the most useful information available for defining the risks of ice-storm damages and for developing a true description of the climatology of icing in the United States.

Drier conditions prevailed during the period of 4–11 January, but then another series of storms began, lasting from 12 to 27 January. Extremely heavy snows fell during 22–26 January. Donner had 51 inches from 20 to 24 January (Fig. 3.16). Ice storms also occurred in parts of Oregon and Washington on 26 December, and on 16–17 and 26–27 January.

Flooding was rampant throughout January and into February. Rivers in central California, including the Sacramento and San Joaquin, reached all-time record peak flows. California reported that 9 persons lost their lives, 120,000 persons were evacuated, 25,000 homes were badly damaged, and losses totaled $1.6 billion (NCDC 1997; see pages 5, 22–24, 105–106, 133–135). The governor of Washington declared 19 counties as having emergency status, with 25 highways closed and 19 deaths attributed to the storms.

In addition to these West Coast storms, the northern High Plains also experienced very bad winter weather during the same period. Several Arctic storm systems swept south from Canada into Montana and the Dakotas, with six blizzards occurring between 17 December and 22 January. Temperatures fell to −40° at two different times during this stormy period.

This 5-week period of extremely bad weather over a large area of the United States produced massive problems and damages to the region's railroads. This mainly involved two of the rail giants, the BNSF and UP. As a result of the weather-induced disruptions to many of their main lines from Washington south into central California, both railroads frequently lost use of all of their lines. Since many rail lines in this region are built alongside valley walls or near water bodies, numerous line washouts occurred, and mud slides and rock slides also blocked lines (Fig. 3.17). Among the lines closed were the following:

- UP's Shasta Route between Sacramento and Klammath Falls had 25 mud slides and washouts: closed 2 weeks.
- UP's Feather River Canyon route west of Keddie, California, was washed out on 3 January and was closed until April 1997, once the line had been rebuilt: closed 4 months.
- BNSF's Seattle Subdivision along Puget Sound had 70 mud slides: closed 10 days.
- UP's main line along the Columbia River was hit by mud slides: closed 2 days; BNSF's parallel line was hit by three snowslides, each more than 100 feet long and 25 feet deep: closed 5 days.
- BNSF's Oregon trunk route and UP line were both blocked near Bend, Oregon, by six mud slides: closed 8 days.
- SP's San Joaquin Valley line was closed by flooding and washouts: closed 2 days.
- Donner Pass main line was closed by numerous slides and undercuts: closed 4 days.

Several Amtrak trains were halted. The Portland–Seattle trains were stopped for 5 days, and the two trains (Empire Builder and Pioneer) operating east of these two cities were stopped on 28 December and did not resume operations until late January. On 1 January, Amtrak suspended the Coast Starlight north of Oakland, which did not resume service until 17 January, and the California Zephyr west of Salt Lake City was suspended on 1 January (Ingles and Lustig 1997).

The early storms also caused a major stoppage of freight movement. For example, when the lines were reopened on 4 January, BNSF operated a backlog of 140 freights through Spokane.

The Feather River Canyon line was the hardest-hit main line. UP lost 100 miles of track to slides, stranding several locomotives and maintenance crews and their vehicles. Reconstruction of the Feather River Canyon line cost the UP $89 million (2005 dollars). The SP's former Modoc route, which had been scheduled for abandonment by UP, became an invaluable detour route for California–Oregon trains. The late December rainstorm closed the Shasta Route with 25 mud slides between Redding and Dunsmuir, California; 600 feet of the line were washed away in one locale. North of Sacramento, UP's East Valley line was closed on 1 January by a 300-ft washout south of

Fig. 3.17. One of the many washouts from the extensive snowmelt flooding in California in late December 1996.

Biggs, California. The Cal–P line between Oakland and Sacramento was closed by flooding at Martinez for 20 hours, and the local depot was also flooded. The UP line between Sacramento and Stockton had severe flood damage, closing the line for two days in early January.

The Donner Pass line was first closed by heavy snows and snow slides on 1 January, then reopened briefly on 2 January but was shut down again the next day when a bridge east of Reno was washed away. With the Feather River line closed, the UP worked rapidly to get the Donner Pass line reopened by 5 January. While it was closed, UP trains were detoured via Salt Lake City and on the Sunset and Golden State routes through New Mexico.

Another severe snowstorm hit northern California on 21–22 January (see Fig. 3.16), producing heavy snows in the Sierras. Amtrak's eastbound California Zephyr was trapped in a 6-ft snowdrift on Donner Pass. The train was freed after 14 hours and was able to continue on to Salt Lake City.

On 15 January, an intermodal train bound for Seattle was struck by a huge mud slide and rock slide near Edmonds, Washington. The slide was 200 feet long, 40 feet deep, and stretched 400 feet into Puget Sound. It carried 5 container cars into the water. On 17 January, a northbound UP train hit a mud slide north of Vancouver, Washington, closing the Seattle–Portland line again for 2 more days.

Short lines were hurt, too. The McCloud Railway in northern California had a major washout; the Northwestern Pacific had a tunnel collapse and yards flooded; and washouts on the California Western closed the line for two weeks.

Weather problems in the High Plains were also severe. In late December 1996, lines in the Dakotas experienced 30 broken rails and "pullaparts" from the severe cold. The blizzards of the northern plains often paralyzed traffic flow. BNSF dispatched all of its snowplows from locations in South Dakota, North Dakota, and Minnesota to try to clear its lines. On 30 December, an avalanche blocked the main between Havre and Whitefish, Montana, for 7 hours.

The Empire Builder was blocked on 28 December by a snowslide at Blacktail, Montana. A preceding freight train had hit this slide, trapping the crew in the cab. The Empire Builder sat all night unable to move. Two freight engines sent from Havre attached to the train's rear and towed the train back to Havre.

A blizzard on 10–11 January halted all BNSF train operations from eastern Montana, across the Dakotas, and into western Minnesota. Winds were 50 mph, temperatures fell to 50° below zero, and 10-ft snowdrifts were common. Three trains were buried in 30-ft drifts. The Empire Builder was stopped for three days at Minot, North Dakota. For the first time in several years, all the available rotary snowplows were put in use to free the lines.

Another blizzard struck on 15–16 January with 8 inches of new snow and 55 mph winds. All BNSF train operations were halted in South Dakota and eastern Montana for two days.

This massive series of bad storms and resulting railroad problems imparted two railroad lessons (Ingles and Lustig, *Trains* 1997). First is the importance of having alternate routes, sometimes considered redundant as a result of rail mergers. Second, because of their fixed plants, railroads are at a disadvantage in comparison with truckers and air shippers, who can detour more easily.

Identifying Cloud Types in Train Photographs

TRAIN PHOTOGRAPHY is a major hobby of most railroad enthusiasts. These photos occasionally capture beautiful cloud formations. Identifying the types of clouds seen and photographed can be interesting and informative. Meteorologists have identified and labeled different types of clouds in train photos, classifying them according to their form and their height, as in Figs. I.1–I.16.

Fig. I.1. The central Illinois sky has numerous "fair weather" cumulus clouds on a July day as a westbound BNSF intermodal train passes through a signal bridge. These cumulus are classified as "low clouds" and have no potential for vertical development and becoming showers.

Fig. I.2. Fair-weather cumulus clouds lie above the Rockies here at Como, Colorado, where a crossbuck and old wooden depot mark the abandoned line of the Colorado & Southern.

Fig. I.3. This picturesque scene at the Monticello Railroad Museum in Illinois shows a refurbished Wabash F-9 diesel and its tourist train beneath a sky of cumulus congestus clouds, capable of vertical development into showers or thunderstorms.

Clouds with their bases in the boundary layer, which is the atmosphere less than 2 miles above the surface, are low clouds. They are influenced by their proximity to the earth's surface. Solar heating of the surface can initiate convection, and rising columns of warm air cause cumulus clouds to form. Cumulus clouds are small, but some can develop further into cumulonimbus clouds, which extend vertically to several miles above the earth with portions above the freezing level in the atmosphere. Cumulonimbus clouds are associated with thunder, lightning, and showery rain.

Fig. I.4. A Dash8-40B and two other Santa Fe engines lead an eastbound freight around the curve at Holliday, Kansas, with nearby showers falling from a cumulus congestus cloud, and stratocumulus from spreading cumulus (to the right).

Fig. I.5. When cumulus clouds grow vertically several thousands of feet, they can become cumulonimbus clouds, or thunderstorms. Here the dark base of a developing cumulonimbus cloud is seen above an F40PH of an Amtrak train.

Other low cloud types include stratus and stratocumulus, both of which are horizontally extensive. Fog is a cloud at the surface, usually in the form of stratocumulus. Nimbostratus clouds are much thicker low clouds that precipitate rain or snow, depending on the season. They result from large-scale uplifting of moist air in frontal storms.

Fig. I.6. Two forms of low clouds are present, stratocumulus (layerlike) and small cumulus, as this Santa Fe train heads south out of Streator, Illinois, and over the Vermilion River.

Fig. I.7. Cumulus congestus clouds are present above the historic depot in North Conway, New Hampshire, as an FP9 of the Conway Scenic Railroad backs to the engine house.

Fig. I.8. The roll-like structure typical of certain stratocumulus clouds is evident at Blue Island, Illinois, as a westbound CSX train heads across the GTW junction.

Fig. I.9. Stratus clouds uniformly cover the sky above Puget Sound as a southbound train heads for Tacoma, Washington.

Clouds with bases 2–6 miles above the surface are termed “middle” clouds. Two types are formed: altocumulus, which has some vertical growth, and altostratus, which is flat, similar to stratus.

Clouds with bases 6 miles or higher are labeled “high” clouds. They are above the freezing level and consist of ice crystals, and as a group they are labeled “cirriform” clouds. There are three types: cirrus, cirrostratus, and cirrocumulus. They can result from uplift from large-scale storms or from horizontal clouds sheared off the tops of cumulonimbus.

Fig. I.10. Altocumulus (middle level) clouds, cover the sky in southern Wisconsin as this southbound Wisconsin Central train behind two SD45s heads toward Chicago.

Fig. I.11. Well-defined rows of altocumulus clouds cover the Oregon sky as a BN train passes.

Fig. I.12. A sky covered with altostratus clouds provides a gray background with a few cumulus clouds also present above an eastbound Conrail freight in Indiana.

Fig. I.13. Cirrus are defined as high clouds. This form is labeled cirrus strips, which are here outlined by a blue summer sky. Two IC freights, IO2 left and CHMA right, are meeting.

Clouds are important to the climate and influence daily weather conditions. They shield the surface in daytime, leading to cooling, and at night they retard outward radiation and warm the surface.

Several cloud types also have species and varieties depending on shapes, structure, and amount of transparency. For example, a stratocumulus cloud can have a ragged and irregular appearance. Frequently the visible sky has more than one of the 10 cloud types present. For example, a sky with small cumulus present may also have a layer of high cirrus clouds.

A few railroad–cloud photographs have been included to illustrate the 10 cloud types. In some instances, a mix of 2 or 3 cloud types appear in a single photograph.

Fig. I.14. Cirrus filaments are another form of high-cloud cirrus, as seen here above the westbound "California Zephyr" as it enters Sparks, Nevada.

Fig. I.15. Cirrus castellanus is a form of cirrus cloud that is often indicative of instability in the atmosphere and stormy conditions several hours in the future. A westbound Santa Fe freight is crossing the long steel trestle at Media, Illinois, beneath the cirrus castellanus in April 1996.

Fig. I.16. Cirrostratus clouds typically cover the sky with a thin layer and have a transparency, as illustrated by the Texas sky above this westbound UP freight on 10 January 1997.

CHAPTER

4

Effects of Various Weather Conditions

Fog

In some ways, fog may be less troublesome now than in yesteryear when train movements relied on seeing signals. Today, with radios and Centralized Traffic Control (CTC), fogs are a lesser problem. However, it is still important to see signals, and fog still reduces visibility of objects immediately ahead, be it another train, a red signal, or a vehicle on a crossing. Switching is made more difficult and time-consuming because the engineer cannot see the cars being joined. Figure 4.1 shows the nation's average frequency of days with heavy fog, defined when the visibility is less than 1/4 mile. The pattern illustrates low fog incidences in the drier climates of the southwest with fewer than 5 fog days a year. Heavy fogs occur on 25 days or more along the coasts and in the higher elevations of the Northwest and Appalachian Mountains. Figures 4.2–4.5 illustrate the fog problems affecting train operations.

An example of a serious fog problem occurred on 31 December 1983. A BN freight train moving at only 5 mph through a thick fog near Portland, Oregon, ran past obscured red signals, through a damaged derail device, and onto an open drawbridge over the Willamette River. The lead engine (a GP39) plunged into the river, drowning two crewmen. A case illustrating crossing problems with fog present occurred when the southbound

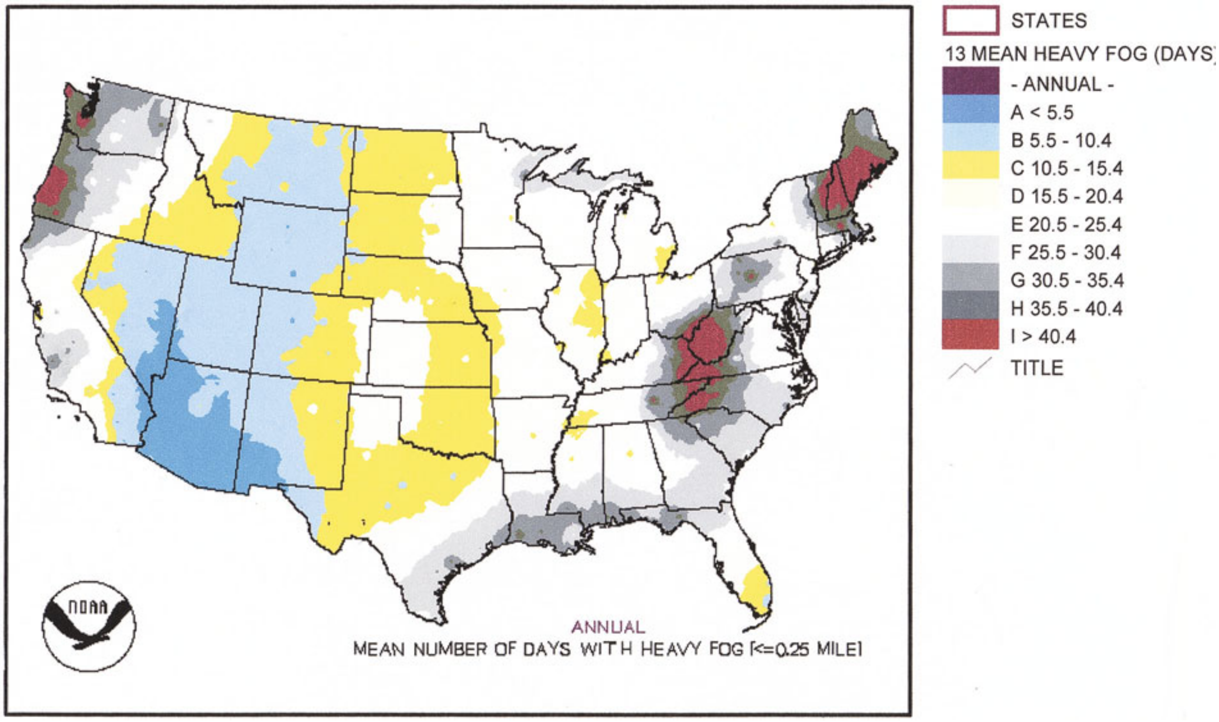

Fig. 4.1. Pattern based on the average annual number of days with heavy fog (visibility less than 0.25 mile) (National Climatic Data Center).

Fig. 4.2. Amtrak's northbound "City of New Orleans" arrives at the Kankakee, Illinois, station on a foggy February morning.

Fig. 4.3. A NS GP38 locomotive eases by a signal in thick fog in Indiana.

Fig. 4.4. Two NS trains move slowly as they meet in a dense winter fog in central Illinois.

Fig. 4.5. IC’s fast-moving northbound train #I01 appears in the very dense morning fog in southern Illinois.

San Joaquin hit a truck on a road crossing at 9 a.m. (local time) near Stockton, California, in December 1979. Heavy fog in the area obscured the crossing and the flashers from the truck, and the F40 engine and five cars were all derailed (*Trains*, March 1980).

High and Low Temperature Extremes

Temperatures extremes—those times when temperatures are either higher than 90° F or lower than 32° F—can cause a variety of problems, but they are not considered major factors that seriously delay rail operations. The problems are usually resolved in a short period of time, and most temperature-related problems do not occur on main lines. However, temperature extremes have detrimental effects on workmen who must function outdoors (Fig. 4.6).

The national pattern of days when temperatures exceed 90°F (Fig. 4.7) reveals only 5 days a year on average in northern parts of Minnesota, Wisconsin, and Maine, but more than 150 such hot days annually in the deserts of southern California and Arizona. The sharp elevation differences in the western mountains result in sharp spatial differences on hot days. The average annual number of days when temperatures fall below freezing (Fig. 4.8) shows a north–south gradient across the eastern two-thirds of the nation, from fewer than 5 cold days along the Gulf Coast to more than 150 cold days in the northern sections. Again, the pattern in the western mountains reveals sharp spatial differences due to the wide elevation differences.

Fig. 4.6. A CSX crew is heavily bundled to try to stay warm as they switch a train in the snow-covered rail yards.

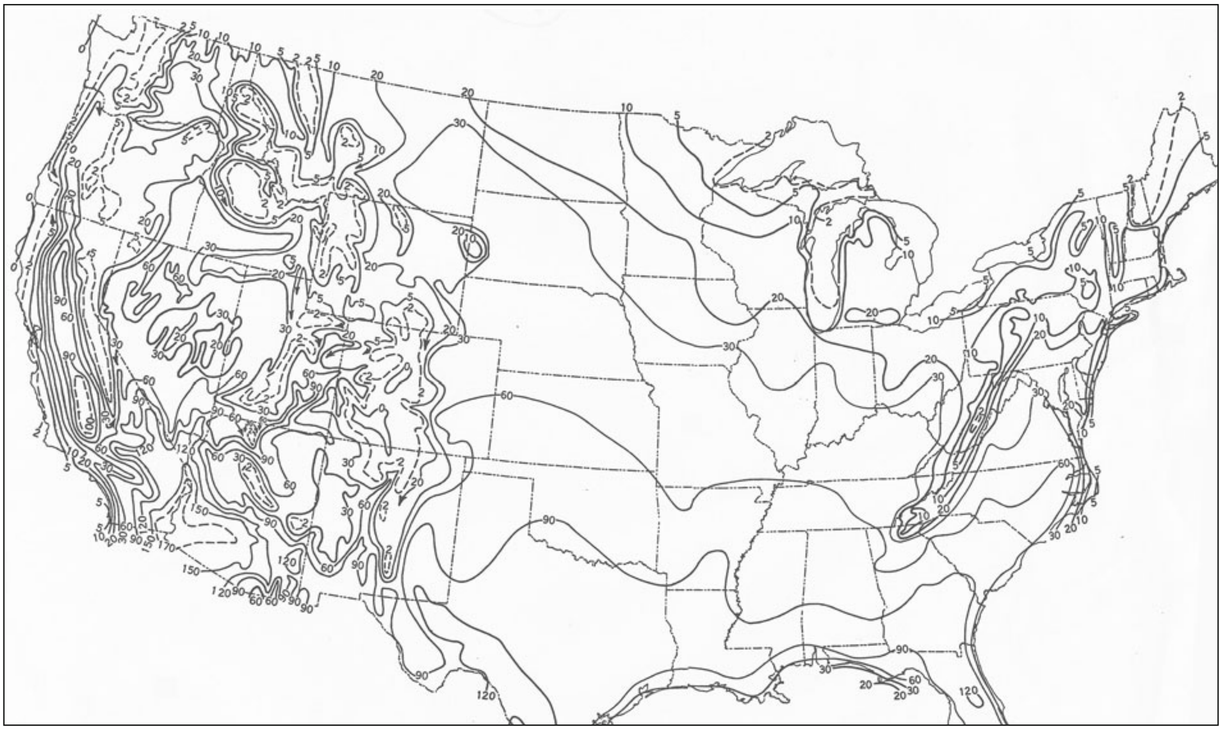

Fig. 4.7. Pattern based on the average annual number of days with temperatures of 90°F or higher (National Climatic Data Center).

Fig. 4.8. Pattern based on the average annual number of days with temperatures of 32°F or lower (National Climatic Data Center).

When temperatures fall below freezing and particularly below 0°F, rails in switches often freeze together. Frozen switches plagued railroads for years, but by 1950 switch heaters had been developed, and today most main line switches have heaters. Yet many switches, including those in most rail yards, have no heaters and are susceptible to being frozen at low temperatures, particularly when accompanied by snow, ice, or rain (Fig. 4.11). Cold

Fig. 4.9. Two Dash8-40Cs of the C&NW move their train west through the heavy haze and heat (96°F) of a July day. A still-standing abandoned coal tower is barely visible.

Fig. 4.10. A grain train wrecked due to a rail broken by severe cold conditions.

temperatures can also lead to breakage of rails, rail joints and bolts, couplers, wires, wheels, and brake lines (Fig. 4.12). Frost heaving can cause roadbeds to be disrupted. Pressure systems for air brakes do not work as well, since low temperatures reduce the rate that air passes through several cars. This leads to use of shorter trains—an expensive outcome. Cold can also prevent diesel engines from starting, and extreme cold has sometimes caused outages on CTC systems.

Years ago, several car ferries crossed Lake Michigan, hauling rail cars between Michigan and Wisconsin. In cold winters, however, the lake

Fig. 4.11. A workman uses a pick to dig the snow and ice from a frozen switch.

Fig. 4.12. A broken rail from the severe cold on the Shasta Line of the SP in the mountains of northern California caused this major wreck of the "Cascade."

freezes for 2–4 months, forcing the railroads to move cars on trains around the lake's south end and through Chicago, a much more expensive and time-consuming alternative than use of the car ferries.

High temperatures are most notable for causing sun kinks in rails, creating delays or derailments. Proper installation of continuous welded rail usually keeps kinks from occurring, but heat-related sun kinks can be serious when they do happen. For example, on 5 August 1988, Amtrak's westbound Empire Builder, moving at 79 mph, hit a sun-kinked rail near Saco, Montana, where the temperature was 100°F. The two Amtrak engines did not derail but the train's 12 passenger cars did, and 149 passengers suffered minor injuries (*Trains*, June 1989). As shown in Fig. 4.7, this occurred in an area where hot days are not frequent.

Temperatures that are unusually high or low for conditions during a given season can also cause problems. For example, on 7 March 1987, a stretch of track on Boston & Maine's line in northeastern New York state shifted, forming a large kink, a result of sudden abnormally warm spring temperatures of 63°F in early March. Such a value in summer would not have caused a problem.

Heavy Rains and Floods

Rainfall at any level causes minor problems, such as reduced traction and slippage with wheels on wet rails. Figure 4.13 depicts the average number of days with rain across the nation. East of the Mississippi River, the frequency exceeds 90 days, reaching frequencies above 150 days in the Appalachian Mountains from North Carolina north to Maine. Rain falls on fewer than 30 days annually in the deserts of southern California, Nevada, and Arizona. Rain also reduces visibility, making train operations more difficult and dangerous (Figs. 4.14 and 4.15).

Heavy rains falling in a few hours over a small basin cause flash floods. If moderate to heavy rains persist for a period of several days or weeks, they can create massive large-scale flooding, as in the summer of 1993 and in the winter of 1996/97 (see Chapter 3). Floods also come from rapid melting of heavy snow cover and from hurricanes.

In all instances, flooding creates major problems. Some of the most costly problems for railroads are floods, and thus forecasting these events is of utmost importance to rail operators. Flood problems include washouts of roadbeds, erosion of bridge foundations with an occasional loss of bridges, water over the tracks (including debris and wreckage accumulated on tracks), and deposits of silty mud in and on tracks, yards, and buildings (Fig. 4.16). Flooding can also uproot trees and cause trees to fall across roadbeds, blocking trains. Floods can halt all rail traffic in affected areas anywhere from a few hours up to days or even weeks. Rains and floods cause 21% of all weather-related train accidents.

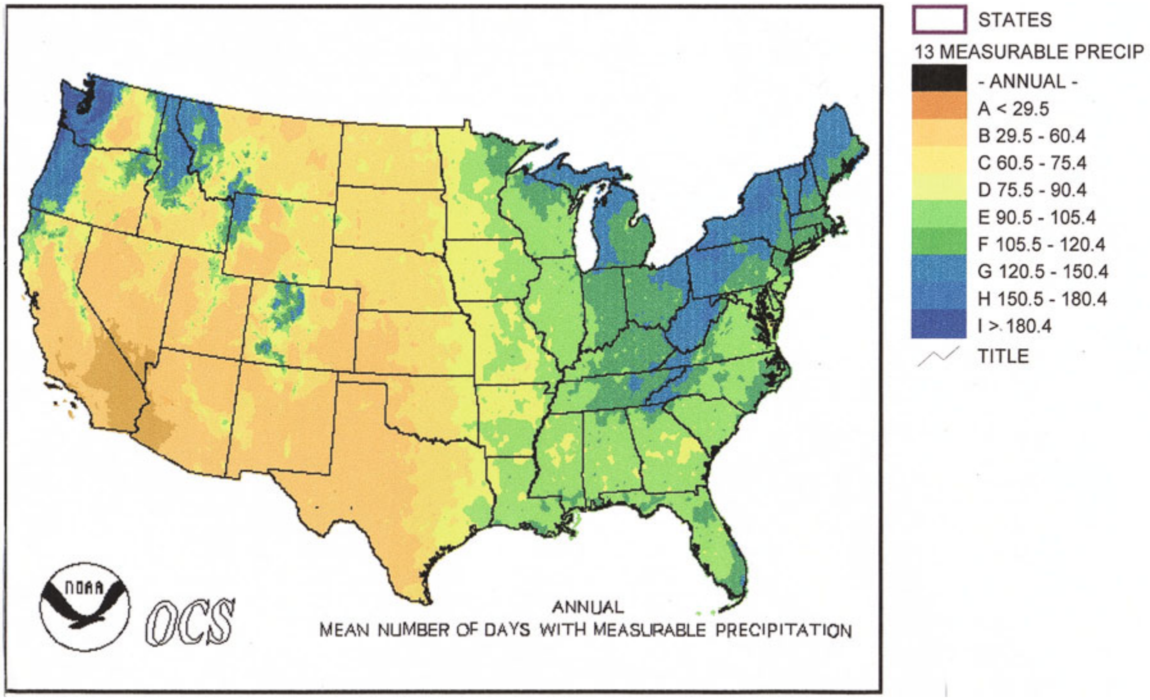

Fig. 4.13. National pattern based on the average annual number of days with precipitation of 0.01 inch or more (National Climatic Data Center).

Fig. 4.14. A westbound Conrail freight is seen moving through a heavy spring rain as it passes a series of grain elevators.

Fig. 4.15. A southbound IC freight on the left meets a northbound TOFC near Chicago in a driving, all-day December rain.

Fig. 4.16. A wrecked IC passenger train in Mississippi, resulting from a saturated roadbed that collapsed during the record 1937 flood. Note the high waters to the right of the roadbed.

Hurricane Juan in early November 1985 produced 8- to 10-inch rainfalls in parts of Maryland, West Virginia, and western Virginia, badly damaging the Baltimore & Ohio (B&O) and Chessie System. The B&O main was flooded for 100 miles along the Potomac River, and 30 diesel engines were badly damaged from floodwaters. The flooding along a river caused a slope beneath the B&O main to erode, and the earth slid downward. A passing B&O train was wrecked and the two engines tumbled 425 feet into the river, killing the crew.

Another problem that heavy precipitation creates is mud and rock slides in mountainous terrain (Fig. 4.17). Rain helps loosen soil and rock on slopes above rail lines and becomes the lubricant for the soil and rocks to descend, blocking rail lines, as occurred repeatedly on the West Coast during the winter of 1996/97 (see Chapter 3). Some western railroads use wire detector systems installed along tracks to detect slides in areas where rock slides are apt to occur. Delays of trains are usually a matter of hours or a day to get the rock cleared and tracks repaired. Rains can also affect certain electrical systems and create shorts and power outages. Intense rainfall rates can lead to water leakage into rail cars, resulting in damage to materials being shipped.

Flooding and rail damages often occur in the Midwest and East Coast regions, but they also occur everywhere else in the nation. For example, a series of Pacific rainstorms rolled across central and northern California during a 10-day period in February 1986, resulting in massive flooding (Ingles 1986). All SP and UP lines in the northern two-thirds of California were closed from 3 to 14 days. Hundreds of washouts occurred, along with

Fig. 4.17. A flash flood on a mountain stream in Montana washed out mainline tracks, resulting in the badly bent rails on the NP, causing the three locomotives leading a freight train west to derail and fall down this embankment.

numerous sink holes and many mud slides. Eight bridges were washed out, and four trains were trapped in the Feather River Canyon for seven days. The trains in the canyon were trapped by 14 major rock slides, high water, and 10 washouts (Walker 1991). Repairs cost the UP $15.7 million (2005 dollars) and took three months to complete. All Amtrak passenger trains were stopped for a week in the large area defined as being south of Portland, Oregon, west of Salt Lake City, and north of Los Angeles. The Northwest Pacific Railroad, a subsidiary of SP, had 63 washouts in 110 miles of its main line, and the line was not reopened until late April. Fortunately, there were no major accidents in California.

Review of the railroad literature reveals that train wrecks resulting from an unknown washout in front of an unsuspecting train occur at least once a year. Washouts caused 18 train accidents during 1993–2002 (Rossetti 2003). An example of this problem occurred at 6:30 a.m. on 29 May 1984, when the B&O's westbound Capitol Limited hit an unknown washout that had occurred during the preceding 2 hours. This led to the wreck of the train's two engines in Pennsylvania.

Heavy Snowfall and Blizzards

Heavy snowfall ranks high as one of the major problems for railroads, particularly those in the northern two-thirds of the nation. The average annual snowfall pattern for the nation (Fig. 4.18) shows major areas of greater than

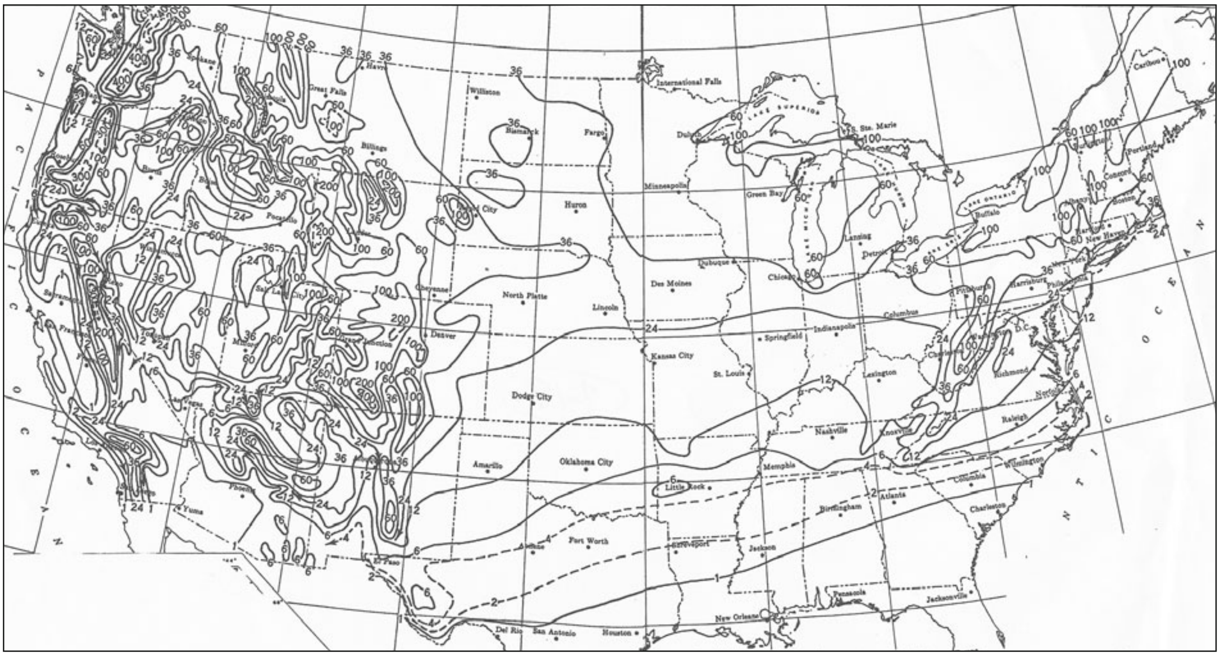

Fig. 4.18. The national pattern based on the average annual snowfall (in inches) (National Climatic Data Center).

200 inches in various western mountains. East of the Rockies, a latitudinal, north–south distribution exists with averages of less than 1 inch along the Gulf Coast, and more than 36 inches in the northern Midwest and East Coast. Snowfall is particularly heavy in the lee of the Great Lakes. Extremes of wind, low temperature, and drifting of snow are often found in the Dakotas, Minnesota, Montana, and Wyoming. Extremes of snowfall, snow slides, and drifting are major problems in the central and northern reaches of the Appalachians, Rockies, and West Coast ranges.

Like heavy rain, snowfall obstructs visibility, often seriously. Snow can stick to the lens on signals, obscuring the signal lights. Meteorologists classify snow as heavy when it causes the visibility to be less than 5/16 of a mile (Glickman 2000). Snow accumulates on rails and can reduce traction, making train movement more costly, and sometimes requiring additional engines. It also can freeze to the rails and flangeways such as those at road crossings, switch frogs, and station platforms, and cause trains to derail. The average annual number of days with snowfall exceeding 1 inch (Fig. 4.19) shows the Midwest having 2–10 snow days per year, with 20–30 days in the northern parts of Montana, North Dakota, Minnesota, Wisconsin, and Michigan. Heavy snow days exceed 60 per year in the Rockies from Montana and Idaho south through Wyoming, Utah, and Colorado.

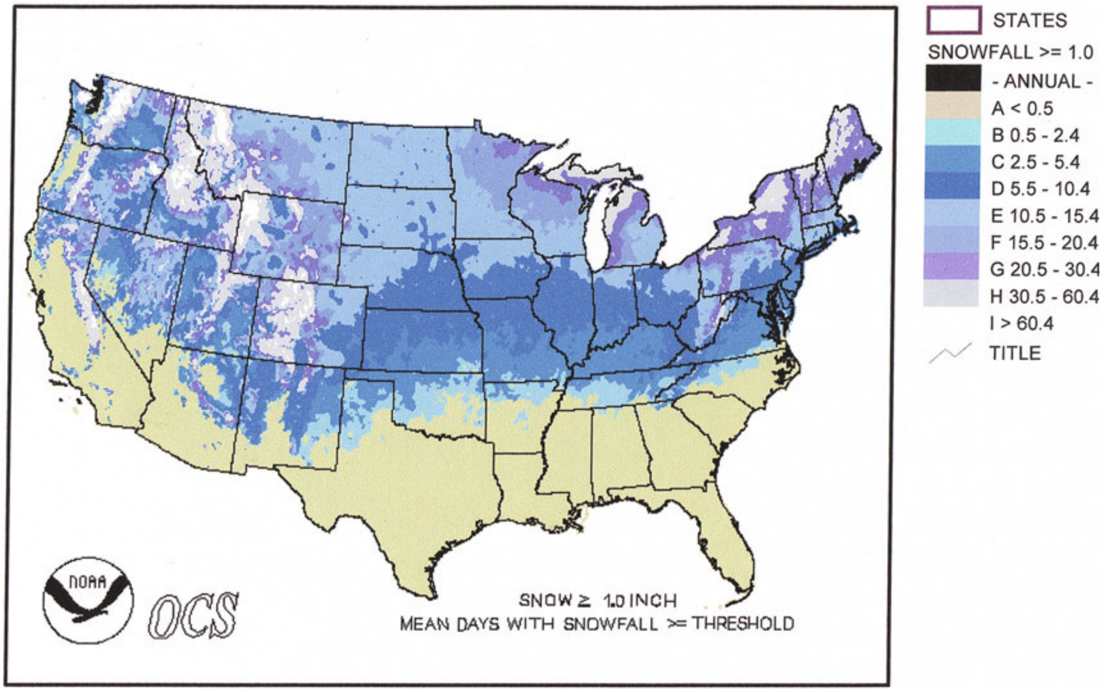

Fig. 4.19. The national pattern based on the average annual number of days with 1 inch or more snowfall (National Climatic Data Center).

Trains Trapped by Heavy Snows

The *National Summary of Climatological Data* for January 1957 (U.S. Weather Bureau 1957) included this description of an event that beset the Denver, Rio Grande & Western lines beginning on 25 January 1957:

"Three trains, including a freight, a rescue train, and a work train, were stalled by heavy snow of record proportions on and near Cumbres Pass, near the Colorado–New Mexico border, isolating about 60 members of the train crews from the 26th through 31st. The first train became stalled by very heavy snow which had begun on the 25th, and the rescue train and work train attempting to reach first train were blocked by avalanches. Continuing heavy snow and high winds through the end of the month created severe, ground-blizzard conditions, hampering efforts to reach the isolated men by Army snow weasels* and helicopters."

* A snow weasel is a tanklike vehicle that can be used to cross deep snow and drifts.

When snowfall is accompanied by high winds (greater than 32 mph) and low temperatures, it is classified as a blizzard. The blowing snow typically reduces visibility to less than 500 feet and often to 0 (Fig. 4.20). Damage to rails and switches results. Switches become frozen and cannot be turned, and rails can split. Another hazard in mountainous terrain is ice slides, which occur when layers of ice that have accumulated on slopes above rail lines break loose, fall, and block the lines (Fig. 4.21).

Fig. 4.20. A fast-moving eastbound BN train, led by a Dash8-39B LMX on lease from GE, crosses a junction amidst a heavy snowstorm.

A series of blizzards in January 1949 did huge damage to certain western railroads. Winds reaching 70 mph formed drifts of up to 35 feet in height that were as solid as concrete (Hay 1957). Rotary snowplows could tunnel into the drifts, but the overburden of snow and ice had to be dislodged by blasting. Many lines that were cleared became blocked again. On the Rock Island's main line in eastern Colorado, 20-ft-high drifts put the line out of service for 36 hours, and 35-ft-high drifts on the Chicago, Burlington & Quincy's (CB&Q) line south from Billings, Montana, to Alliance, Nebraska, ended service on that line for 8 days. The Union Pacific had to hold all its trains at Cheyenne for 4 days until a detour could be opened. The California Zephyr was stalled in the High Sierras for 4 days, causing great discomfort to its passengers, and the Empire Builder was halted by deep snows in Montana (Fig. 4.22).

Fig. 4.21. A view of the deep snow cover in the High Sierras, as an SP train waits on a siding before a tunnel.

Fig. 4.22. Blizzards have closed the Great Northern's mainline in Montana, and passengers taken from the Empire Builder are transferring to buses to be taken to Havre to await the line's clearance.

The accumulation of snow on railways with frequent high drifts leads to train stoppages, or at best, a slowing of trains. This requires removal of the snow and acquisition of specialized equipment like snowplows to remove snow. In past years, deep snow on tracks was removed either by wedge-shaped snowplows pushed by several engines (which often got stuck in deep drifts), or by crews of diggers, essentially men with shovels. A rotary-style snowplow was first developed in 1869, but became perfected by 1884, and was thereafter widely used by railroads in the north like the Northern Pacific and Great Northern.

Even under severe conditions, a well-organized railroad of the 1990s could continue operating with only minimal delays for each train (Fig. 4.23). Railroads accustomed to bad snow conditions usually experience few delays. However, very severe conditions and repeated storms can tie up any railroad for 12–96 hours and branch lines for 1–10 weeks (Fig. 4.24). The worst storm conditions occur when a blizzard is followed by a quick hard thaw, then followed by another blizzard (Fig. 4.25).

Snow removal activities incur major additional costs to operations during a snowy winter. Rail yards filled with snow become a problem because of the multiplicity of switches and crossings, and most yard switches do not have heaters. There is a constant need for snow clearance and switch thawing to maintain use of rail yards in the northern reaches of the United States.

Snowfalls considered light in one area can be a problem in areas not accustomed to a few inches of snow. For example, an unusual half-inch of snow along Florida's east coast in December 1989 brought most local train operations on CSX, NS, and Florida East Coast Railroad (FEC) to a standstill (*Trains*, 1990). This was the heaviest snow in that area since 1899.

Fig. 4.23. A hustling northbound "City of New Orleans" passes a waiting TOFC amidst a blizzard with the thermometer at 14°F, high winds, and heavy blowing snow.

Fig. 4.24. An IC grain train struggles south with snow from penetrating drifts plastered across its front. A wrecker waits on the right to address a snow derailing on a branch line a few miles away.

Fig. 4.25. Two UP trains meet during a heavy snow in Nebraska. A westbound merchandise freight is meeting an eastbound behind SP locomotives, and a decrease in visibility is quite evident.

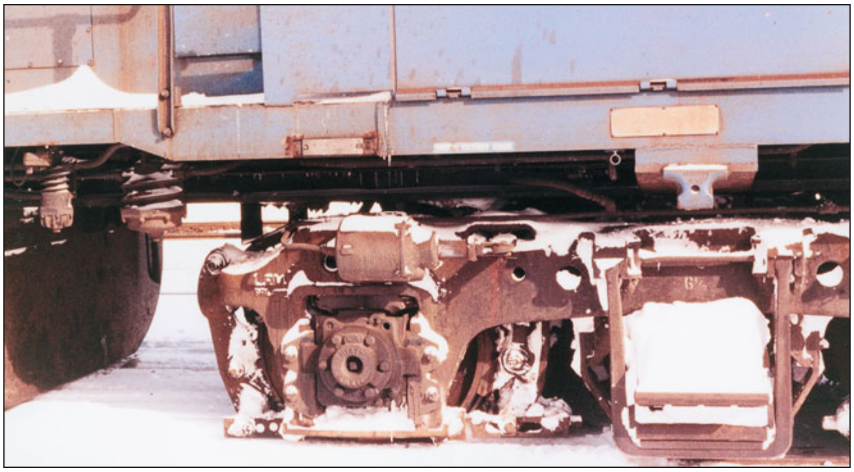

Fig. 4.26. An example of how snow gets packed and frozen around wheels and brakes, affecting traction and braking.

A sampling of railroads operating in the Missouri–Kansas area during the winter of 1955/56 identified the following types of delays and average times to their regularly scheduled trains (Hay 1957). Operations through heavy, drifting snow produced average delays of 7 hours; following slow-moving snow plows produced delays of 3 hours; a need to reduce tonnage of a train (fewer cars) caused 5-hour delays; problems with snow in switches led to 2-hour delays; and problems with moisture in diesel engines from blowing snow led to 1-hour delays (Fig. 4.26).

Ice Storms

Like snowfall, freezing rain produces serious traction problems, often requiring additional engines for trains. Accumulated ice on rails has also led to derailments. Ice storms occur in most parts of the country, but as shown in Fig. 4.27, they are most frequent in the Northeast, Midwest, and Northwest (Changnon 2003b). Ice storms are infrequent west of the High Plains, and some parts of the southwestern United States and Florida do not experience this weather event.

Freezing rain accumulates on all structures and is particularly damaging to wires (Fig. 4.28). The advent of radio communication without dependence on telegraphy and telephones reduced some of the serious problems ice

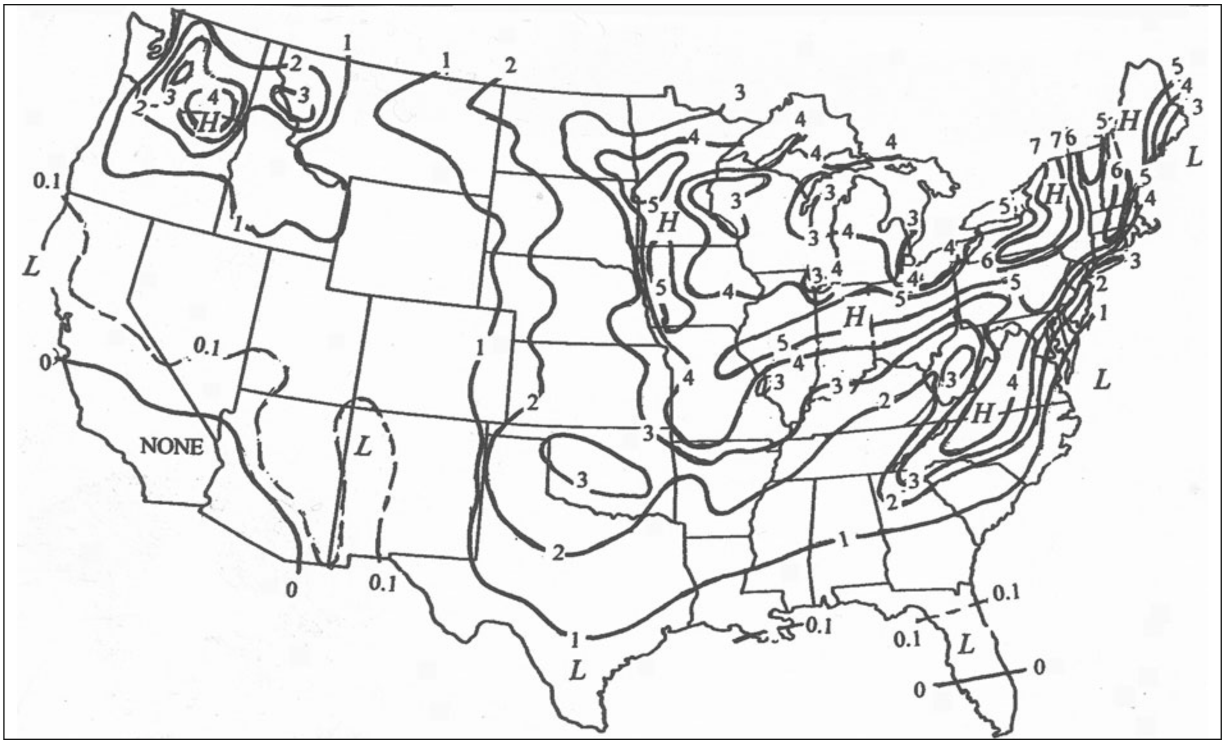

Fig. 4.27. The national pattern based on the average annual number of days with freezing rain (Changnon 2003b).

storms once posed for railroad communications (see sidebar on freezing rain, page 49). However, ice layers still break many railroad-related power lines, causing problems for signaling and operation of other electrical equipment used by today's railroads. Ice accumulates on trees, and broken branches and fallen trees also break wires or block right-of-ways. Ice also accumulates on rail cars, adding train weight and making it to difficult to open car doors (Fig. 4.29). Icing conditions are also very dangerous for train crews and yard workers. Another problem in mountainous terrain relates to ice slides, caused when layers of ice on slopes above a rail line fall and block the line.

Fig. 4.28. A southbound IC freight approaches a guard rail of an overpass that is covered with ice from a freezing rainstorm that was followed by a 6-inch snowfall, further complicating train movements.

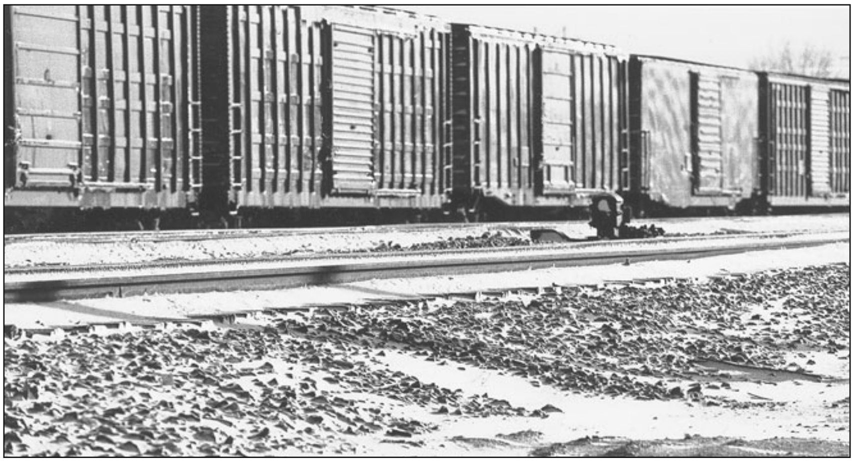

Fig. 4.29. A row of NYC box cars covered with ice from a freezing rainstorm sit in the Rochester, New York, yards. The ice adds considerable weight, reducing efficiency and increasing operational costs.

Winds, Hurricanes, Tornadoes, Lightning, and Dust Storms

Wind by itself is not generally considered a serious problem in railroading. However, high winds associated with hurricanes or tornadoes can cause loss of life and rail property. Wind has a major impact on train operations, since trains often are not able to make scheduled speed without additional locomotives in high-wind situations. When moderate to high winds are associated with heavy snowfall, strong rainfall, ice storms, or dust/sand storms, the combined problems become larger. Hurricane-related problems are largely restricted to coastal areas. Tornadoes occur anywhere in the nation but are most common in the High Plains and Midwest. Blizzards occur in the northern sections of the nation. Winds can also cause discomfort and inconvenience for railroad workers.

A principal problem caused by high wind speeds, with or without storms, is damage to structures. Exceptionally high winds, those exceeding 55 mph and blowing at right angles to a train or a row of parked cars, can blow them off the track. High winds can blow trees down and across rail lines. Studies of wind damages and associated wind speeds are summarized in Table 4.1, revealing a range of problems for speeds of 8 mph and higher. Mildly heavy winds create a nominal delaying effect through drifting snow or sand, retarding train movements. High winds accompanying heavy snowfall create blizzards and the many problems associated with them, as do moderate to high winds with ice storms. Figure 4.30 shows the annual average number of days when wind gusts exceed 50 mph. These gusts occur most frequently in the eastern Rockies and western High Plains, averaging 5 or more occurrences per year. Other locales such as Florida, southern California, and Louisiana have very few strong gusts, averaging 1 or fewer a year. Thunderstorms often cause high damaging winds, created by strong downdrafts produced by the storms' descending rain shafts (Fig. 4.31).

Table 4.1. How varying wind speeds affect railroads.

Wind speed (mph)	Effects on railroads
8–18	Weed spraying halted because of wind drift; burning of right-of-ways cannot be done; snow and sand drift.
19–31	Equipment needed to remove drifting snow and sand; visibility reduced by dust and smoke; retarding of trains.
32–46	Bridge erection stopped; workmen have difficulty walking; dust storms occur; wave action scours bridge embankments; trees and branches break, disrupting train operations.
47–63	Dust and snowstorms reduce visibility to zero; snow drifts faster than it can be plowed; trees are uprooted; frame structures apt to be damaged; outdoor work halted.
64 and higher	Decks blown off trestles; debris blown onto tracks; cars and locomotives can be blown from tracks; widespread structural damages.

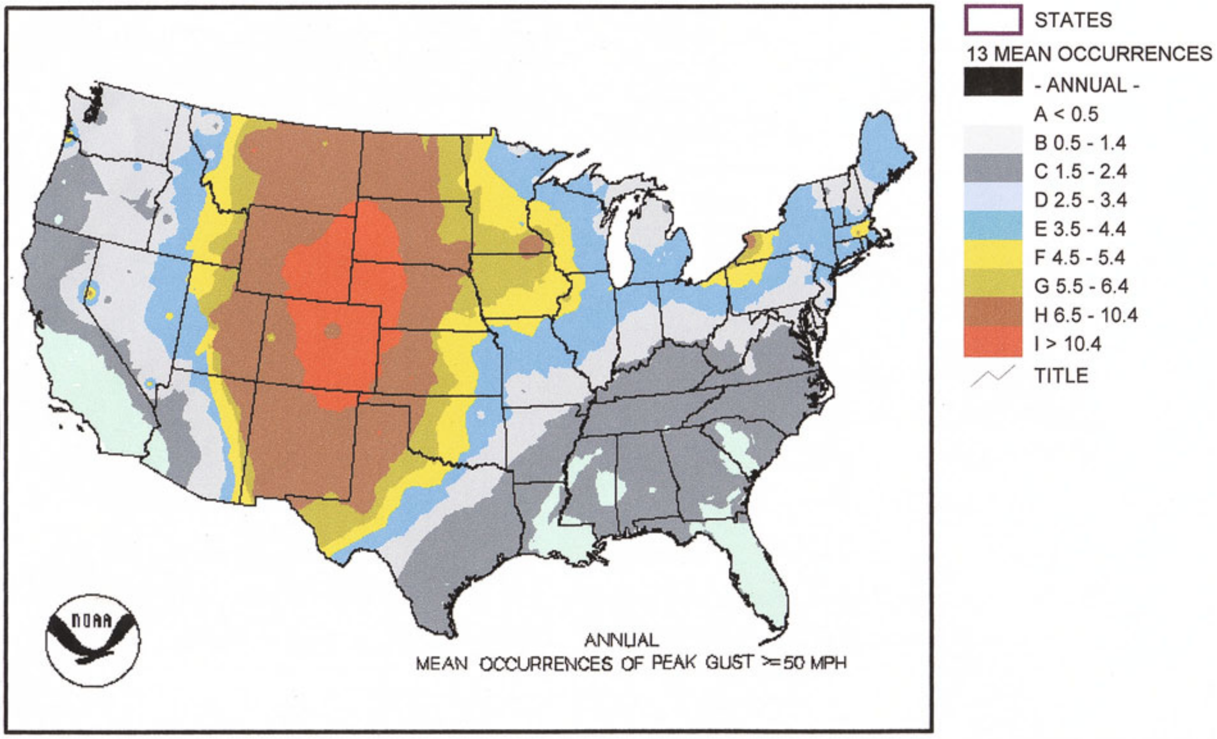

Fig. 4.30. The national pattern based on the average number of days when peak wind gusts are 50 mph or higher (National Climatic Data Center).

Fig. 4.31. A thunderstorm is developing overhead causing a sharp downdraft and high gusts as two Amtrak trains meet on a summer afternoon in Lincoln, Illinois. On the left is the waiting "Loop," and on the right is the northbound "Texas Eagle," both operating on the SP line between Chicago and St. Louis.

The exceptionally high winds of tornadoes, with speeds in excess of 100 mph, have been noted to actually move tracks and get rails out of alignment. Signals have been blown over also, and tornadic winds destroy most railroad structures. A Rio Grande unit coal train was returning from a power plant in Indiana and operating on an UP line in Kansas on 31 May 1990 when a tornado in Bushton, Kansas, blew 88 of the 105 empty coal cars off the track (*Trains*, March 1990).The dangers of tornadoes, which can occur in all parts of the nation, have been somewhat alleviated by the use of commercial weather forecasters hired by the railroads to give them warnings of areas of tornado occurrence along their right-of-way. In these instances, trains are halted outside the warning area.

Hurricanes also produce high winds, particularly when they reach land. Hurricane Hugo on 21–22 September 1989, with winds of 125 mph at landfall, did sizable damage to rail buildings and structures in North and South Carolina (Wrinn 1989). In Charleston, 26 Trailer-on-Flat-Car (TOFC) cars were blown over, and CSX's microwave communication system was taken out of operation for a week by downed towers. The area of high hurricane winds also affected many forests alongside the rail lines, downing thousands of trees, blocking the main lines of the NS and CSX, and cutting off power to signal systems. Hundreds of blades on crossing gates were also broken. Train operations on main lines were delayed from 2 to 5 days, and by more than week on various branch lines in the two states. This was a fast-moving hurricane, so the amount of rain at a given location was not large. Hence, no serious flooding developed.

Hurricane Andrew, the nation's most costly storm at the time it occurred (second now to Hurricane Katrina), ironically caused very little damage to railroads. This storm hit south Florida in August 1992. CSX reported $2 million in damages to signals, and the Gold Coast Railroad Museum was badly damaged (Keefe 1992). The railroads played a major role in poststorm restoration efforts. For example, CSX and its employees provided, at no cost, a train with 65 flat cars that brought trucks, bulldozers, and cranes donated by construction firms in the Carolinas. Danville, Illinois, donated five tank cars of drinking water to Homestead, Florida, which had lost its water plant.

The southeastern United States was devastated by a series of four hurricanes (Charley, Frances, Ivan, and Jeanne) and two tropical storms that occurred from early August to late September 2004. Four of the storms first hit Florida, and all moved north into Alabama, Georgia, the Carolinas, and Virginia, producing major damages everywhere. Each hurricane had high winds (130 mph or more), heavy rains (10 to 15 inches), and numerous tornadoes. The resulting damages to the CSX and NS lines in the southeast included mud slides, rock slides, and washouts on many miles of track. Several train wrecks resulted from trees on tracks and washouts. Floods covered main lines and rail yards; many railroad buildings were damaged from winds and floods; and signal systems were knocked out due to fallen tree damage and widespread power outages. Hundreds of trains were held or suspended, and some were detoured on undamaged lines to the north. At the peak of Hurricane Frances, the CSX had 151 trains tied down, and floods from Tropical Storm Gaston immersed 600 rail cars in the NS yards at Richmond, Virginia (*CTC Board*, 2004). Hurricane Katrina in 2005 was very damaging to New Orleans (see Chapter 5).

Lightning strikes can cause power outages and stop communication systems. A few years ago, the entire East Coast operation of CSX was halted for several hours when lightning hit a switching station in Jacksonville, Florida (Fig. 4.32).

Dust storms occur only in drier areas and at times when winds reach 47 mph or higher. The areas prone to dust storms include eastern Colorado, western Kansas, southwestern Nebraska, Oklahoma, the Texas panhandle, and parts of New Mexico. Dust storms are most prevalent in drought years. The blowing sand and dust choke switches; fill drainage ditches and cuts; obscure signals, often reducing visibility to 20–30 feet; and can block rail lines. Storms often lead to slow train movements and some derailments, and can require after-storm right-of-way maintenance. Costs to address dust/sand storm problems, when sampled in 1952, revealed the costs per mile to be $1,700 on the SP, $1,400 on the UP, and $700 on the Santa Fe (Hay 1957). If adjusted to 2005 dollars, these values would be $2,820, $2,325, and $1,163, respectively.

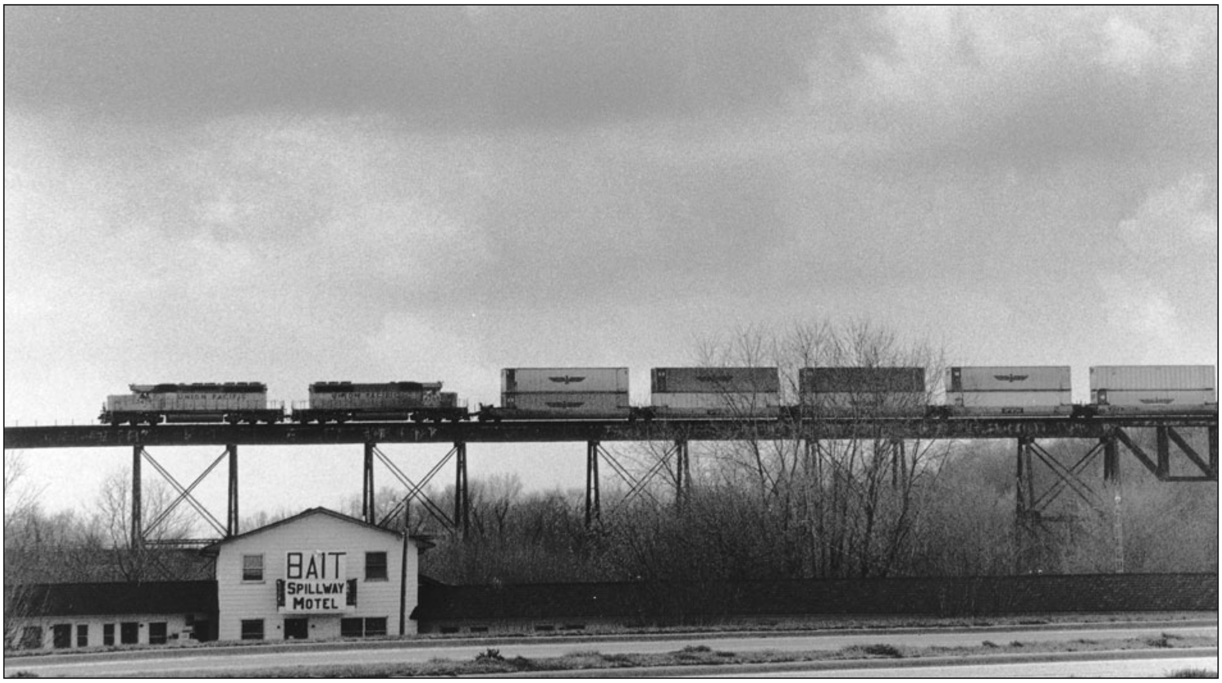

Fig. 4.32. Thunderstorms are developing as a southbound UP doublestack heads across a steel trestle in southern Missouri. Lightning struck the bridge a few minutes after the train passed.

Climate Aberrations

Climate aberrations, defined as multiyear periods when certain weather conditions become more extreme, also have certain effects on railroads. For example, major railroad problems occurred during the extremely cold and snowy regime that existed in much of the United States during 1976–80, the severe drought of 1987–89, and the ever increasing wet conditions during the 1980–86 period. The following text describes the impacts on railroads from different climate aberrations.

Droughts

Figure 4.33 displays the nation's extent of drought from 1950 to 1997. This is based on an annual index measuring severe drought, and shows that in the mid-1950s, 35%–40% of the nation was experiencing severe drought conditions. The occurrences of severe drought conditions over 10% or more of the nation include several major multiyear periods including the most recent, the 1987–90 drought.

Prolonged droughts in the grain-growing regions of the nation bring on a series of years with below-normal crop yields. This, in turn, reduces rail shipment of grain, resulting in lower-than-expected income by granger-type rail lines like the UP, BNSF, C&NW, and Soo. Smaller regional lines, like the once-famous Chicago & Great Western and the Minneapolis and St. Louis, can become seriously financially strapped by prolonged droughts. Droughts in the west also create conditions favorable for major forest fires.

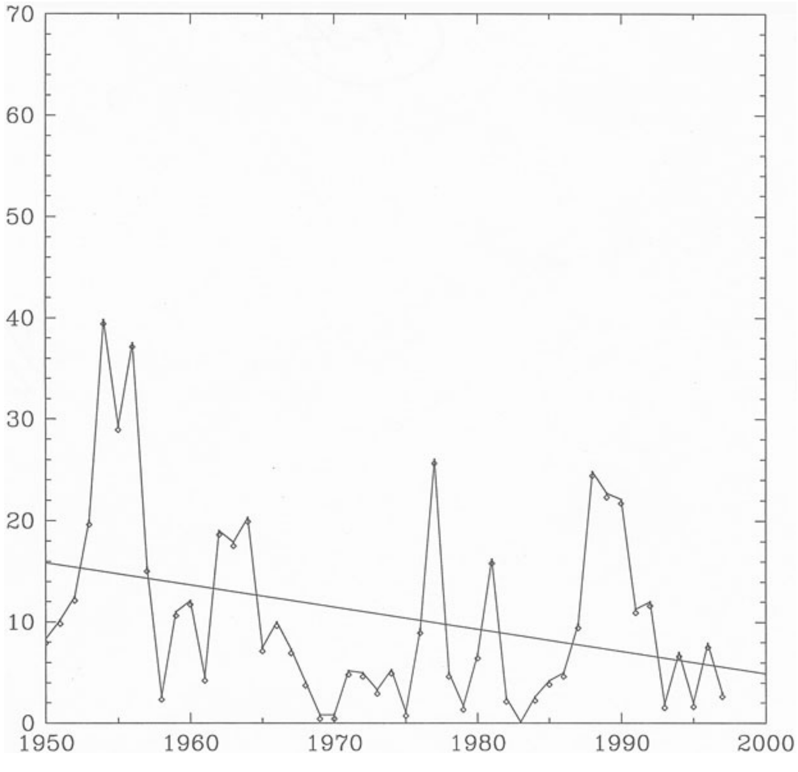

Fig. 4.33. A graph based on the annual value of severe drought extent, expressed as a percent of the nation, for the 1950–1997 period (National Climatic Data Center).

A near-record number of forest fires developed during the very dry summers of 2002 and 2003, spreading across large areas of California, Arizona, New Mexico, Utah, and Colorado. The fires produced enormous volumes of smoke that affected visibility on the BNSF and UP lines in the region. Some timber fires threatened rail lines. An interesting outcome is that thousands of burnt tree trunks in Arizona were later cut during 2003. These burnt logs were hauled west by rail on BNSF trains and by the Sierra Railroad to wood mills in California, providing added income to these railroads.

Railroads have also become helpers in droughts. For example, during a severe drought during 1986 in the deep South, which had resulted in a major shortage of hay, several railroads operated trains loaded with donated hay, mainly from New England, south to the drought area at no cost to the users of the hay. The rail crews also worked for no pay (*Trains*, November 1986).

Wet periods

Extended multiyear wet periods can also produce a variety of impacts, including enhanced flooding. Figure 4.34 presents the extent of unusually moist conditions across the nation for 1950–97. It shows several multiyear periods such as 1971–75, 1982–85, and 1991–93 when more than 20% of the nation had surplus moisture conditions.

An interesting outcome of too much precipitation and overly moist conditions relates to the Southern Pacific and the Great Salt Lake. From 1901 to 1903, the SP, seeking to shorten and improve its Overland Route between San Francisco and Salt Lake City, built a long causeway across the Great Salt

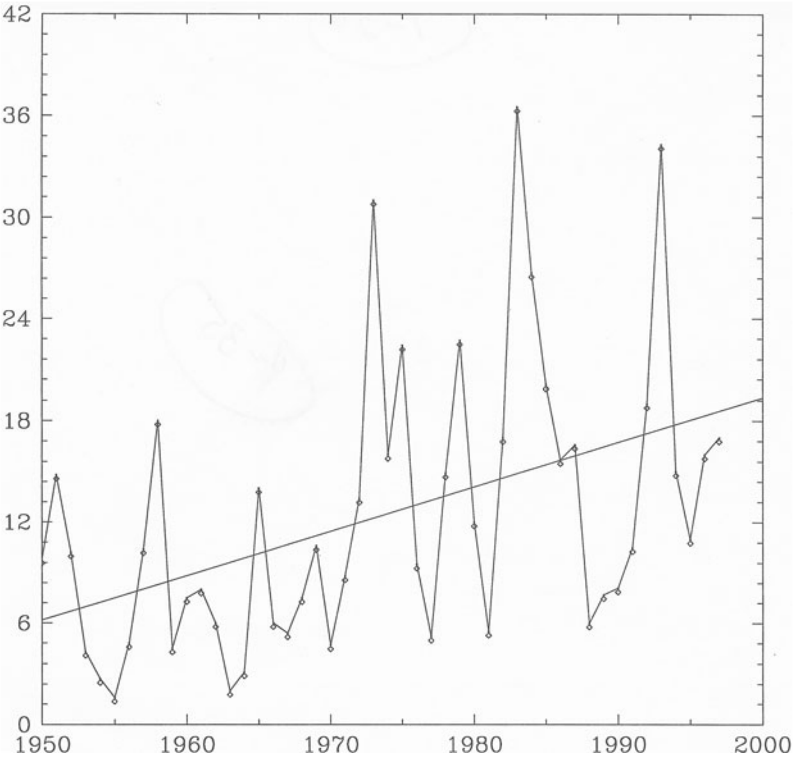

Fig. 4.34. A graph based on the annual value of severe moisture surplus, expressed as a percent of the nation, for the 1950–1997 period (National Climatic Data Center).

Lake. This enormous undertaking cost $76.3 million (2005 dollars) and involved construction of a 12-mile permanent timber trestle bridge and a 26-mile-long fill of rocks, which became known as the Lucin Cutoff. During 1955–59, part of the aged trestle fell, and the SP had a million cubic yards of rock brought in, plus dredging of 16 million cubic yards of muck from the lake bottom, to construct a fill over the 12 miles where the aged trestle had existed. The cost was $78 million (2005 dollars), but more costly problems related to the weather lay ahead.

Much of the nation began experiencing above-average precipitation during the late 1960s, and this trend continued into the mid-1980s. One consequence was increased streamflow into the lake. The level of the Great Salt Lake rose by 21 feet between 1963 and 1985, reaching an all-time record high level by early 1986. By 1983, the water was just barely below track level across the 30-mile causeway, and waves were causing the fill to erode. The line was closed to train operations several times during 1983–85. The SP hauled in hundreds of unused boxcars and buried them along the fill to try to halt the erosion.

Major rainstorms passed over the region during 5–7 June 1986, bringing winds of 60 mph. The resulting waves created major damages to the cutoff, with some of the track washed into the lake. Eleven miles of track were entirely submerged, and the line had to be closed. SP trains detoured on an old line that skirted the lake's south end.

Work crews were brought in (300 men), a temporary village was constructed on the lake's west side to house them, and seven work trains were assembled to bring supplies and rock (Steinheimer 1987). Two million tons of rock were brought and dumped to rebuild the cutoff. The state of Utah decided to pump lake water into the desert west of the lake to lower the lake level, and this new area of water required another 20 miles of fill to be developed for the SP line. All the reconstruction was completed by 23 August 1986, 2½ months after the line was cut, and SP trains began using the cutoff at restricted speeds.

Extended cold periods

An unusually cold winter can result in freezing to various extents of all the Great Lakes. This halts lake shipping and brings added business to the railroads of the area. For example, iron ore normally shipped on the lakes from Minnesota to Pennsylvania is shifted to the railroads.

Other victims of occasional freezing of Lake Michigan were the train car ferries that once plied Lake Michigan between Wisconsin and Michigan (Figs. 4.35a and 4.35b). These ferry connections allowed rail shipments a shorter route than around the lake's south end and avoided the train congestion at Chicago. The use of rail car ferries began in 1892, and by the end of World War II there were seven routes operating across the lake. However, all use of rail ferries ended in 1990, partly as a result of a sequence of cold winters and non-use of the ferries during the 1970s and early 1980s.

Figs. 4.35a and **4.35b.** For many decades certain Midwestern railroads bypassed the rail congestion at Chicago by using large ferry boats to haul freight cars across Lake Michigan, operating between Wisconsin and Michigan. However, in cold winters the lake would freeze for months, ending ferry boat operations. Fig. 4.35a (top) shows a side view of a rail ferry at Kewaunee, Wisconsin, in June 1970. Fig. 4.35b (left) shows a string of boxcars being pushed onto the ferry by a locomotive located just behind the photographer.

CHAPTER

5

Planning for and Responding to Weather

Pre-Event Preparations and Post-Event Adjustments

For 150 years, American railroads have pursued numerous actions to address the challenges of weather. These have involved development of equipment and construction of operational facilities, collectively designed to minimize weather problems. In preparation for weather events of both a routine and extreme nature, railroads now rely on a combination of federal safety guidance, their own guidelines and standard operating procedures, plus weather forecast guidance provided by public and private meteorological services. Considerable attention is given to monitoring track and roadbed conditions using remote sensing (Fig. 5.1) and visual observations (Fig. 5.2).

Fig. 5.1. One of the many weather-related preventive actions railroads take is to check roadbeds using sensors in special cars operated by the Sperry Rail Service. Here, one such car is parked on a North Carolina siding awaiting permission to begin measurements along an NS line.

Fig. 5.2. Frequent observations of rails, ties, and roadbed are performed by track inspectors who move along rail lines in trucks such as this one in Minnesota.

In 1950, the U.S. Weather Bureau released bridge design criteria based on flooding frequency. To protect against floodwaters, railroads started using high fills, 4–6 feet higher than the elevation of surrounding land. Railroads also upgraded bridges (Figs. 5.3 and 5.4) and added rip-rap (rocks and large chunks of concrete) at bridge supports. The railroads also gave considerable

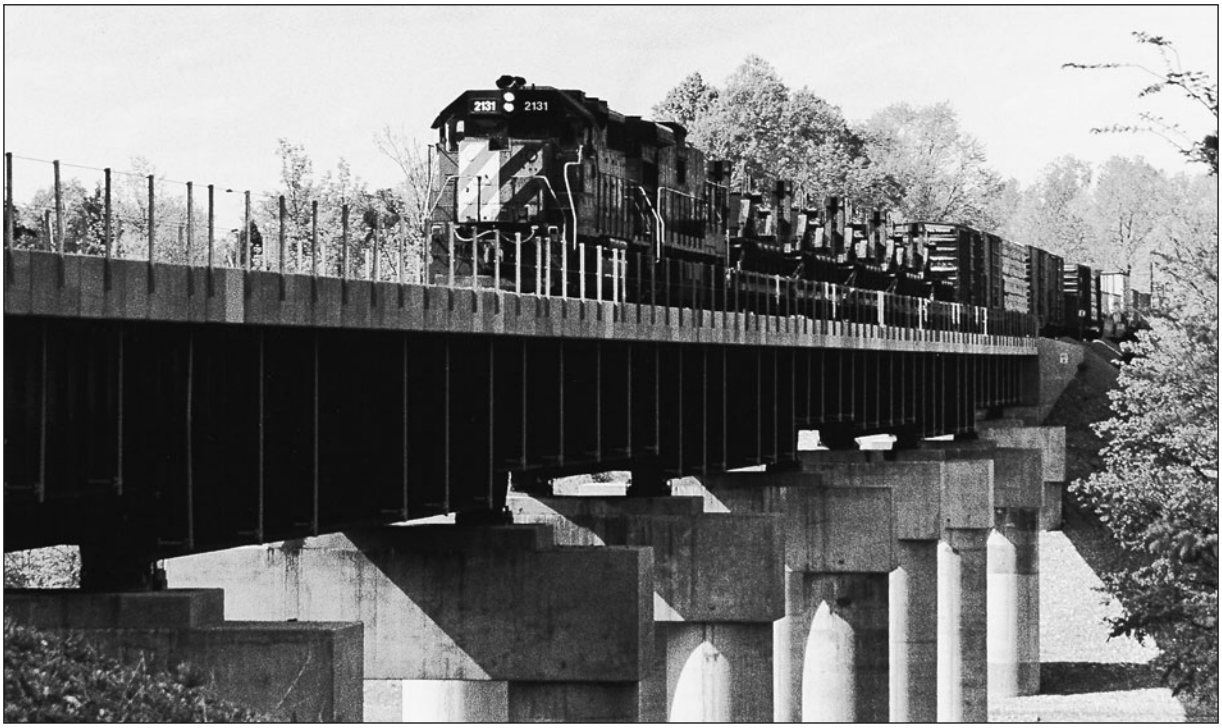

Fig. 5.3. Floods create the need for costly new bridges. The UP built this viaduct-style trestle across a creek valley in 1990 to replace an aging steel trestle.

Fig. 5.4. The CB&Q built this high truss bridge across the Mississippi River in 1959–1960 to replace an aged swing bridge. Here, a BN local pulled by a locomotive on loan from Conrail crosses it.

attention to proper drainage, as inadequate drainage alongside roadbeds causes unstable track and washouts, worsening flood effects (Fig. 5.5). However, railroads did not satisfactorily address harmful weather conditions with planning and adjustments until the mid-20th century, when sufficient historical climate data had become available. These data had been widely collected since late in the 19th century, providing lengthy records allowing definitive measures of weather extremes and their frequency of occurrence. These data have allowed meaningful designs of structures and on-line roadbeds (Fig. 5.6) to better withstand weather hazards.

For handling snow, several actions have been taken. One was to install switch heaters (using gas or propane) to melt the snow and ice so the switch

Fig. 5.5. Adequate on-line drainage is necessary for flood protection and maintenance of a quality roadbed. Here a westbound Santa Fe train Q-NYLA races past a drainage ditch filled with water from heavy spring runoff in Oklahoma.

Fig. 5.6. There are many forms of flood protection. This portion of the UP's line near the Mississippi River has recently been raised several feet by additional ballast. Furthermore, in front of the locomotive the concrete wall with an opening was built to hold a floodgate for a levee alongside a tributary river.

could be operated (Fig. 5.7). Other actions have included the construction of snow sheds (of wood or concrete) to protect track in mountainous country from drifting snow and snow slides or avalanches that bury the tracks. The slopes of cuts through terrain were altered to be wider and flatter so snow could not be trapped in them as easily. Snow pots that contain oil were used to melt snow in vulnerable flange areas. Flangers were built and used to remove relatively light snows of 3–12 inches. They were designed to remove snow from flangeways. A light plow typically hung below track level and was usually mounted on an engine. Such flangers require engine-generated power and controls to lift them above rail top at obstacles like switch cross rails or road crossings, and then to lower them again between the rails. Various other forms of snowplows were designed, including wedge-shaped spreaders (Figs. 5.8, 5.9a, and 5.9b). Then, rotary snowplows were

Fig. 5.7. The switch heater is an important technology for winter operations; it keeps switches from freezing closed. This heater has an exhaust chimney and is ignited on a cold day; the line that connects the hot air to the switch extends to the left. The wiring on the back is for remote control operations.

Fig. 5.8. Snowplows take on several configurations. The simplest form is seen here—a simple wedge mounted on a hopper car that gets pushed by an engine when in use. Note the light atop the plow for night operations.

Figs. 5.9a and **5.9b.** A more complex snowplow is seen here. Fig. 5.9a (top) shows the control room windows above the plow—the plow is actually a rail car. The wedge is shaped to throw the snow away from the tracks. The side view of this Conrail plow (Fig. 5.9b, bottom) shows the "wings." These are hinged and can be extended out from the car to help push heavy snow away from trackside.

developed to remove the heaviest of snows (Fig. 5.10). When plows cannot remove extremely deep snow, bulldozers are used (Fig. 5.11).

Electric fences have been installed to detect rock or mud slides in hilly or mountainous territory. Major improvements in communication systems (radios) have nullified past problems with icing and winds that for many decades cut telegraph or phone wires.

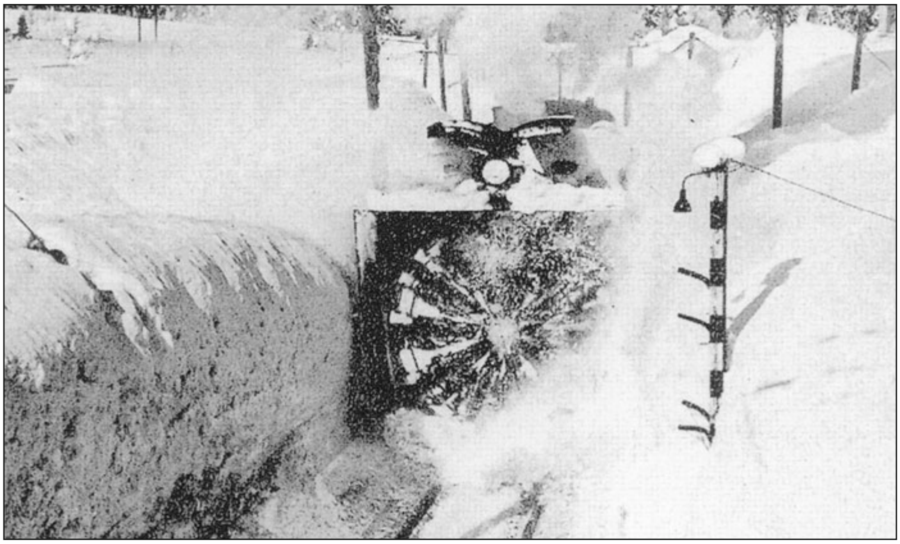

Fig. 5.10. The most sophisticated snowplow is the rotary-type plow. The car carrying the plow fans has an internal engine that turns the large blades that cut the snow and blow it away. Here a rotary plow is being pushed by locomotives through a deep snow.

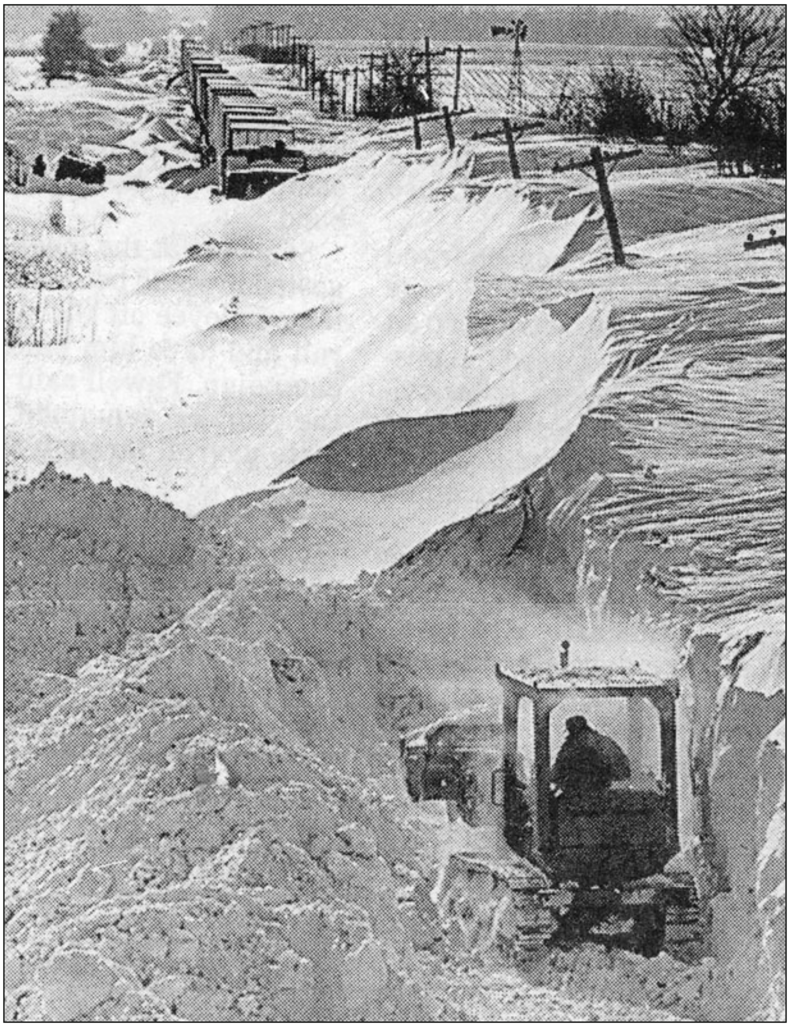

Fig. 5.11. When all else fails to remove deep snows, bulldozers are brought to dig out the rail line. Here a snow-clogged line on the UP main in Nebraska is being dug out. Note the snow-stalled train in the distance on a bleak winter landscape.

Another means of reducing weather-related problems was the use of creosote pressure-injected into wooden ties (Fig. 5.12). This process began in 1875 to restrict moisture uptake in ties, allowing them to last much longer. Before treatment, ties are left to dry for several months (Fig. 5.13). In flood-prone areas, special levees have been constructed to separate the rail line from the adjacent area subject to flooding. Railroads have developed special equipment and trains to handle trains wrecked by weather (Figs. 5.14 and 5.15). In anticipation of damages to rail lines from flooding, railroads add ballast (Fig. 5.16) to threatened roadbeds and sometimes build temporary structures to hold back floodwaters (Fig. 5.17). These do, however, require expensive postflood removal efforts (Fig. 5.18).

All railroad buildings have been designed to withstand high winds. Most heat-related problems can be overcome by proper design of facilities. Timely installation of rails in warm weather helps prevent development of sun kinks during hot weather. These thermal misalignments of the rails can be prevented by determining the rail temperature, recording the rail temperature at the time it was installed, and then de-stressing the rails as necessary during hot periods.

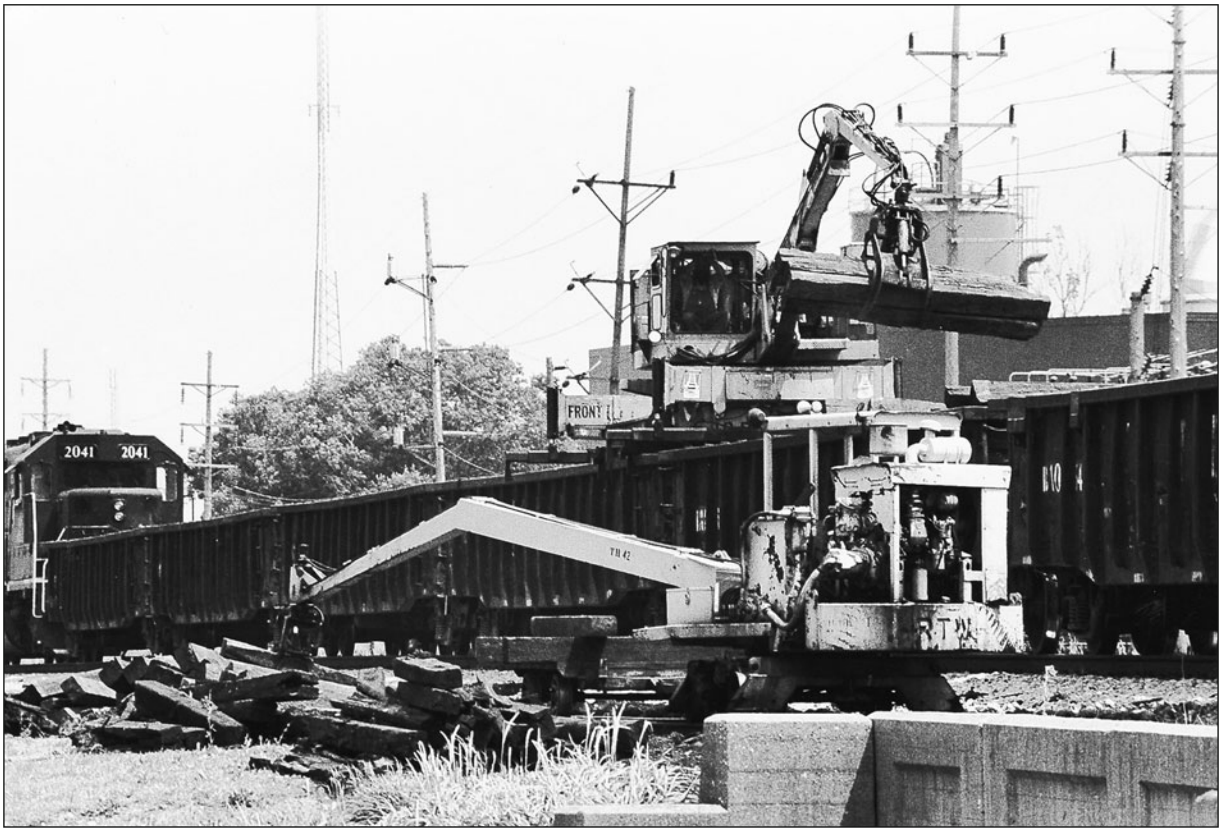

Fig. 5.12. Another weather-preventive action relates to care and maintenance of ties. Here an IC crew is removing and replacing aged ties.

Fig. 5.13. All ties are weather-proofed. The process begins with several months of storage to let the moisture in the wood dry out. Then the ties are treated by creosote inserted under pressure.

Fig. 5.14. A wrecker train is being assembled in the NS yards at Decatur, Illinois, to go to a snow-caused wreck and rerail the cars.

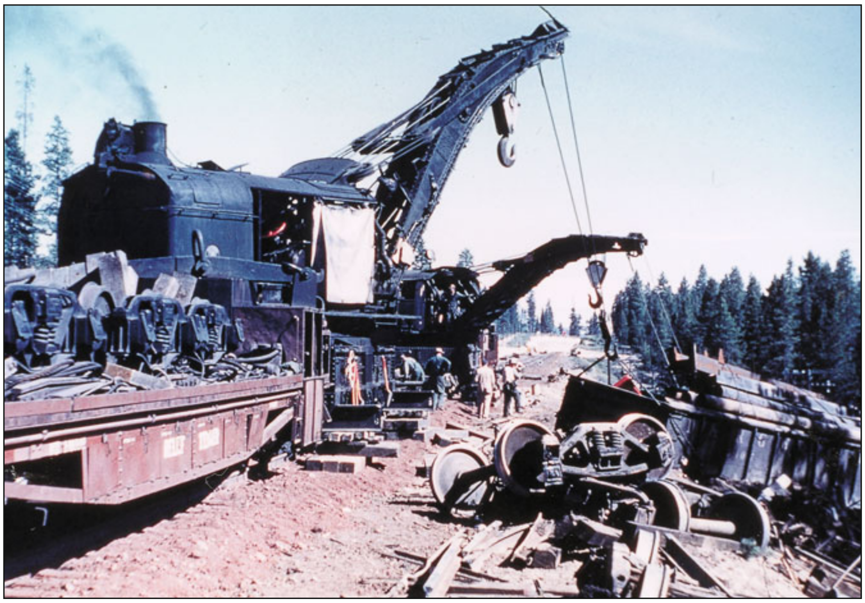

Fig. 5.15. Twin wreckers of the NP are lifting lumber cars derailed by a flood-caused washout in Idaho.

Fig. 5.16. A special Soo work train with cars loaded with rock excavated from the river bluffs near Savanna, Illinois, heads along the Mississippi River shore on 13 July 1993. The rock was dumped along the railroad's vulnerable river line near Davenport, Iowa.

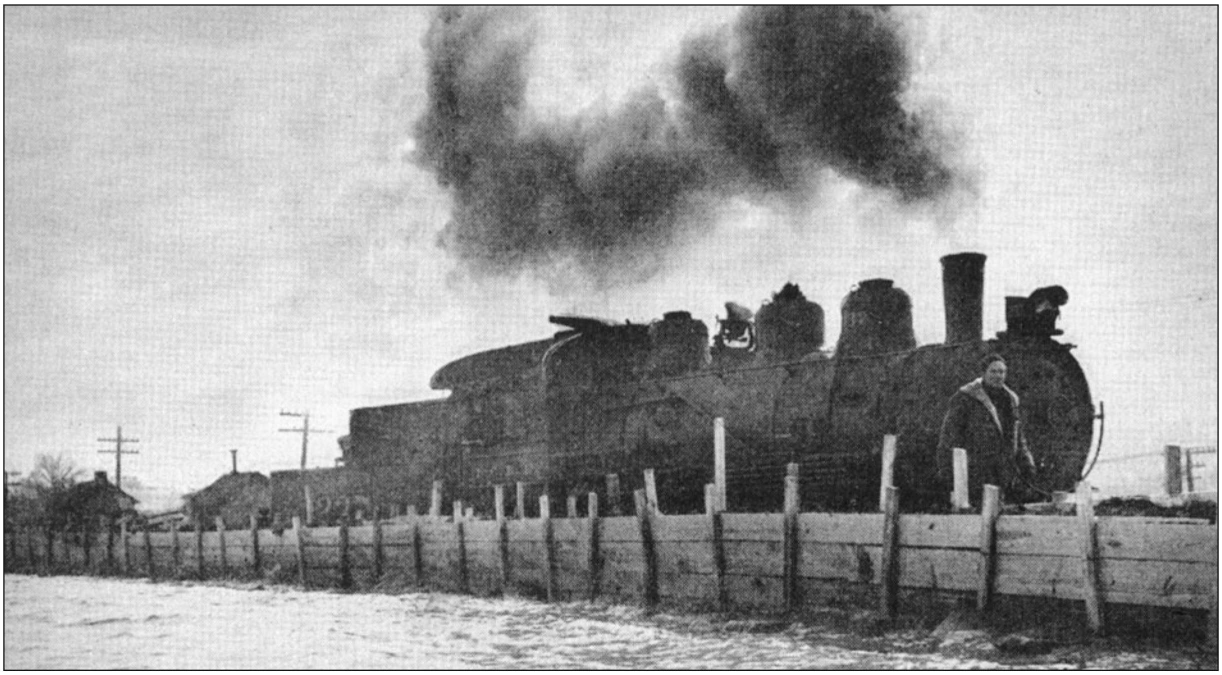

Fig. 5.17. A costly but essential means for keeping high waters from washing over a rail line is shown here. South of Memphis during the famed 1937 flood, a wooden wall was constructed along the IC main. An IC 2-8-0 creeps along. The crewman walks ahead of the engine to detect weak spots and stop the locomotive if he sees any trouble spots.

Fig. 5.18. A special levee was constructed across this UP line alongside the Mississippi River during the massive 1993 flood. A few days after the waters receded, a bulldozer is removing the rock and fill that crossed the tracks.

Terrorist threats have now placed urgent emphasis on the security of hazardous materials and spent nuclear fuel shipped by rail. The release and dispersion of such materials shipped by rail are potentially affected by existing weather conditions. Hence, the railroad companies have increased security for trains carrying such materials.

The Federal Railroad Administration sets safety rules that define maximum speeds for all lines depending on variations in gauge alignment, curve elevations, ballast, crosstie placement, rail anchors, and switch frog clearances. Each rail line is graded and nine track classes have been established, each with allowable speeds for passenger and freight trains. Railroads have also set speed restrictions for high temperatures, snow, and flooding conditions. Table 5.1 presents the 2003 restrictions for high temperatures.

Numerous slow train orders (orders issued by railroad dispatchers that call for trains to move well below posted speed limits when conditions warrant) occurred during 2003 in the western United States as a result of exceptionally high temperatures. These conditions caused numerous delays for Amtrak trains (*Trains*, 2003).

Table 5.1. Railroad heat restrictions established to control train speeds (mph) in 2003.

Railroad	**Temperature (°F)**	**Restricted speed (P = passenger train and F = freight train)**
Amtrak	95°	P: 80
BNSF	85°–115°	P: 70 to 50 F: 50 to 40
CN	95°	P: 65, F: 50
CSX	85°	Reduce 20 mph from posted speed
NS	None	
UP	100°–115°	P: 50, F: 40

Railroads have also turned to meteorologists to obtain forecasts of potentially damaging weather so as to avoid operational problems and minimize weather damages. During the 1980s, a private weather firm began providing the AT&SF with warnings of potentially severe storms along their lines (Weather Data 2004). The firm's weather forecaster would call the railroad's dispatcher for the district where the storms were likely to occur, indicating the likelihood of tornadoes, high winds, and/or heavy rains capable of causing washouts. Trains then would be stopped or slowed in the danger areas. Such interactions required the services of private firms who could commit personnel to learning the railroad's vulnerability and operational procedures, and thus provide meaningful and informed forecasts for specific rail locations.

These specialized forecasts have proven to be very valuable. For example, on 31 May 2000, forecasters warned of severe thunderstorms along the BNSF main line south of La Crosse, Wisconsin, with a potential for flash flood rains that could create mud slides and washouts. Regional maintenance leaders sent a crew to investigate, and they found a 60-ft-long mud slide covering the tracks. Approaching trains were halted. On 12 May 2004, tornadoes developed in southern Kansas, where the BNSF's busy Chicago–Los Angeles route passes through. Forecasters detected a storm approaching the rail line and issued a warning for the location where the tornado would cross the line. As a result, the district dispatcher stopped three trains approaching this site. The tornado crossed the rail line 30 minutes after the warning. This action prevented major damages to the passing trains and possible injuries to train crews.

The BNSF has realized numerous benefits from the weather warnings since they became available in the 1980s. As a result of their successes with the forecasts, the BNSF developed a comprehensive plan labeled the "Weather Preparedness Plan" in 1997. This included five steps for each section of the 33,000 miles of the railroad: 1) winterizing of all equipment, 2) safety preparations and training of staff, 3) material inventory, 4) weather monitoring, and 5) notification protocol (Gips 2001). Importantly, the weather monitoring includes obtaining specialized weather forecasts. The weather monitoring also includes use of specialized remote weather sensors strategically placed along the railroad that relay their measurements of winds and other conditions to dispatchers. The plan has also led to the selection of different kinds of equipment at different locations to adjust for regional differences in climate. For example, to deal with snow, the BNSF uses jet snow blowers in the Dakotas where severe freezing conditions often accompany snow, whereas the heavy snows of Montana require availability of rotary snowplows capable of removal of heavy but drier snowfall. An example of the plan's effectiveness relates to spring floods that developed along the Upper Mississippi River in 2001. Forecasts of these high floods were given to BNSF a week before the flooding. This allowed the BNSF to use its plan to establish rerouting arrangements for its trains to operate on other rail lines away from the river's edge (Fig. 5.19). Special trains carrying rock to reinforce the rail embankments also reinforced vulnerable locations of track along the river. As a result of these actions and other on-line preparations, the BNSF was able to maintain limited train operations along the nearly flooded line, and some trains were diverted to other lines without any confusion. The plan worked well. As a result of such successes, the use of specialized forecasts has expanded to other railroads (Gips 2001).

Railroads are also consumers of atmospheric and environmental data and could become data producers. Onboard sensors may one day prove useful as a data source for meteorological models and forecast decisions. Similarly, stationary sensors mounted in track-side bungalows and along track right-of-ways could provide meteorologists and railroad traffic managers with valuable, multipurpose observations from remote locations. Railroad-specific smart systems, such as positive train control (PTC) technology, electronically controlled brakes, intelligent grade crossings, automatic equipment identification, and automated scheduling systems, also facilitate the use of enhanced weather information. The Federal Railroad Administration now encourages the railroad industry to implement these technologies as integrated systems, thus making more efficient use of communication systems and achieving economies of scale in the deployment and integration of such systems.

Fig. 5.19. Another action taken in response to weather problems is rerouting trains from flooded or snow-blocked lines. A rerouted Santa Fe train races south from Chicago in July 1993 on the IC main as it heads for Memphis as a result of the 1993 flood. From Memphis, it went west on other rail lines to reach its main line in Oklahoma.

Post-Event Responses

There are numerous ways in which railroads react to weather-induced problems. These include snowplowing, temporary raising of track, constructing earthen levees or wooden walls, rerouting of trains, and shorter trains. These are among the many adjustments used to quickly resolve or forestall ongoing weather-caused problems.

Flangers can handle snowfalls of 3–12 inches. Conditions with 2 feet or less of compacted drifts, or noncompacted snow depths of 5–10 feet, can be handled by pushing a wedge plow at a good rate of speed (30–40 mph). Snow 8–10 feet deep or with packed drifts 3 feet or higher requires rotary plows. The speed of rotary plows is only 4–6 mph in areas with heavy drifts. In 1951, the now-defunct Milwaukee Railroad operated the following snow removal equipment along its main line between Chicago and Seattle: 10 rotary plows, 56 wedge plows, and 31 flangers. Trains or trucks are often used to haul away deep snows plowed from right-of-ways.

When weather causes train accidents, derailed cars sometimes spill their contents, and removal is necessary (Fig. 5.20). Of course, accidents require a work train to get the wrecked cars and engines back onto the track.

In some flood situations, the water level adjacent to a rail line is only a few inches below the rails, and waves can sweep water over the tracks. In such instances, earthen fill, rocks, or even wooden walls are constructed to keep the high water away from the rails (Fig. 5.17).

In extremely hot or cold weather, track inspections are increased to detect any sun kinks or rail splits from cold. Prior to major weather events

Fig. 5.20. A wrecked grain train has spilled corn everywhere, and this special truck can literally "vacuum" spilled grain from along the track and from inside wrecked cars.

that can be well-forecasted a day or two in advance, such as hurricanes, railroads will assemble special trains of ballast to use where flooding erodes existing roadbeds, and they also import special work crews in order to repair broken signal systems or to remove blown-down trees from rails lines. Such actions were important in dealing with the four hurricanes that struck the southeastern United States in 2004.

Railroad Responses to Hurricane Katrina: A Success Story

Hurricane Katrina, at one point a category 5 monster storm, struck the Gulf Coast on 29 August 2005. The impacts resulting from the huge storm surge and high winds were diverse and widespread. Katrina left a footprint of flattened houses, toppled trees, washed-out roads, and flooding from New Orleans east across southern Mississippi and Alabama. Katrina's total damages exceeded $100 billion, the greatest disaster dollar loss on record for the U.S. Moreover, the loss of 1,299 lives ranked Katrina as one of the nation's deadliest natural disasters.

The storm surge and flooding damages were particularly severe in New Orleans. Six of the nation's class one railroads converge on New Orleans, which serves as a major interchange point and is also a major harbor served by railroads. Hence, damage to the railroads was excessive. The class one railroads that suffered Katrina damages included the BNSF, Canadian National (former IC), CSX, Kansas City Southern, Norfolk Southern, and Union Pacific. There were also 14 short-line railroads (companies with 100 miles of rail line or less) operating in the storm-affected area. Three suffered major losses. For example, the Port Bienville Railroad in Mississippi had all its engines and 480 rail cars totally submerged by flooding. Two-thirds of its tracks were washed away, and more than half its 47 employees lost their homes.

The CSX has a main line paralleling the Gulf Coast for more than 100 miles, from east of New Orleans to Mobile. This line was essentially destroyed, including six bridges, one of which was the massive bridge over the Bay of St. Louis. At one location, ten shrimp boats were deposited on the line. Massive repairs were employed, and it was estimated the line would require eight months to re-open (at press time, the CSX is considering relocating this line inland). The CSX had more damages than any other railroad, with losses totaling $250 million. Its massive Gentilly rail yard in New Orleans was entirely under water, as were the yards of the NS and CN.

The storm surge washed 5 miles of track off the NS's bridge across Lake Ponchatrain, with excessive NS track damages in Mississippi and Alabama. The NS got 10 barges, each with a derrick, and lifted the 5 miles of track back onto the bridge by 12 September. The NS also had to remove 5,500 fallen trees from its lines, install 11,000 new ties, and replace 55,000 tons of ballast. NS losses and costs totaled $44 million.

The CSX, NS, and other major carriers preemptively shifted east–west moving freight to other gateways—including Memphis and St. Louis—with few delays. Such well-planned responses enabled the rapid repair of damaged lines and yards. Union Pacific trains were able to enter New Orleans by 1 September, with BNSF freights entering by 8 September, CN and NS trains by 13 September, and KCS by 14 September. Thus, within two weeks after Katrina struck, freight service in and out of New Orleans had been restored. The major railroads also made sizable financial gifts to the states with major losses.

Amtrak normally operates three trains in and out of New Orleans each day, but flooding kept them from entering New Orleans. They were stopped and turned at non-flooded locations well away from the coast. Amtrak passenger cars and dining cars were used beyond the damaged area to house and feed Amtrak staff who had lost their homes. Ironically, Union Station in New Orleans was used as a temporary jail for looters. Rail repairs were executed rapidly, and by 9 October 2005, the “City of New Orleans” and “Crescent” were operating in and out of New Orleans. On 4 November, the “Sunset Limited” was able to serve the city from the west.

New Orleans has three streetcar lines, with considerable trackage exceeding that of any other U.S. city. Katrina did great damage to these unique lines, destroying their power cables and eroding tracks. Many of the streetcars were flooded, several beyond repair. Limited car operations resumed on 18 December.

A positive aspect to the storm was the organized manner in which the major railroads handled the event. First, based on the Katrina forecasts issued by the National Weather Service two days before the storm, they assembled repair crews and equipment, and gathered huge loads of ballast, ties, and rails with which to later repair damaged lines. The railroads also moved their diesel engines away from the coast before Katrina struck because flooding can ruin diesel engines. The major lines preset plans for rerouting their trains away from damaged lines. The preparations, good planning, and efficient execution allowed the railroads to handle the damages supremely well (Fig. 5.21).

Furthermore, the railroads got many of their threatened workers out of harm’s way, placed them in safe locations, and were able to get them back to work in other locales. They extended loans to employees in need. Through all of this, the media noted that railroaders handled the event in good spirits, revealing how well railroads respond to weather adversities. It was an organized approach and a positive attitude not found in the region’s other damaged companies or government agencies that had to address the storm (many of which did so in a haphazard manner).

Fig. 5.21. Workers repair a flood-damaged rail line east of New Orleans.

The railroads' years of experience with weather extremes had paid off. The response and recovery by the railroads was rapid and incurred the lowest possible cost: $320 million. This may become ever more important in the future. Katrina was one of 24 tropical storms in 2005, a record number, and this raised scientific questions about the possible influence of global warming and the potential for more future weather extremes.

CHAPTER

6

The Evolving Relationship between Weather and Railroads

RAILROADS PLAYED a significant role in the settlement and ensuing development of the United States. Their rail lines allowed growth of communities, mining and hauling of coal and other minerals, and the development of agriculture and manufacturing across the nation. Before the existence of trains, all forms of transportation, such as stagecoaches, steamboats, and canal barges, were very slow and unreliable. The "iron horse" brought an element of speed never before known, plus a new capability to reliably deliver goods and products to their destination on time.

The rail industry faced serious challenges in achieving these goals, however. A wide variety of weather factors affected railroads, slowing trains and causing accidents: engines and rail cars were damaged, roadbeds weakened or destroyed, rails bent, and communication systems ruined. The battle with weather was an ongoing struggle, but over time the railroads found many ways to lessen the detrimental impacts of weather. However, extremes such as too much rain and ensuing flooding, deep snowfalls, thick fogs, and extremely high or low temperatures remain challenges today.

Weather extremes such as tornadoes, freezing rainstorms, hurricanes, blizzards, dust/sand storms, and lightning, also cause damages and operational problems. Climate extremes, groups of years with prolonged wet periods or droughts, have major impacts as well.

Some major weather extremes over the past 50 years have been excessively damaging and costly to railroads. Hurricane Diane in 1955 caused $141 million in losses to 14 railroads, and Hurricane Katrina caused an estimated $320 million in damages. The record Midwestern floods in 1993 brought losses and costs amounting to $480 million, the greatest weather-related loss ever experienced by U.S. railroads.* Major West Coast storms in the winter of 1997/98 created havoc for the railroads. Rail lines were washed out or covered by mud slides and trains were blocked by heavy snow for days, leading to 2-month losses totaling $355 million.

In some instances, major weather extremes have brought benefits. The 1988 drought prevented river barges from operating on the Mississippi River system, so railroads saw an increased business in hauling grains and other bulk commodities.

Since the 1860s, railroads have worked to nullify their weather problems. A variety of snowplows were developed, and in areas that see heavy snow in the West, sheds were built over rail lines to keep snow off the tracks. Bigger and stronger bridges were constructed to minimize flood losses, and heaters were designed for switches so the rails joints would not freeze. Other recent innovations included electric fences to detect and warn of rock or snow slides, welded rail that diminishes extreme temperature problems and derailments, computer-based communication systems with weather data from weather sensors installed along rail lines, and special levees to hold back floodwaters. Loss of visibility due to fog or heavy precipitation has always been a curse, but the development and use of radio systems for communication has helped lessen these problems.

The development of climate data during the 19th century led to information allowing better designs for extremes as well as average weather conditions, thus improving the design and construction of weather-sensitive structures. Now railroads are embracing weather forecasts to minimize losses. For example, trains are stopped before passing through an area with tornado forecasts, and heavy rain outlooks lead to prestorm preparations along lines susceptible to high water.

In recent years, many railroad companies have merged, leaving the nation with only five major rail systems, each of which is extensive. For example, the BNSF has 32,185 miles of track and operates in the desert Southwest, the humid Northwest coast, throughout the Rocky Mountains, and across the stormy Midwest and South. This calls for greater weather

---

*All amounts are expressed in 2005 dollars.

information in real time and a wide variety of equipment to deal with weather-induced problems in disparate regions.

The railroads of today and the future rely ever more on the timely delivery of freight loads like truck trailers, hauled over thousands of miles on tight schedules. Low-sulfur coal mined in Wyoming and Colorado is being hauled almost daily to power plants everywhere including Florida and New England, another major task requiring operational dependability. All of these economic forces put high demands on railroads to address their weather problems, particularly those that block their main lines.

Recent weather-induced problems reveal certain truths and lessons about dealing with weather in future years:

1. Weather extremes will continue to affect railroads, particularly extremes of moisture (heavy rains and snows) and bad visibility (fogs and precipitation).
2. It is important to retain and/or save alternate rail routes that are considered redundant, as they can serve as detours when main lines are blocked.
3. The use of weather assessments and forecasts will only continue to grow and become more valuable to the railroads of the future.

SOURCES

American Railway Engineering and Maintenance of Way Association (AREMA), January 1994: Railroads vs. 1993 floods, 231–234.

Changnon, S. A., 1989: The 1988 drought, barges, and diversion. *Bull. Amer. Meteor. Soc.*, **70**, 1092–1104.

——, 1994: Trains and water don't mix. *Rail Classics,* **23**, 54–61.

——, 1996: Impacts on transportation systems: Stalled barges, blocked railroads, and closed highways. *Great Flood of 1993*, Westview Press, 276–299.

——, 2002: Weather on our side. *Weatherwise*, **55**, 11–12.

——, 2003a: Measures of the economic losses from weather extremes: Getting better but far from perfect. *Bull. Amer. Meteor. Soc.*, **84**, 1232–1235.

——, 2003b: Characteristics of ice storms in the U.S. *J. Appl. Meteor.*, **42**, 630–639.

CTC Board, December 2004: Railroad News, 7–10.

Gips, M. A., 2001: Railing against the weather. November 2001, *Security Management Online*, www.securitymanagement.com.

Glickman, T., Ed., 2000: *Glossary of Meteorology*. 2d ed. Amer. Meteor. Soc., 855 pp.

Harper, E. L., 1993: *Testimony of the President of the Association of American Railroads before the Subcommittee on Transportation and Hazardous Materials.* Committee on Energy and Commerce, Washington, DC, 15 pp.

Hay, W.H., 1957: *The Effects of Weather Upon Railroad Operation, Maintenance, and Construction.* University of Illinois, 236 pp.

Ingles, J. D., May 1986: Strangulation and resilience. *Trains*, p.18.

——, and D. Lustig, April 1997: Storms stagger western railroads. *Trains*, 24–29.

Keefe, K. J., November 1992: In hurricane's wake. *Trains*, 7–8.

NCDC, 1997: *Storm Data.* Vol. 39, No.1, 146 pp.

Pacific Rail News, August 1993: Water water everywhere, Issue #357, 5 pp.

Railway Track & Structures, September 1993: Coping with the Midwest flood, 42–43.

Riebsame, W. E., Changnon, S. A., and T. R. Karl, 1991: *Drought and Natural Resources Management in the United States*. Westview Press, 216 pp.

Rossetti, M. A., 2003: Potential Impacts of Climate Change on Railroads. *Proc, Workshop on Potential Impacts of Climate Change on Transportation*, Alexandria, VA, U.S. Department of Transportation Volpe Center, 1–13.

Shafer, M., 2000: *More Classic American Railroads.* Motorbooks Int., 160 pp.

Steinheimer, R., 1987: The bear vs. the lake. *Trains*, 24–29.

Traffic World, July 26, 1993: Flood waters recede in Midwest but rain, delays and detours persist. ID# 9301200227, 15–16.

Traffic World, July 30, 1993: Traffic damage to flooded roads; official coffers won't cover repairs, 16.

Traffic World, August 23, 1993: As floodwaters recede, railroads take stock of track needs. ID# 9301220836, 14.

Trains, October 1993: Santa Fe vs. nature at milepost 364.4. 18–19.

Trains, March 1980: Fatal fog. 10.

Trains, November 1986: Drought in the South. 7.

Trains, January 1989: Drought of 1988. 4.

Trains, June 1989: Soo has problems. 7–8

Trains, March 1990: Not prepared. 14.

Trains, September 1990: Big blow. 11.

Trains, September 2003: Fast trains on slow tracks. 22–23.

Transportation and Distribution, January 1994: Flood means lost income to railroads. Vol. 35, 16 pp.

U.S. Weather Bureau, *1957*: *National Summary: Climatological Data for January 1957*, 15 pp.

Walker, J., April 1991: The shield and the feather. *Trains*, 38–53.

Weather Data, 2004: *Weather Risk Management Services, Software and Products*. [Available online at www.weatherdata.com.]

Wrinn, J., December 1989: CSX and NS were prepared. *Trains,* 17.

GLOSSARY

Ballast	All rail lines are underlain by gravel-type rock, placed there as part of the right-of-way, to allow water to drain away from the rail line and to serve as a partial cushion for heavy trains.
Block of trains	On some single main lines, railroads organize several trains going in one direction together in series, or block, while holding all trains going in the other direction.
Branch line	A section of track that extends away from main lines to serve one or more customers.
Centralized Traffic Control (CTC)	A centralized system that remotely controls train movements through signals and switches. Trains operate based on signal indications rather than on written train orders or timetables.
Control tower	A building, usually two-story, located at a junction of two or more rail lines where controls for local switches and signals control train operations through the junction.
Cuts	V-shaped areas created by removing dirt, typically from a hill, to allow the tracks to be located so as to maintain the track level on either side of the hill.
Dispatcher	Person responsible for controlling the movement of trains over a fixed portion of a railroad.
District	Section of track, often approximately 150 miles long, where track maintenance and other train-related activities are centralized and launched.
Electric fence	In areas where there is a danger of rock, mud, and/or snow slides onto tracks, a fence with wire detectors is built along the tracks for sensing and, through an electric signal, warning approaching trains when there has been a slide.
Fill	A mound of dirt and/or rock constructed in low-lying areas to support the track at higher levels.
Flanger	A snowplow with a scoop capable of removing the snow located between the rails.

Flangeway	Rail installed just inside the regular rail to keep car wheels from de-railing at junctions, switches, or crossovers.
Gauge	The distance between the running rails of track: 4 feet 8.5 inches.
Icing stations	Buildings along a rail line where ice is loaded into refrigerator cars.
Interchange	A junction of two railroads where cars are transferred from one road to another.
Intermodal traffic	Traffic moving by more than one mode on its trip from shipper to receiver. The term is often used for piggyback or TOFC (Trailer on a Flat Car) traffic, but includes containers transferred from seagoing ships to special rail cars (Container on a Flat Car, or COFC traffic).
Rail hub	A location where several rail lines come together and where extensive train car exchanges occur.
Right of way	The track, roadbed, and property along the track owned by the railroad.
Roadbed	The dirt and rocks (ballast) beneath a rail line.
Rotary snowplow	A rail car, often self-powered, with a large fan on one end for blowing snow off the right-of-way.
Short line	A railroad with less than 100 miles of main line track.
Signal bridge	A steel, bridge-like structure built above railroad tracks and used to hold signals for controlling trains on the rail lines below.
Snow shed	A structure built over a rail line to keep snow from falling on the rail line; usually constructed of wood or concrete.
Staging yard	A yard of many tracks and sidings where either loaded rail cars are brought for combination into trains, or empty cars are brought for distribution to nearby users of rail shipment.
Sun kink	Bent track that has been damaged so by high temperatures and/or prolonged sunshine. Sun kinks can change the track gauge, which can cause wrecks.

Switch heater	A device installed at switches and typically remote (radio) controlled. It creates heat from the burning of natural gas to keep rails at switches from freezing together.
Switch frog	A rail installed at a switch to prevent derailments; see *Flangeway*.
Tie	The crosswise member of the track structure, usually made of wood or concrete, to which the rails are fastened.
Tie tamper	A special rail car with powered devices that apply pressure on ties to keep them in position and alignment.
Trackage rights	One rail company may receive rights to operate their trains on the lines of another railroad for a fee or for an exchange of track privileges.
Trestle	A type of bridge with numerous supports, often made of wood. Some longer trestles are supported by steel members and are called viaducts.
Turn	A train that travels from one place to another and then comes back to its place of origin.
Turnout	A name for a switch, or where two lines join.
Turntable	A short section of track mounted on a structure (often motor driven) that can pivot, for turning around and/or parking engines on rail sidings in a roundhouse.
Water tank	A large, often round-shaped, structure built along a rail line and used to provide water to steam engines.
Wedge plow	A wedge-shaped snowplow that mounts on a rail car and pushes snow off the rails.
Welded rail	Sections of rail welded end to end, extending up to 1500 feet or more.
Wire detectors	See *Electric fence*.
Wreckers	Rail cars equipped with derrick-like booms used to lift wrecked rail cars and engines.

RAILROAD ABBREVIATIONS AND INDEX

GENERAL INDEX

STANLEY A. CHANGNON is Professor of Geography and Emeritus Chief of Illinois State Water Survey at the University of Illinois, Urbana-Champaign. A prolific author in the atmospheric sciences, Mr. Changnon has also written numerous books and articles about his lifetime hobby, railroads. His 39 railroad articles have appeared in such publications as *Rail Classics*, *Midwest Rail*, and *Historic Illinois*. His six previous books, including *Railroad Bridges in the Heartland,* are available by emailing schangnon@uiuc.edu. Mr. Changnon lives in Mahomet, Illinois, with his wife, Joyce.