LABOR DAY STORM OF 1970 REVISITED 30 YEARS LATER

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The 1970 Labor Day storm caused more loss of human life than any other storm in Arizona's recent history. Many dwellings, roads, bridges, and other structures were also damaged or destroyed by the record flooding. Most of the widespread and unprecedented human and economic losses occurred in central and northeastern Arizona, with other losses reported in southeastern Utah and southwestern Colorado (Roeske 1971; Thorud and Ffolliott 1973). At the request of Governor Jack Williams, President Nixon declared the flood-damaged areas a major disaster, permitting political jurisdictions and, in a restricted sense, private entities to be reimbursed by the federal government for eligible expenditures made as a result of the storm. It is difficult to assess the total dollar cost of the storm, although it has been estimated that initial expenditures to immediately repair storm damages to infrastructures approximated $25–35 million in terms of current dollars.

Preliminary reports on the storm and its effects were presented at the 1971 Arizona Watershed Symposium (Thorud and Ffolliott 1971) and the 1972 Western Snow Conference (Thorud and Ffolliott 1972). A more comprehensive report on the 1970 Labor Day storm and associated flooding was prepared at the request of the Arizona Water Resources Committee, a private nonprofit organization formed (but later disbanded) to promote the development of Arizona's water resources with particular emphasis on water yields from watershed lands (Thorud and Ffolliott 1973). Meteorologic and hydrologic features of the storm, the resulting upland watershed damages, relationships to land management practices, and the degree to which upland watershed damages have been mitigated in the 30 years since the storm are reviewed in this paper.

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The Storm and Its Consequences

The 1970 Labor Day storm caused rainfall of varying amounts at different locations in Arizona beginning on September 3 and ending mostly on September 6. Skies cleared over much of the state by late afternoon on September 7, and relatively little rainfall was reported for that observational day. Flooding began near the border with Mexico on September 4, occurred in the Mogollon Rim area in central Arizona and westward on September 5, and continued along the Little Colorado River basin and in the Tucson vicinity on September 6. High peak streamflows and flooding were observed at various locations, but the most disastrous flooding and loss of human life occurred on September 5.

Meteorological Event

The conditions that led to the 1970 Labor Day storm developed initially with a northward advance of moist, unstable air from the eastern Pacific Ocean and Gulf of California that was associated with tropical storm Norma (National Oceanic and Atmospheric Administration 1970; Thorud and Ffolliott 1973). Following this air mass invasion, the triggering mechanisms that contributed to heavy rainfall in the state included an orographic uplift associated with strong southerly winds in the lower atmosphere, the invasion of an unusually intense late-summer cold air mass from the Pacific Northwest with its associated frontal activity, and daytime convective heating over the desert valleys.

Rainfall totals of 5 inches or more were associated with the mountainous terrain of the Mogollon Rim northeast of Payson, the Sierra Ancha Mountains southeast of Payson, the Mazatzal Mountains south and southwest of Payson, the Bradshaw Mountains east of Prescott, the high country south of Flagstaff, the Santa Catalina Mountains northeast of Tucson, and the Baboquivari Mountains and Kitt Peak southwest of Tucson

(Thorud and Ffolliott 1973). New precipitation records for a 24-hour observational day were established at many National Weather Service stations. Perhaps the most spectacular record was established at Workman Creek in the Sierra Ancha Mountains, where 11.4 inches of rainfall were recorded in an official rain gauge between 2200 hours on September 4 and 2000 hours on September 5, a new record for the state (National Oceanic and Atmospheric Administration 1970; Kangieser 1972). The previous official National Weather Service record for a 24-hour observational day was 6 inches, recorded at Crown King on December 19, 1967. Rainfall intensities of greater than 3 inches in 4 hours were reported for several stations during the storm period (Roeske 1971). Rainfall intensities of these magnitudes easily exceed the infiltration rates on many watershed lands with shallow soil storage over bedrock, facilitating large amounts of surface runoff and high peak streamflows.

A 24-hour rainfall total of 5–6 inches is a 100-year event at many locations in central Arizona (U.S. Weather Bureau 1967). This amount of rainfall was equaled or exceeded at several of these locations during the storm (Thorud and Ffolliott 1973). Such a storm does not necessarily occur at 100-year intervals, however. The same event could occur 2 or more years in a row at the same location, although such a sequence is unlikely.

Hydrologic Event

High peak streamflows and flooding events occurred as a result of the storm. Peak discharges of several streams in central Arizona, where the most damaging flooding occurred, exceeded the 20- to 25-year flood (Thorud and Ffolliott 1973). The return period was much higher on small watersheds of 25 square miles or less. As expected, much of the flooding was associated with areas receiving the higher rainfall amounts and intensities. Record peak discharges and flood stages were measured at selected stations (Roeske 1971). At least 30 USDI Geological Survey gauging stations in the Gila River Basin measured record peak streamflows.

The highly used recreation sites near Kohl's Ranch on Tonto Creek were severely damaged by flooding, and sadly, it was here that more human lives were lost than at any other area (Elson 1971; Thorud and Ffolliott 1973). The hydrologic event here was, therefore, of special interest. An estimated peak streamflow of about 18,400 cubic feet per second (cfs) occurred on Tonto Creek at Kohl's Ranch on September 5. This flow, combined with the high flows from two tributary streams (Chistopher and Haigler Creeks), resulted in a peak streamflow of 38,000 cfs at Tonto Creek near Gisela on September 5. Studies of recurrence intervals have suggested that the peak streamflow of Tonto Creek near Gisela was a 10-year event (Thorud and Ffolliott 1973). This means that, on the average, a flood of this magnitude will be equaled or exceeded once in 10 years over the long run. Or, in other terms, there is a 10 percent chance of a flood of this magnitude being equaled or exceeded in any given year. However, the situation was compounded by the frequent breaching of debris dams during the flood.

Reservoirs on rivers and streams helped to reduce the damage potential of the flood flows. Roosevelt Reservoir on the Salt River stored all of the flow from the Tonto Creek Basin, and Horseshoe Reservoir on the Verde River to the west absorbed the flows from its upstream tributaries (Roeske 1971). The storage in these reservoirs helped to prevent significant damage to Phoenix and other downstream population centers. Some of the small reservoirs (recreation lakes) on upland watersheds had available storage capacity at the time of the storm, and therefore stored water to also prevent or reduce destruction downstream (Thorud and Ffolliott 1973). However, some upland reservoirs received an influx of floating woody debris that was considered to be potentially hazardous, because it could jam spillways during future runoff events and contribute to dam failures.

Upland Watershed Damages

Many stream channels on upland watersheds were detrimentally altered as a result of flooding during the storm. Types of damages included accumulations of uprooted trees and other materials in debris dams at restriction points in the channels, deposition of boulder fields in the channels, channel scouring (to bedrock in some channels), and bank cutting (Morrison 1970; Willams and Russell 1970; Elson 1971; Arnolt 1972; Thorud and Ffolliott 1973). Debris dams resulted from high streamflows carrying uprooted trees and other vegetative debris and rocks. This churning mass of material tended to lodge and form the dams in narrow places, on sharp curves, in stands of trees, and around bridges and culverts. These channel diversions resulted in a head of water being built up behind the dams; these dams often breached, sending a surge of water, timber, and rocks downstream in flood waves to the next restriction point where the process might be repeated. There was a concern that the debris left in the channels following the storm might again plug channels, culverts, and bridges, or divert subsequent spring snowmelt streamflows into the unstable banks, causing more erosion. As a consequence, riparian and channel restoration efforts were undertaken on some of the stream systems.

Massive boulder fields were deposited at various locations in some of the channels. Some deposits were 10–30 feet deep, extending the width of the channels, and up to 2 miles in length. Rock size varied, but the larger boulders were 6 cubic yards in volume and weighed up to 50 tons. Streams flowed through or under the boulder fields in some places, while water was diverted laterally toward the banks elsewhere. This latter situation was undesirable because it could lead to further bank erosion and attendant soil loss and more trees could be undermined and dropped into the channels. Future channel damage could likely be caused by rock piles considered unstable and subject to movement during subsequent high streamflows. Channel scour to bedrock occurred in some locations; a tributary of Tonto Creek was virtually swept clear of loose sediments above bedrock for much of its length. Creation of vertical stream banks was another result of flood flows during the 1970 Labor Day storm, particularly where debris deposits caused streamflows to be diverted against the banks, at curves in channels, and where channel scouring was deep. Some of the vertical banks were unstable and constituted a potential source of sediment and timber debris due to sloughing during subsequent high flows. The hazard of unstable banks was accentuated where trees and large boulders were precariously suspended at high locations on or near vertical stream bank faces.

Damage to Fishery Resources

Damage to fishery resources was extensive throughout the flood area (Arnolt 1972; Thorud and Ffolliott 1973). Streams were sometimes split into multiple channels by rock piles, often with insufficient flow to support fish populations. Other conditions detrimental to the fishery resources (resulting from the flood and difficult to correct) were created by channel scouring to bedrock, filling of pools with boulders, sand, and silt, and the diversion of channels. The loss of streambank (riparian) vegetation which ordinarily shades the stream resulted in water temperatures too high for trout populations in some instances.

Relationship to Land Management Practices

Hydrologic relationships between land management practices on upland watersheds and overwhelming meteorologic events such as occurred with the 1970 Labor Day storm are difficult to isolate and quantify (Thorud and Ffolliott 1973). If a large rainfall event occurs in a short period of time, flooding might occur regardless of the management practice. However, if a watershed has been largely cleared of vegetation (for whatever reason) and has bare soil exposed to the elements, the rates of surface runoff, erosion, and sedimentation can be higher than would be expected if a protective vegetative cover was on the watershed. The hydrologic response of the Beaver Creek watersheds in north-central Arizona to the Storm (Baker et al. 1971; Brown et al. 1974; Clary et al. 1974) provided insight to this phenomenon. Total runoff, peak streamflow, and total sediment yield associated with the storm were higher on a watershed in the pinyon-juniper woodlands that had been cleared (cabled) of overstory vegetation 6 years earlier than would otherwise be expected. Total runoff and peak streamflow from the storm were also higher on watersheds in the ponderosa pine forests that had been either totally clearcut 3 years earlier, thinned 1 year earlier, or partially clearcut in strips 3 years earlier. Total sediment yield was highest on the watershed that had been totally clearcut. Although strictly limited to conditions at Beaver Creek, the analysis by Baker et al. (1971) was helpful in attempting to understand the relation of the 1970 Labor Day storm to some of the land management practices that had been implemented on the upland watersheds in Arizona at the time of the storm.

Restoration Activities

Restoration activities on larger, often perennial stream systems whose natural hydrologic functioning was damaged by the storm included corrective actions taken to mitigate the effects of boulder accumulations, timber-related debris, vertical stream banks, channel scour, sand and silt deposits, stream channel diversions, road and trail damage, loss of streamside vegetation, and bank-hanger and pedestaled trees (Arnolt 1972). Boulders were pushed against cutbanks to form riprap to stabilize the banks. Channels were cut through boulder fields to divert water through the boulders and away from stream banks. Margins of boulder accumulations were stabilized by leveling them out with dozers. Some of the timber-related debris piles were burned in place. Non-timber debris was removed from trees where it had lodged and was piled and burned. Logs were skidded onto high ground, decked, and either left there or loaded onto trucks and hauled to disposal sites. Bank-hanger and pedestaled trees were removed as a preventative measure. Large and long logs were placed at the bases of vertical stream banks; the tops of the banks sloughed off on top of many of them. Vertical stream banks were sloped with dozers to a stable angle of repose and seeded with grass species or planted with willows, alders, and other tree species. Backhoes and dozers were used to consolidate multiple channels created by the storm into one flow pattern by lowering one channel below the others.

Plantings of willow, alders, and other tree species restored much of the lost streamside vegetation. Live trees that were undercut by the flood were removed from stream channels and stream banks by cutting. Pedestaled trees that were situated part way up the bank where poor footing existed were felled by blasting with high explosives. The most extensive of these restoration activities occurred on the Tonto National Forest, including Tonto Creek from its headwaters to Bear Flat, the East Verde from its headwaters to East Verde Park, and Christopher Creek from its headwaters to the Ellinwood Crossing. On-the-ground surveys made in January of 1971 determined that approximately 13.7 miles of stream required restoration activities of some kind because of the potential hazard to life and property. All of this work was performed within the water influence zones of the various streams.

Sites Revisited

Insights on the degree to which upland watershed damages have been mitigated in the 30 years since the 1970 Labor Day storm have been derived from limited and largely qualitative observations from the Kohl's Ranch–Tonto Creek area and the Beaver Creek watersheds, and analysis of paired 35 mm color photographs (slides) from selected locations. One set of photographs was taken immediately after or within 1 year of the flooding. The second set of photographs was taken at these locations in October of 2000.

Channel Characteristics

Trees and other vegetative materials in the debris dams formed as the result of flooding have largely decomposed. Only a few larger tree parts and some of the larger sediments that accumulated behind the debris dams remain visible. Channel restoration on some of the streams after the flood has further obliterated signs of the dams. Most of the restoration took place on channel sites where high seasonal streamflow is expected and around bridges and culverts. Large boulders in channels remain where they were deposited in the flood. However, smaller sediments have washed away in the intervening time. It is not possible to relate subsequent streamflow volumes to the movement of these smaller sediments, either because the streams are ungauged or because gauging was discontinued at some point since the flood, precluding a complete record of streamflows. Vegetation has become established near the stream banks in some of the original boulder fields, especially on sites with low streamflow regimes. Evidence of channel scour remains at some locations, although accumulations of sediments are found in some instances. Vertical stream banks created by the flood also remain along channels that carried the larger flood flows. Some of these banks have sloughed off into the stream channels.

Status of Fishery Resources

Fishery resources have responded favorably to the restoration work on Tonto Creek and other perennial stream systems in the flood area. Creation of artificial pools and riffles and the reestablishment of streamside vegetation have especially benefited trout populations in these streams. The Tonto Creek Hatchery was rebuilt by the Arizona Game and Fish Department after being destroyed when a dam broke and sent a 35-foot wall of water down on the hatchery during the flood.

Effectiveness of Restoration Activities

Observations made in October of 2000 on the effectiveness of the restoration activities suggest that the hydrologic functioning of the treated perennial streams has been largely restored. Bank erosion is not excessive, streamflow response to precipitation appears relatively slow, and baseflow is sustained between storms. There are accumulations of sediments on many of the scoured channel bottoms. Streamside vegetation consisting of small trees, shrubs, and herbaceous plants has also been reestablished artificially and naturally along many of the streams to stabilize the banks and maintain water temperatures in a range favorable to the stocked trout populations. Although a rigorous benefit-cost analysis of the restoration activities has not been made, the investment made 30 years ago in restoring the natural hydrologic functioning of streams following the 1970 Labor Day storm seems justified.

Summary

The 1970 Labor Day storm caused more loss of human life than any other storm in Arizona's recent history. Many dwellings, roads, bridges, and other structures were also damaged or destroyed by the record flooding. Much of the widespread and unprecedented losses occurred in central and northeastern Arizona. Stream channels on many upland watersheds were detrimentally altered by breached debris dams of uprooted trees and other materials, depositions of boulder fields, channel scouring, and bank cutting. Some boulder fields were 10–30 feet deep, extending the width of the channel, and up to 2 miles in length. Streams were sometimes split into multiple channels by rock piles, often with insufficient flow to support fish populations. Damage to fishery resources was extensive. Restoration activities undertaken on the larger streams included corrective actions taken to mitigate the effects of boulder accumulations, timber-related debris, vertical stream banks, channel scour, sand and silt deposits, stream channel diversions, road and trail damage, loss of streamside vegetation, and bank-hanger and pedestaled trees. The most extensive restoration activities occurred on Tonto Creek, the East Verde River, and Christopher Creek.

Insights on the degree of damage mitigation after 30 years are derived from limited and largely qualitative observations from the Tonto Creek and Beaver Creek watersheds areas. Trees and other vegetative materials in the debris dams have largely decomposed. Only a few larger tree parts and some of the larger sediment accumulations remain visible. Channel restoration on some of the streams after the flood has further obliterated signs of the dams. Vegetation has become established in some of the boulder fields and many of the scoured areas have new accumulations of sediment. Creation of pools and riffles and reestablishment of streamside vegetation have benefited trout populations. Observations on the effectiveness of restoration activities 30 years after the 1970 Labor Day storm suggest that the hydrologic functioning of many of the treated streams has been largely restored. Bank erosion has not been excessive, streamflow response to precipitation appears relatively slow, and baseflow on perennial streams is largely sustained between storms. Streamside vegetation of small trees, shrubs, and herbaceous plants has been reestablished to stabilize most banks and help to maintain water temperatures in a range favorable to the trout populations.

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