HYDROLOGY AND STREAM CHANNELS

Stream Morphology

Reference Conditions

Reference conditions within the Upper Greenbrier Watershed can only be speculated upon, since all the subwatersheds, and the streams that drain them, have been substantially altered by past and, to a lesser extent, present day land use. The dominant land use that has affected how streams and watersheds look and function today is logging and access development that occurred primarily between 1900 and 1920. Also, substantial clearing for livestock grazing, and some hay production, in some localized areas has substantially modified riparian and aquatic conditions in those streams, and downstream. Some of the present day transportation system, and older access roads and trails, also are having effects within the watershed.

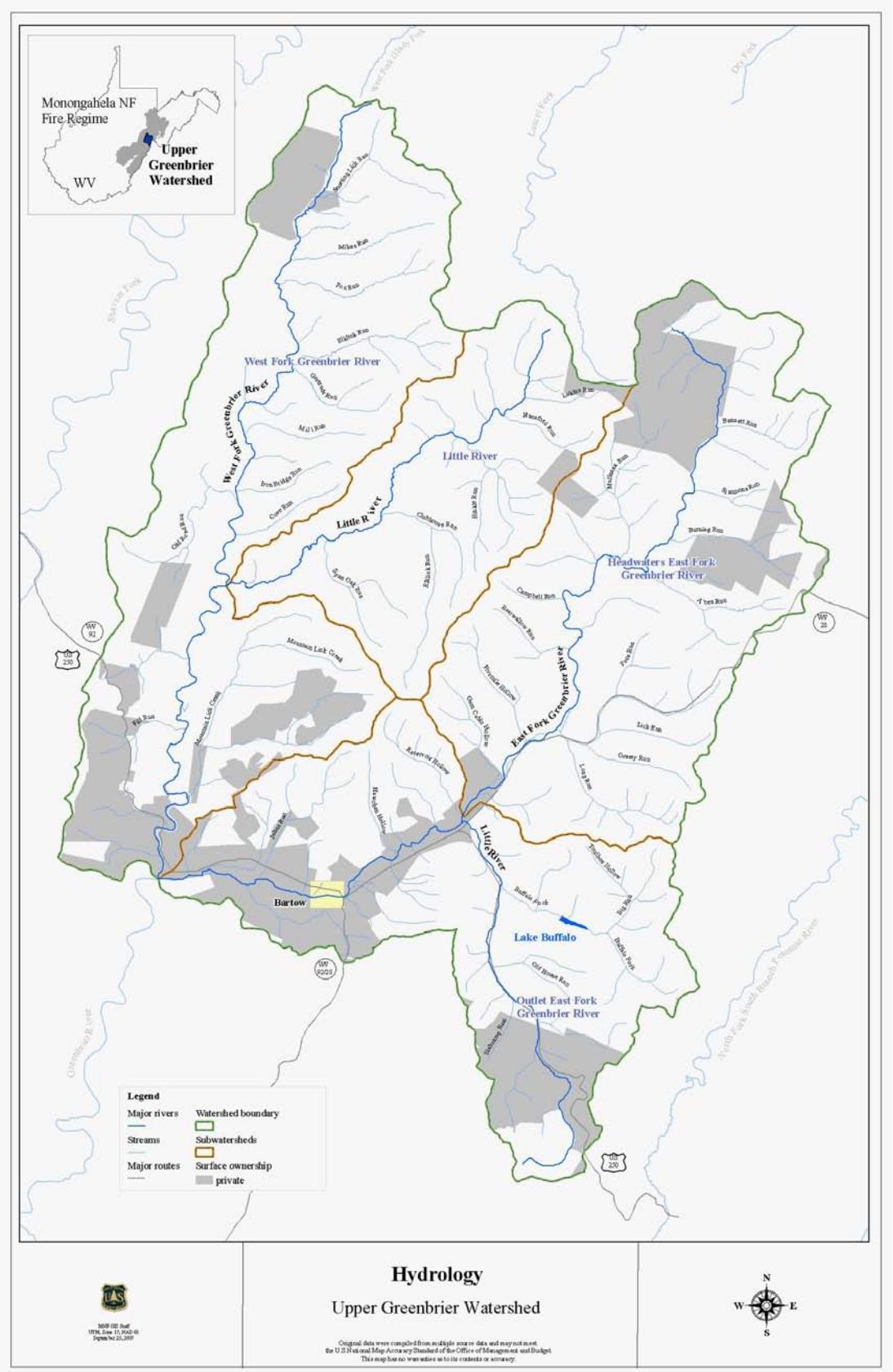
Streams have developed in response to the soils/geologic/topographic and vegetation conditions within the watershed, precipitation characteristics, and past and present land uses that occur. Streams exhibit a combination of stable and unstable forms, which reflects the influence of natural stream processes and the effects of certain land uses within the subwatersheds. Some portions of channels exhibit channel bank erosion, and there are sections of channel deposition as well. Some of this is a natural process, and part of the "dynamic equilibrium" nature of streams. However, the effects of roads and other land uses, riparian clearing, and within channel modifications such as loss of large woody debris contributes to channel changes from more stable to less stable forms.

Stream channel morphology in the late 1800s, before extensive timber harvesting occurred, was likely substantially different than the channel shape and condition of today. In general, channels would have exhibited more stable forms, with narrower width and more quality habitat features. There would have been considerably more large woody debris in the channels, contributing to long-term morphological stability and habitat quality and complexity. Channel profiles would have been more stable, with greater channel roughness to dissipate energy. Non-perennial headwater channels, and small perennial channels would have exhibited more of a step-pool profile. Less channel incision would exist, and floodplain function would have been improved. Channels would have been better "connected" to their floodplains, and floodplains would have performed their natural function of storing floodwaters more efficiently than in some present day locations. These conditions would have reduced flood energy within the channels, reducing the amount of bank erosion and instability. Overall, channels would have tended to be narrower, and base flows deeper.

Current Conditions

There are at least 263 miles of perennial streams in the Upper Greenbrier Watershed. The major streams in this area are the East and West Forks of the Greenbrier River, Little River that drains into the West Fork, and Little River that drains into the East Fork. There are no natural lakes, but 22-acre Lake Buffalo was created in the 1960s (Map 3-1).

Map 3-1. Major Water Features in the Upper Greenbrier Watershed



Streams within the assessment area have developed within watersheds underlain by sedimentary rocks, predominantly shales, siltstones and sandstones, within topography of moderate to relatively high relief. The maximum elevation difference within the watershed is approximately 1,900 feet. A thin band of Greenbrier limestone outcrops on the east flank of Shavers and Back Allegheny Mountains, west of the West Fork. Slopes are moderately to very steep (up to 60 percent and more) in some parts of the watershed, especially on slopes immediately west of the West Fork, and on mountain sides in the southern half of the watershed. Large areas of moderate to somewhat gentler slopes occur throughout the watershed however, particularly along the upper ridges and ridgetops, and in the northern half of the watershed. Portions of the East and West Forks of the Greenbrier River, Little River, and limited portions of some tributaries, have developed moderately wider floodplains; otherwise floodplains are mostly narrow. Perennial streams exhibit a range of channel entrenchment from high (narrower flood prone areas) to low.

Channels have developed under these conditions of geologic and soil parent materials, topography, land uses, and climatic conditions. Stream morphology has been influenced by past and present land uses, particularly the historic logging that occurred between 1901 and 1920. Essentially the entire Upper Greenbrier Watershed was logged during that time, by especially harsh methods that had severe impacts on soils and streams.

Turn of the century logging developments and practices that impacted stream stability and morphology included the construction of logging camps and mill towns, mill ponds, log drives on the East and West Forks, and logging railroad lines and roads, among others.

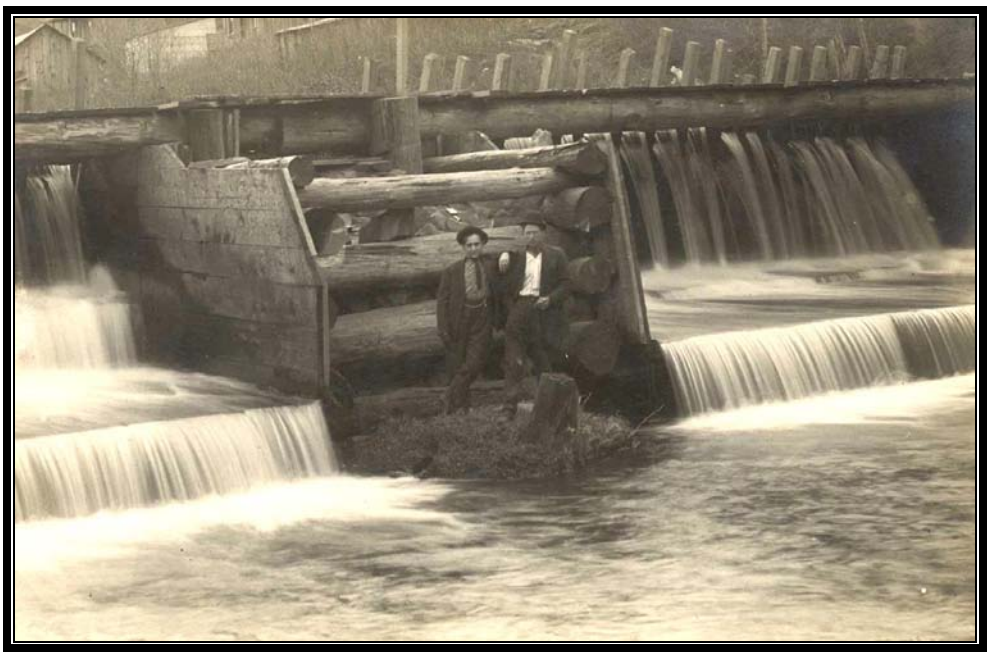


Figure HY-1. Mill Pond Dam at Burner, Circa 1905

There is no known physical evidence visible today of splash dams being used in the Upper Greenbrier Watershed, although log drives did occur on the main stems. Splash dams on

tributary streams are believed not to have been used because the tributaries were logged by railroad transport.

These logging developments affected streams and rivers by removing the riparian forest, converting riparian areas to wood processing and storage facilities and mill towns, damming streams and rivers for mill ponds and modifying runoff characteristics, filling or occupying channels, creating widespread severe erosion of the landscape, and delivering enormous amounts of sediment for many decades. Channels still exhibit the effects of such practices, and are in a long, slow state of recovery.

More recent land uses within the watershed that affect stream condition include natural gas well development and pipelines associated with the Horton Field and Glady Storage Field, federal and private timber harvesting, a dense network of state, Forest and private roads (some of which closely follow and cross streams), some agriculture and livestock grazing, and residential and industrial uses mostly in the Durbin, Frank, and Bartow corridor.

Stream Channel Types

Rosgen Stream Types (channel types) is a method of classifying and describing streams (Rosgen 1996) based on morphologic and pattern characteristics and channel substrates. Classification is based in part on stream measures of channel entrenchment, width/depth, sinuosity and channel slope, and the occurrence of single-thread or multiple channels. The method leads to classifying a stream with a letter designation (A through G) that describes the range of stream types, and lumps streams with similar physical and behavior characteristics together.

Very little quantitative data was available for stream classification in the assessment area. Field observations and professional judgment are the primary basis for description of the stream types represented within the Upper Greenbrier Watershed.

Smaller perennial and non-perennial channels are expected to be largely “A” and “G” channel types, and with some segments of “B” channels as well (Rosgen 1996). “A” channels are entrenched streams with low sinuosity, low width to depth ratios, and moderately steep to steep gradients. “G” channels are entrenched with moderate sinuosity, low width/depth ratio and moderate gradient, sometimes forming within gully-like channel segments, and often are unstable streams with high bank erosion rates. “B” channels are moderately entrenched, with moderate sinuosity, width/depth ratios and gradient, and generally are stable streams with stable banks. Larger perennial tributaries to the East and West Forks are likely a mixture of stream types, including “B” and “C” and “G” channels. “C” channels are also stable channels but with low entrenchment and gradient, and higher width/depth ratio and sinuosity. Some “C” channel segments have been typed (measured) in perennial tributaries to the West Fork.

Also, some “E” channel types have been found within low gradient segments of tributaries to the West Fork, such as Mikes Run, and these tend to be highly sinuous with low entrenchment and very low width/depth ratios. “E” channels are generally stable, with wider floodplains and well-vegetated banks, although some “E” channels may be forming in old alluvial deposits. The causes of that deposition may include a variety of factors including natural landform shape,

historic beaver damming influence, and the disturbance and sedimentation associated with turn of the century logging.

Few "D" channel type (braided channels with low entrenchment and high width/depth ratios) streams have been observed within the assessment area, although they could potentially occur to a greater extent than what is known. "D" channels often occur in aggrading stream situations with higher bedload and eroding banks. Some areas in the upper East Fork may have "D" channels, especially where grazing influence is greater (such as on some private lands), although this is speculative. A segment of "D" channel occurs in the main stem of the East Fork Greenbrier River upstream from Island Campground, and in short sections of Poca Run.

The main stems of the East and West Forks may have limited segments of "D" channel type. But the predominant channel types in these rivers is expected to be "C", "B" and "G", with small inclusions of "F" (wide, low gradient channels, highly entrenched and with moderate sinuosity, and typically high bank erosion rates).

Stream morphology is influenced in portions of some perennial tributaries by substantial alluvial deposits along those streams, especially within the watershed of the West Fork (Mikes, Fox, Elklick, Gertrude, Mill and Cove Runs and Little River, for example). These lengthy stream segments are largely devoid of woody overstory in the riparian zone, and portions of their riparian habitats are typed as wetlands. Stream morphologies in these areas are likely to be slowly evolving from less stable to more stable types, partly because of the open, herbaceous nature of the riparian areas, although this is where some of the stable "E" channel type has been observed.

In general, stream types within the assessment area are a combination of stable channels and unstable channels. The unstable channels have likely developed in response to natural factors (sedimentation and floods), but more so to historic and recent land uses. Historic logging in the early 1900s is likely the dominant land use influencing channel morphology today, because of the widespread harvesting of the entire watershed, and the destructive treatment of riparian areas and the stream channels themselves. Other land uses that continue to influence morphology have been mentioned above. Of these, roads are likely to be the dominant factor in driving channels toward an unstable condition, largely by concentrating and speeding runoff to the stream system, and increasing rates of sedimentation and bedload. Timber harvesting contributes to the problem through truck and skid road development, and their effects on runoff and erosion rates. Grazing also contributes with increased erosion rates and loss of woody riparian vegetation.

Desired Conditions

Stream channel and bank stability is protected during management activities. The physical integrity of aquatic systems, stream banks, channel substrates and other habitat components are intact and stable. Where channel shape is modified (e.g., road crossings), the modification preserves channel stability and function (Forest Plan, p. II-9).

Flow Rates

Reference Conditions

Reference conditions of streamflow would also be somewhat different than flows as they exist today. The primary factors that control those differences are the amount of present day roads, skid roads, old woods roads and railroad grades, compaction, and land clearing. Streamflow would have been somewhat less flashy in presettlement times, because there would have been less channel extension from the present and old transportation network, and less compaction from a variety of land uses. It is likely that base flows and low flows would have been somewhat greater than the present day, because the effective drainage density (length of channel per unit area) would have been less, and soil infiltration would have been greater.

In subwatersheds affected by present day clearing and conversion to livestock grazing, the reference condition would have been a nearly intact forest throughout almost all of the watershed. Primarily small openings would have existed as part of the natural forest condition, caused by infrequent and small mass wasting events, fire, wind-throw and flood damage, and some other naturally occurring influences. Largely intact forests would have had greater evapotranspiration losses, so streamflow in those subwatersheds would have been somewhat less during the growing season. The magnitude of this effect would have been relatively small. However, greater infiltration and soil storage would have existed in the reference condition, because roads and compaction from grazing would have been absent. So to some extent, there would have been offsetting factors in those localized areas where openings now exist.

Also, timber harvesting (as we know it today) would not have existed in the presettlement era. Timber harvesting in the East has been found to increase the annual water yield from harvested area, with the majority of those increases occurring in the growing season and mostly as increased base flows and low flows. But those water yield increases are relatively small and short term, with streamflow returning to pre-harvest levels in about 10 years or less. In the reference condition, streamflow would have been unaffected by harvesting, so yield increases would not have occurred. However, compacted roads, skid roads, and railroad grades did not exist, so precipitation would have infiltrated and been detained more efficiently.

Overall, streamflow in the reference condition was very likely to have been somewhat more evenly distributed and not as flashy. Soil moisture storage was greater and release to the stream channels was slower. Base flows were likely greater than the current condition, as well as low flows. But the magnitude of this difference is difficult to assess. Greater base flows, especially low flows under the reference condition, combined with narrower channels and more large woody debris, would have maintained better quality habitat in the streams.

Current Conditions

Streamflow within the various subwatersheds tends to be highly variable, dependent on season, rates of evapo-transpiration, and precipitation patterns. The nearest streamflow gage for quantifying flow characteristics is on the Greenbrier River main stem just below the confluence of the East and West Forks at the town of Durbin (immediately downstream of the Upper

Greenbrier assessment area). The drainage area for this gage is 133 square miles, the same as the Upper Greenbrier assessment area. Mean annual discharge at this gaging station for the 1943 to 2003 period of record is 265 cfs (cubic feet per second; equivalent to 1.99 cubic feet per second per square mile, or 27.07 area inches of annual runoff), but the highest and lowest annual means were 472 cfs (1996) and 164 cfs (1999), respectively. Monthly mean discharge ranges from 570 cfs in March, to 71.7 cfs in September. The highest mean monthly discharge occurred in November 1985 (1,336 cfs), while the lowest occurred in September 1953 (1.82 cfs). The highest daily mean flow of 13,200 cfs, and the maximum peak flow of 37,100 cfs, occurred on November 4, 1985, while the lowest daily mean flow of 0.5 cfs occurred in September/October of 1953, 1968 and 1995. The variable nature of flows within the upper Greenbrier river system is further described by the flow value exceeded for a specified percentage of time (in this case the period of record):

10% of flows exceed	617 cfs
50% of flows exceed	139 cfs
90% of flows exceed	16 cfs

Thus, the highest 10% of flows exceed 617 cfs, while the lowest 10% of flows are 16 cfs or less. The median flow is 139 cfs (compared to the mean annual discharge of 265 cfs). In the 2003 water year, mean annual discharge was 457 cfs, while the highest and lowest daily means were 4,120 and 39 cfs, respectively. The difference between high and low flows is, therefore, very great.

These data, and what is known about the watersheds, indicates that streamflows are highly variable by season, and dependent on seasonal and precipitation characteristics. Evapo-transpiration losses in the vegetative growing season contribute most to lower streamflows. Also, snowmelt in the late winter and spring contributes somewhat to higher streamflows.

As mentioned, streamflow tends to be not only variable, but higher runoff rates can be flashy, responding quickly to the influence of topography and soil/geologic characteristics, soil moisture conditions at the time of precipitation, rainfall amounts and intensity, and to land uses as well. Also, intense summer storms and large frontal system storms are common, as are periodic drought conditions, adding to the wide range of flow conditions in these streams.

As discussed above, streamflow has been influenced by land uses in the Upper Greenbrier Watershed. Some increased runoff occurs in certain portions of the streams where private land clearing has taken place. Runoff rates are also affected by compaction within the watershed, such as in grazing areas, on roads and highways, and other uses that substantially disturb and compact soils. Also, roads and other facilities that intercept surface and shallow groundwater have the effect of concentrating and speeding flow away from the upper portions of the watershed. Less water is available for soil storage and floodplain recharge. This likely is having the effect of increasing flows during storm runoff and snowmelt situations, but also reducing base flows and low flows as well. Thus, flows are re-distributed to a less even flow condition. The magnitude of this effect could be substantial in some localized areas, but its overall effect within the watershed is less clear.

These changes in flow conditions are likely having an effect on the morphology of the upper non-perennial streams, and to some extent the downstream perennial streams as well. Altered flows also increase the fine sediment supply to aquatic habitats, and during low flows the available aquatic habitat is reduced, putting an even greater stress on aquatic biota.

Desired Conditions

Streams are in dynamic equilibrium; that is, stream systems normally function within natural ranges of flow, sediment movement, temperature, and other variables that provide for healthy aquatic systems (Forest Plan, p. II-9).

Storm Flows

Reference Conditions

Reference conditions for storm flows would have been unaffected by the land uses that came later, such as old roads and railroad grades, present day roads, timber harvesting, and land clearing for hay and grazing. Of these, the dominant influences are felt to be old roads with inadequate drainage, and lands cleared for grazing. In general, storm flows would have been slightly to moderately less (less volume) because of the undisturbed nature of the subwatersheds. Storm runoff would have been less concentrated and slower, with a greater percentage of the precipitation being detained in the soil for slower release. The greatest difference between the current and reference conditions would likely have been for the smaller to moderate sized storm events. Also, floodplain function would have been more effective in presettlement times, and a greater proportion of flood flows would have occupied the floodplain, reducing the erosive energy within the stream channels.

Storm peak flows in presettlement times may have been substantially different compared to today for major flood-producing storms, particularly during the dormant season when most floods occur. Overall, smaller storm flows or longer storm flow duration, and greater floodplain storage in presettlement times would have meant less erosive energy within the stream channels. Stream channels would have generally been more stable, with less channel bank erosion and sediment deposition within the channel. Aquatic habitat would have been higher quality because of the greater bank stability, less sediment deposition, lower fine sediment, and other habitat features. This condition of greater stability and less channel erosion would have existed in all of the subwatersheds.

Current Conditions

Stormflow within the assessment area is characterized as intense and frequent. Streams are frequently flashy in their response to larger storms, especially more intense storms. Streamflow tends to rise rapidly under those conditions, and falls rapidly as well, returning to base flow conditions rather quickly. Major frontal weather systems and tropical storms from the south can carry very substantial quantities of rainfall. The largest 24-hour rainfall event for this area that occurs annually, on average, is about 2.5 inches (US Weather Bureau 1961). However, periodic storms occur with much greater amounts and intensities of rainfall. Major storm events can be

fairly frequent, and generally occur during the dormant season of the year (November through mid-May) when evapotranspiration losses are minimal. This further adds to rapid storm runoff, and in less frequent cases to downstream flooding. Examples of recent dormant season major runoff events include the November 1985 flood, and the January and May 1996 floods.

Stormflows can be further influenced by land use activities and roads within the watershed. Land uses that reduce soil infiltration and water holding capacity, and reduce riparian vegetation, contribute to increased stormflow and stormflow effects on stream channels. Road development can act to extend the channel system within the watershed, intercepting soil water, concentrating flows, and speeding runoff to downstream areas. As mentioned above, the Upper Greenbrier Watershed has a very dense system of roads in place, a combination of State, Forest and private roads, and roads serving natural gas well sites. Ground-based timber harvest activities can have some of these effects as well, through truck and skid-road development. Extensive watershed harvesting of timber can sometimes alter the hydrology and stormflow characteristics of the watershed. Historic logging, discussed above, is believed to have had substantial adverse effects on watershed condition, runoff, and stormflow characteristics. Grazing and agriculture frequently have detrimental effects on streams through soil compaction, reduced infiltration, and loss of healthy riparian vegetation. Grazing occurs in the upper headwaters of the East Fork drainage.

More recent National Forest timber harvesting has occurred in various portions of the watershed, totaling around 3,600 acres in the last 15 years, which is about 4 percent of the watershed, or about 5 percent of NFS lands within the watershed. System, temporary, and skid roads were developed for those activities. An extensive system of old woods roads and trails also occur on NFS lands, and some on private lands. Old railroad grades from historic logging extend up most of the perennial tributaries and along some intermittent streams as well. This assessment describes numerous road types and their locations, and their collective mileages are very substantial. There are an estimated 143 miles of old woods roads, with nearly 18 of those miles in riparian areas. Forest classified roads total an estimated 181 miles within the watershed, and over 30 of those miles fall within riparian zones. There are over 260 road stream crossings on all classified and unclassified roads within the watershed, and most of the 80 or so crossings on unclassified roads are likely directly through a stream channel. See the Roads section of this chapter for more information on the existing road network.

State and federal highways occur within the watershed, especially Routes 28 and 250. These highways concentrate and speed runoff to a greater extent because of their paved, wide surfaces, ditchlines, and higher road cuts.

The cumulative effect of all these facilities and land uses is to capture and concentrate flows, and speed runoff to downstream portions of the watersheds. Stormflows can be impacted when water moving downslope in the soil is brought to the surface at road cuts, when infiltration and evapotranspiration are reduced, and when surface runoff is concentrated and delivered to stream channels more quickly. Rates of runoff, stormflows, and channel stability and morphology can be affected by the cumulative impacts of these land uses and developments, but the magnitude of the effect depends on a complex interaction of factors.

Desired Conditions

Wetlands and floodplains function as detention/retention storage areas for floodwaters, sources of organic matter, and habitat for aquatic and riparian species. Streams are in dynamic equilibrium; that is, stream systems normally function within natural ranges of flow, sediment movement, temperature, and other variables that provide for healthy aquatic systems (Forest Plan, p. II-9).

Figure HY-2. East Fork Greenbrier River Near Island Campground