ANALYZING THE FEASIBILITY FOR REROUTING THE RIO DE FLAG IN FLAGSTAFF, ARIZONA

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Abstract

A significant portion of the city of Flagstaff, Arizona, has been built on the Rio de Flag floodplain. A 100-year flood would result in economic, social, environmental, and regional impacts and damages that can devastate the community. Despite more than 20 in-depth studies about the flooding potential of the Rio de Flag, the city has taken very few precautions, except those required by the Federal Emergency Management Agency's (FEMA) flood insurance policy, issued in 1983. The draft feasibility report and environmental impact statement recommends the elimination of an existing detention pond and the construction of both open and closed channels as well as a new larger detention pond. Shortcomings of this approach include a paucity of data about the streamflow history of the Rio de Flag, and inadequate consideration of greenbelt issues.

Study Area

Flagstaff is situated on the Colorado Plateau just south of the San Francisco Mountains at an elevation of 6,900 feet (Fenneman 1931). Despite its location in a semi-arid climate, the altitude allows Flagstaff to experience four seasons that include hot summers and cold winters. The average annual precipitation is 20 inches, with nearly half occurring as snowfall (Hill 1988). Monsoonal winds bring moisture from the Gulf of California during the late summer and early autumn, causing heavy precipitation events (Fenneman 1931).

Most of downtown Flagstaff and the area along the Rio de Flag lie within a 100-year floodplain. Flooding in this area would affect many residences, businesses, and schools. A major flood in the downtown area occurred in 1923 and again in March of 1982 (Sellers 1985; Compass 2000). The latter inundated Flagstaff's streets, residential areas, and mobile home parks to a depth of several feet (Sellers 1985). The east side of Flagstaff was severely flooded in the 1950s by a flash flood, requiring a complete renovation of the storm drainage system along Route 66 and the Fourth Street commercial neighborhoods (Cline 1990). The last major flood in terms of discharge rate occurred in 1938, and on a volume basis in 1993 (Compass 2000). The past history of flooding within the city indicates that flooding events can occur during any season of the year.

Winter storms generally cover large areas and are usually of long duration. Summer storms are usually associated with tropical depressions (dissipating tropical cyclones) that have a short duration and cover a large area. Local storms, which are usually thunderstorms, generally occur during the summer, with high intensity and short duration. Intense short-duration rainfalls, heavy snowpack with ripe melting conditions, severe rainfall on melting snow, warm rain on snow during the winter with frozen ground conditions, or a series of storms can all lead to substantial runoff and flooding (Compass 2000).

Annual temperature extremes in the Flagstaff area typically range from 33°C to –18°C. The yearly average high and low temperatures are 16°C and 1°C, respectively. The prevailing winds are from the southwest with an average speed of 12–15 kph (Hill et al. 1988).

The geology around Flagstaff consists of a mixture of volcanic and sedimentary rocks. North of Santa Fe Avenue, the city is built on mostly volcanic rock, whereas the south side of the town lies mostly on sedimentary rock from the Kaibab and Moenkopi Formations. The nature of the exposed rocks directly affects the degree of runoff or infiltration. The rock types exposed at the surface in the Rio de Flag channel contribute to rapid infiltration of surface water through either their porosity (volcanic cinders and basalt) or their fractures (lava and calcareous sediment rock). The Soil Conservation Service (SCS) has established

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four hydrological soil groups according to their runoff-producing characteristics (Hill et al. 1988). Group A soils exhibit little to no runoff, and Group D soils exhibit abundant runoff. The Rio de Flag soils are in SCS group D. However, the watershed soils are mostly high in clay content (groups B and C), and when they freeze in the winter their infiltration rate is virtually zero (Hill 1988).

Streamflow Conditions

The Rio de Flag has not been gauged on a continuous basis, making long-term or current flow conditions unavailable. In 1969 the USGS established a network of gauging stations (Hill et al. 1988); the three gauges of interest here are located upstream of Flagstaff at Hidden Hollow Road, downtown, and downstream at Interstate 40. Figure 1 shows the annual peak discharges for these gauges (Hill et al. 1988).

USGS analysis indicates that discharges have recurrence intervals of 2, 5, 10, and 25 years. Peak flow conditions originate mainly in the urban areas, where there are few storm sewers, channel improvements, or storage areas, resulting in variations in computed discharge (Hill et al. 1988).

Problem Statement

According to the "Rio de Flag Draft Feasibility Report and Environmental Impact Statement" (Compass 2000), the major problem in the area is flooding, which results in inundation damage, railroad damage, emergency response costs, and transportation delays. Nearly half of the 100-year floodplain along the Rio de Flag is zoned as residential, with commercial accounting for nearly a quarter. Development within the floodplain is extensive (Compass 2000). The downtown and south side areas contain numerous registered historic structures, some over a hundred years old (Compass 2000; Cline 1990). If no action is taken the city of Flagstaff will continue to be subject to significant economic, social, and environmental consequences from severe floods. Approximately 1,500 existing structures, worth about $385 million, could suffer about $93 million worth of damage from a 1 percent flood event. A significant portion of Northern Arizona University lies within the floodplain, and during severe flood events the university would incur closing and other disruptions and physical damage to facilities and historic buildings on campus. Numerous residential, commercial, downtown business, tourism, and industrial properties would remain at risk.

Planning Objectives and Alternatives

The draft feasibility report and environmental impact study provides four important planning objectives: (1) Minimize flood damages to residential, commercial, public, industrial, and historic property. (2) Develop a comprehensive plan. (3) Provide consistency with local initiatives and the cultural and environmental character of the community, including aesthetics. (4) Protect and improve environmental and cultural resources. To achieve these objectives, seven alternatives were presented to the city.

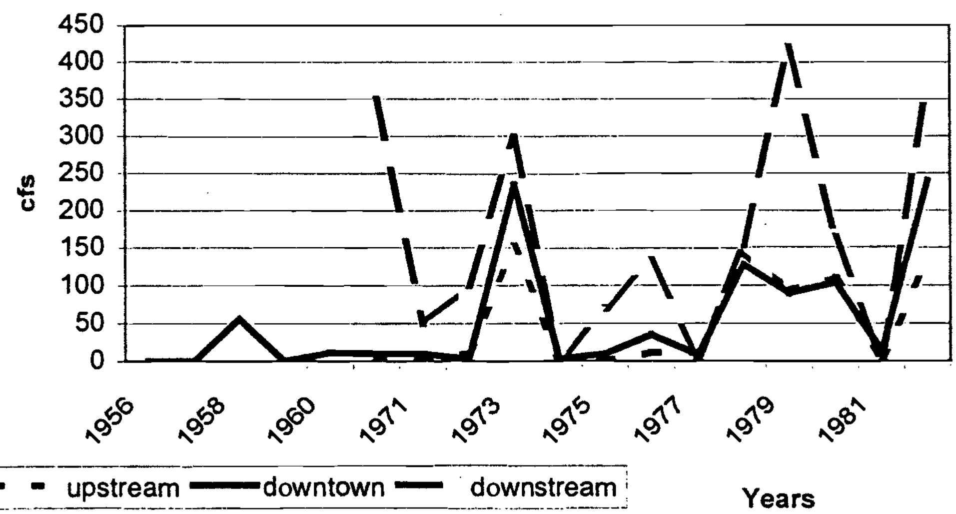

Figure 1. Annual peak discharges for three gauges used by the USGS around Flagstaff, Arizona.

Alternative 1 calls for the construction of flood walls at the Thorpe Park detention basin to minimize outflow into the Rio de Flag. The construction of a detention basin on Clay Avenue Wash west of Flagstaff is also included as a part of this alternative.

Alternative 2 consists of the construction of the flood walls at Thorpe Park as well as extensive channel improvement. The latter would include stretches of open and closed concrete, with earthen bottoms and natural rock revetment. Portions of the current Rio de Flag alignment would remain, with part being realigned to parallel the railroad tracks until the historic Rio de Flag is reached just downstream of Butler Avenue.

Alternative 3 proposes construction of the detention basin on Clay Avenue Wash and a rectangular concrete channel upstream of the Railroad Springs development. Channel improvements of the Rio de Flag from this point are similar to those presented in Alternative 2.

Alternative 4 represents a full channelization plan, with no detention basins. The improvement of Clay Avenue Wash, as presented in Alternative 3, is also included as a part of this option.

Alternative 5 includes both the construction of the detention basins and channel improvements along Clay Avenue Wash and the Rio de Flag upstream of Birch Street. Further channel improvement between the confluence of the two washes and Butler Avenue is also planned.

Alternatives 6A, 6B, and 7 were presented after reevaluations of the engineering, design, and cost of Alternatives 1–5. Alternatives 6A and 6B are similar except for channel treatments along the Rio de Flag between Cherry and Birch Avenues. In Alternative 6A this part of the channel is riprap construction, whereas Alternative 6B calls for a covered concrete arch channel. Both exclude construction of the Thorpe Park detention basin.

Alternative 7 consists of constructing one detention basin upstream of Thorpe Park in addition to the two previously presented detention basins and channel improvements along the Rio de Flag.

Selected Plan

Alternative 6B was selected by the city of Flagstaff because it would "provide flood protection along the Rio de Flag's Downtown Reach and would also reduce flooding along the Clay Avenue Wash" (Compass 2000). Except for portions of Clay Avenue Wash just downstream of the new detention basin, its construction in combination with the channel modifications along Clay Avenue Wash and the Rio de Flag would prevent residual flooding during a 100-year event.

The detention basin along Clay Avenue Wash would allow for the discharge to be over a period of 50 to 60 hours after the basin reaches maximum storage—allowing for an extended period of flow in downstream channels. The design includes an emergency spillway for flood events in excess of the 100-year level of protection and also to prevent basin failure.

Changes at Thorpe Park will consist of new structures on the southern and eastern boundaries of the park. The structures along the southern boundary will be small embankment-wingwalls to direct flows into the existing channel downstream and away from existing development. The eastern boundary of the park will have a series of flood walls to ensure that water does not overtop this part of Thorpe Park, which would flood the adjacent residential area to the east and south. Both the southern and eastern structures will be constructed with aesthetically pleasing local rock fascia, with appropriate native trees and other vegetation (Compass 2000).

Channel modification will be extensive, including stretches of open and closed concrete with earthen bottoms and natural rock revetment along both Clay Avenue Wash and the Rio de Flag (Figures 2 and 3). This alternative also includes adding a greenbelt immediately after the covered concrete streambed (Figure 4). The greenbelt would be located in an established commercial zone to help distribute flood flows before entering the canyon southeast of historic downtown.

Discussion

There are several problems with the placement of concrete structures in the streambed. The placement of open concrete channels, riprap channels, and concrete culverts upstream of a significant greenbelt could be hazardous to the longevity of the downstream greenbelt habitat. Concerns that should be addressed before implementation of this project include reduction of the local water table and water quality due to channelization structures impeding infiltration and capturing non-source point pollution.

The two detention basins at Thorpe Park and Clay Avenue are expected to help reduce the peak flow rate by redistributing runoff over time and enhancing groundwater during and shortly after large storm events (Hall 1984). These basins will

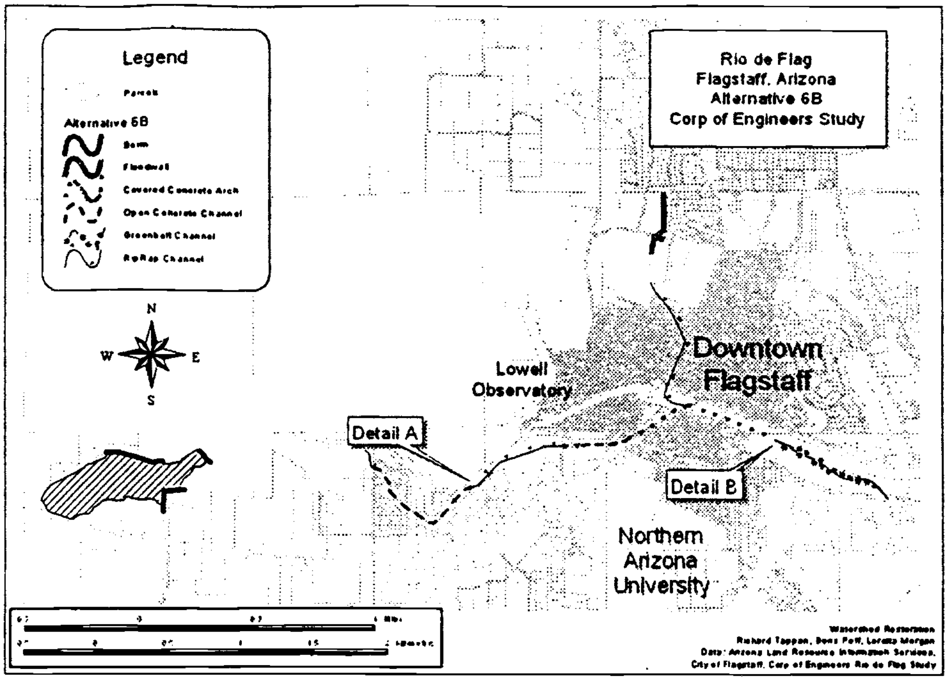

Figure 2. The proposed Alternative B.

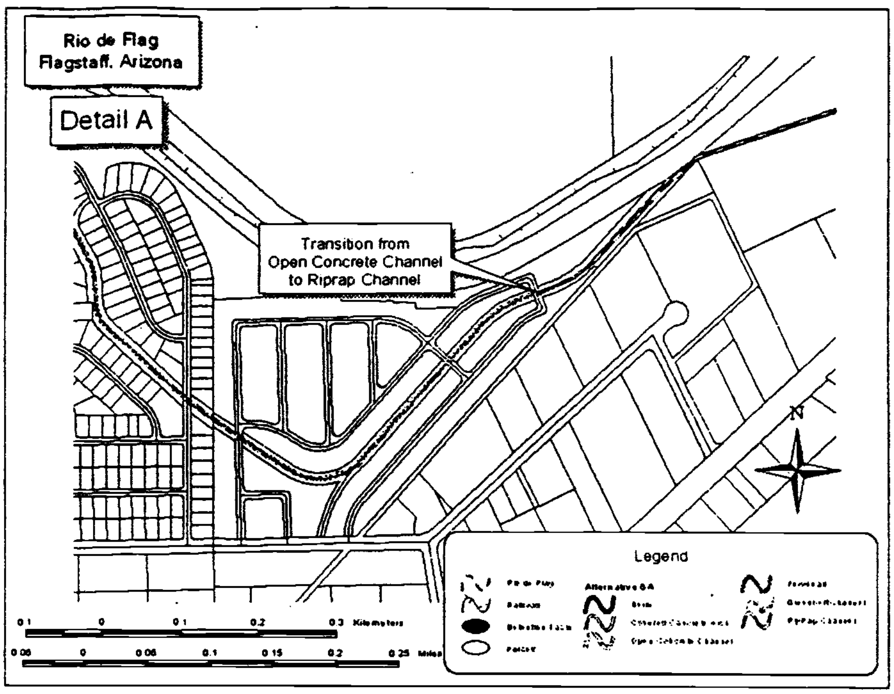

Figure 3. Detail of the proposed Alternative B.

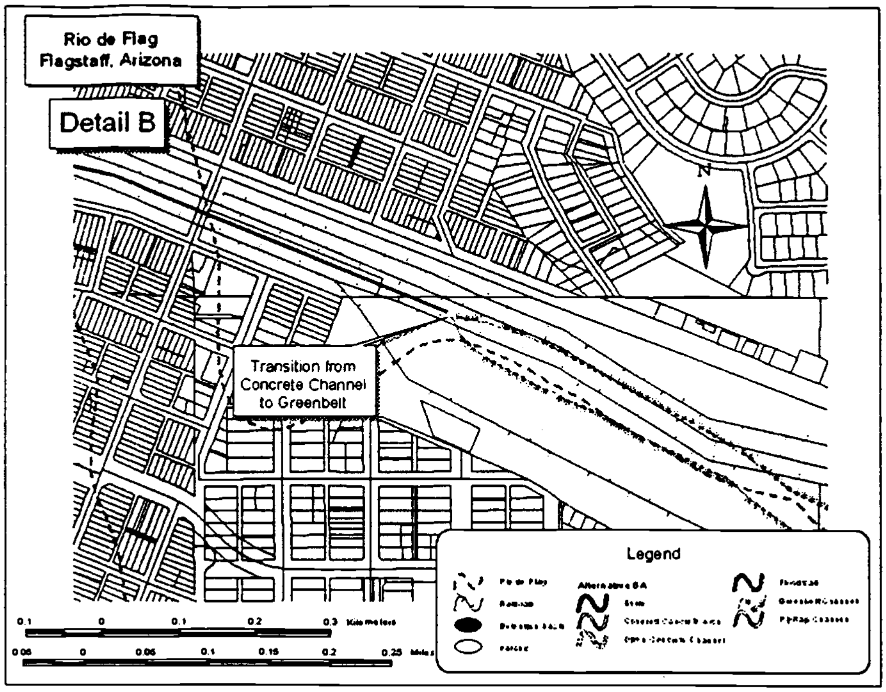

Figure 4. Detail of the proposed Alternative B.

also help waterborne solids to settle out of solution and thereby improve water quality. However, most of this benefit could be negated by the multitude of small to medium scale storms that will carry the bulk of the pollutant load downstream (Gordon et al. 1993).

The basins are located directly upstream from the channelized sections of the Rio de Flag that are of greatest concern to the well-being of the downstream greenbelt. Clay Avenue Wash, the major tributary, combines with the Rio de Flag south of Thorpe Park, posing a considerable problem in the center of town at San Francisco Street. At maximum carrying capacity the two washes join together in a concrete culvert that can accommodate only two-thirds of the total water. Clay Avenue Wash consists of riprap and open concrete channels with a cross section of 132 square feet. Open concrete structures and open channel riprap are proposed for the wash south of Thorpe Park with a cross section of 192 square feet. Both of these washes lead into a culvert 204 square feet in area. It is doubtful that the culvert is large enough to handle a 100-year flood event.

The concrete culvert at San Francisco Street is the last concrete emplacement before the greenbelt. Flow velocities entering this fragile area are most likely greater than the greenbelt's capacity to handle without creating serious erosion. Channelization, or straightening and lining of a stream corridor, increases channel slope and thus water velocity and sediment transport capacity (Gordon et al. 1993). If the stream is starved for sediment due to the upstream catchment basins, erosion problems may result downstream (Riley 1998). Adjusting the sediment budget for the stream could cause erosion in the downstream reaches, slowly working back upstream and causing bank collapse and bank erosion, and locally enlarging the channel width by two or three times (Riley 1998).

According to geomorphologist Robert Curry, streams that overtop their channels during high stage flow "with their ... higher velocities will ... often assume a braided or meandering pattern much to the detriment of the city established along its banks" (Riley 1998). The separation of a channelized stream from the floodplain will hinder the ability of the floodplain to store, release, and direct waters, thereby increasing the downstream flood peak (Gordon et al. 1993).

The greenbelt downstream of the structural channel modifications will help to slow the stream flow moving toward the east side of town, as well as acting as a recharge area for the local water table. There is potential that the created natural beauty will serve as a recreational area given that facilities will be provided. However, the proposed greenbelt is too short a corridor for the flood volume that will be transported through the area. As the flood waters enter the greenbelt, the velocities coming out of the open concrete channel and concrete culvert have the potential to strip the entrance of the greenbelt of all vegetation and redeposit the material further down where velocities will be decreasing (Hall 1984). This in turn might have the effect of damming the stream channel and driving the flood waters out of the greenbelt and into the neighboring areas.

Additional Suggestions

Regarding Alternative 6B, it is unknown how much of a possible flood would be contained within the proposed detention ponds and concrete streambeds, as discussed earlier, because no exact flow rate data are available for the Rio de Flag. It is therefore difficult to make any useful and reasonable suggestions other than those proposed in the alternative projects listed above.

Also, the planning of the proposed greenbelt appears to be inadequate. The greenbelt will be located in an industrial area, but no studies have been conducted on the possibility of chemical pollutants, which are likely to occur in an area after 100 years of industrial use. The greenbelt is designed to slow the floodwaters and recharge the groundwater, but it may inadvertently pollute the watershed downstream, as well as the groundwater. Further, it is doubtful that the Rio de Flag will provide enough moisture to sustain a greenbelt adequate to minimize the erosion concerns mentioned in the discussion. A combination of native sedge grasses (*Poa* spp.) and willows (*Salix* spp.) would be ideal for slowing down the potential velocity of the floodwaters (Kolb and Moore 1999; Briggs 1996). However, these species require a certain amount of moisture, which will not be guaranteed. Would the city of Flagstaff be willing to artificially irrigate the greenbelt if it becomes necessary? These issues should be addressed before any alternative is implemented.

Further, the feasibility report lists several planning objectives, including "the protection and improvement of environmental and cultural resources as well as the provision of consistency with local initiatives and the cultural and environmental character of the community including aesthetics," but there is no indication that these planning objectives were considered. Instead it appears that the only planning objective addressed was how to protect most of the city while spending the least amount of money. Perhaps a survey could assess the views of the local residents about the aesthetics of a concrete channel compared to the other alternatives. In other parts of the country communities are restoring natural channels where the U.S Army Corps of Engineers has constructed concrete channels, often at greater expense than the original project.

One possible alternative would be building the detention basins at Clay Avenue Wash and above Thorpe Park as well as improving the existing detention basin. Instead of a concrete channel, perhaps a clean-up and restoration of the existing channels of the Rio de Flag should be considered. Such an alternative addresses all of the planning objectives outlined in the feasibility study (Riley 1998). Geographers, hydrologists, and hydraulic experts have found that such traditional engineering techniques have unanticipated performance problems (Riley 1998), as mentioned above.

Conclusion

The U.S. Army Corps of Engineers provided several alternatives to help the city of Flagstaff to curb the risk of future potential flooding. Alternative 6B, which was selected by the city, appears to be the most feasible of the alternatives provided. It suggests two detention ponds upstream of the floodplain as well as both open and closed concrete channelization of the stream, followed by a greenbelt. However, there are still several shortcomings. Some of these shortcomings are caused by the lack of information on the volume and intensity of flow that can occur in the Rio de Flag and its tributaries. This missing data has led the U.S. Army Corps of Engineers to rely on their best estimates of future flows. The other shortcoming is the inadequate planning for a greenbelt, which might lead to pollution and further flooding downstream of the modified channel. Further studies should be conducted on the effects that the selected alternative will have downstream and which type of greenbelt vegetation should be implemented and how. None of the alternatives provided, including Alternative 6B, address all of the planning objectives outlined by the feasibility study. An alternative that includes a total of three detention ponds, but refrains from the construction of any concrete channels, might be a better solution.

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