Appendix D: Table and diagrams of risk factors

Table D.1. Summary table and diagrams of risk factors that may influence a system's vulnerability to the two primary threats: 1) loss of stabilizing vegetation and 2) channel impairment. First-order processes (i.e., those that are first to occur) are shown in orange and lead to primary threats designated by a number 1. Secondary processes (those that are set into motion as a result of primary processes or threats) are show in light gray and lead to secondary threats designated by a number 2.

Risk factors	Processes					Threats	
	Erosion/ increased sediment	Altered stream flow	Lowered water table	Decline of riparian vegetation[1]	Reduced access to floodplain	Impaired stream channel	Lack of riparian vegetation[1]
Channelization: ▪ Mechanically straightening, redirecting, or otherwise confining a natural stream, often involving the installation of riprap or construction of berms to reduce the risk of flood damage to other resources. ▪ These techniques decrease sinuosity resulting in increased stream velocity which threatens stabilizing riparian vegetation and increases the risk of erosion, which can ultimately increase channel depth, and further restrict access to the floodplain. ▪ As the channel depth increases downstream, upstream channels are at higher risk of headcutting as the stream equalizes its gradient.	☑	 velocity	☑	☑	☑	1	2
Roads: ▪ Roads function as extensions of the stream system and can focus flow and sediment into streams. Roads can also alter the duration and volume of stream flow. Runoff peaks can be higher and low flow periods longer. ▪ Roads in the floodplain can confine the stream, having similar effects as channelization increasing stream energy, velocity, and erosion. ▪ Undersized culverts at stream crossings can concentrate flows and increase water velocity, ultimately causing channel incision or erosion downstream. ▪ Riprap installed to protect roads shifts the energy of flowing water downstream, potentially causing erosion elsewhere (see channelization).	☑	 velocity, volume	☑	☑	☑	1	2

[1] Native stabilizing riparian vegetation

1 = Primary threat 2 = Secondary threat

Risk factors	Processes					Threats	
	Erosion/ increased sediment	Altered stream flow	Lowered water table	Decline of riparian vegetation[1]	Reduced access to floodplain	Impaired stream channel	Lack of riparian vegetation[1]
Roads (continued) ▪ Roads that cross meadows can concentrate natural diffuse low-velocity flows, creating channels where none may have existed, causing channel incision and disconnection of meadows from the water table.	☑	↑ velocity, volume	☑	☑	☑	1	2
Drought or dewatering: ▪ Long periods of drought or dewatering deprive stabilizing vegetation of moisture due to a lowered water table, causing plant mortality. ▪ Depending on the severity of riparian vegetation loss, streambanks may become susceptible to erosion and channel impairment.	☑	↓	☑	☑	☑	2	1
Incompatible irrigation management: ▪ Diversion of water for agricultural artificially manipulates the flow (quantity, timing and pathway) of water. ▪ Irrigation may divert water such that the natural channel is dewatered (see above). ▪ Tailwater runoff (which can be overland or through unstable, erosive ditches) can increase sedimentation and erosion when water returns to the channel or during high water events.	☑	↑↓	☑	☑	☑	1	1
Dam failure: ▪ Excessive water and sediment from failed man-made and/ or beaver dams can scour the channel and overload the system with sediment.	☑	↑ velocity, volume	☑	☑	☑	1	2
Unmanaged or improperly managed grazing: ▪ Livestock and wild or feral ungulates are attracted to green riparian vegetation (herbaceous and woody), particularly during late summer and fall when other forage is dry.	☑		☑	☑	☑	1	1

Risk factors	Processes					Threats	
	Erosion/ increased sediment	Altered stream flow	Lowered water table	Decline of riparian vegetation[1]	Reduced access to floodplain	Impaired stream channel	Lack of riparian vegetation[1]
Unmanaged or improperly managed grazing (continued): ▪ Repeated late-season grazing (or other forms other forms of overgrazing/overbrowsing) can reduce plant vigor and cause plant mortality. ▪ Excessive ungulate hoof action may destabilize streambanks and increase erosion.	☑		☑	☑	☑	1	1
Wildfire in uplands ▪ Fire changes upland hydrology (by removing upland vegetation and creating hydrophobic soils). These conditions, combined with snow, rain or wind, lead to less ground absorption of precipitation and higher overland flows into streams, which increase stream velocity, volume, and sediment transport. ▪ Flashier stream flows can lead to increased stream erosion and loss of channel integrity.	☑	↑ velocity, volume	☑	☑	☑	1	2
Degraded uplands: ▪ Juniper or woodland expansion reduces water available to streams, which threatens the persistence of native stabilizing riparian vegetation. ▪ Juniper or woodland expansion decreases upland herbaceous understory vegetation. Loss of the upland understory can increase the erosion of soils, overland flow and the "flashiness" of water and sediment flowing into streams. This run-off often leads to increased and faster flows, which can lead to headcuts and channel-impaired streams. ▪ Annual grass invasion increases wildfire risk (see above).	☑	↕	☑	☑	☑	1	1

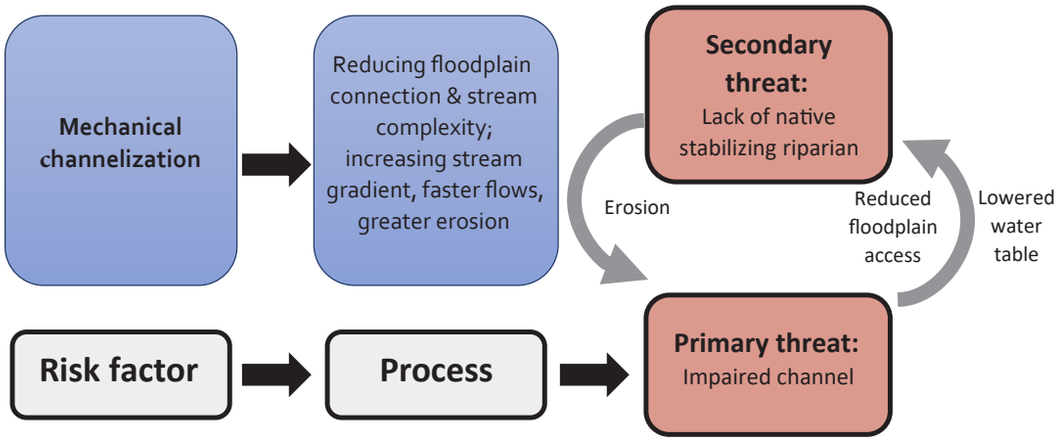

Figure D.1. Mechanical channelization (such as combining multiple channels into one, straightening, redirecting or otherwise confining a stream via placement of riprap or berm construction) is a risk factor that is often intended to straighten a channel or to protect roads, crops or human infrastructure. This risk factor reduces stream complexity, which leads to processes such as increased water velocity by removing natural friction points, which can result in greater erosion, headcuts and reduced access to the floodplain (primary processes). These processes lead to the primary threat of an impaired channel. The threats perpetuate one another; once the threat of an impaired channel is expressed, this sets into motion the secondary processes of lowering the water table, deepening the channel and further reducing access to the floodplain, which can facilitate the secondary process of mortality and decline and loss of native stabilizing riparian vegetation (threat).

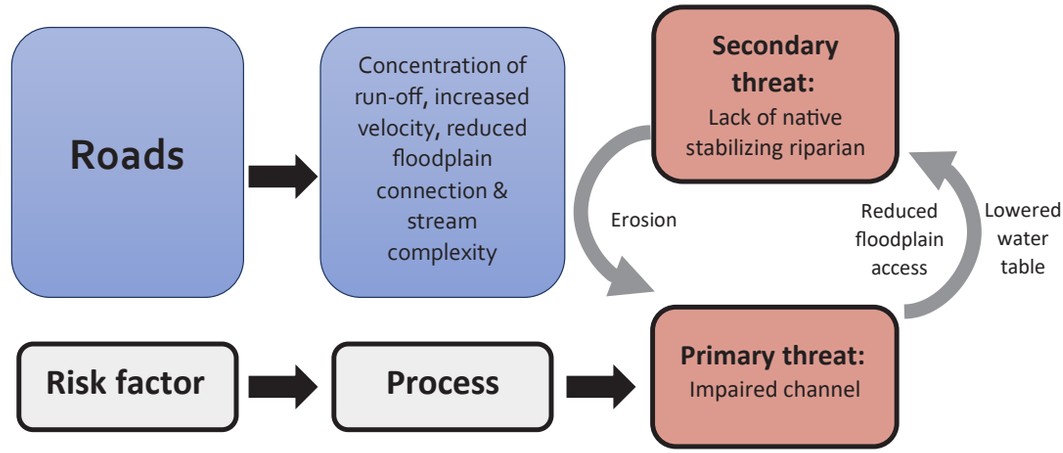

Figure D.2. Roads (risk factor) capture and concentrate runoff, delivering it rapidly to a stream, resulting in increased erosion (processes). Roads taking up space in the floodplain can confine and limit stream meanders, reducing stream complexity. This results in destructive processes like higher energy flows and stream erosion, which ultimately can lead to impaired channels (threat). Secondary processes can be set into motion, lowering water tables, reducing floodplain access, stressing vegetation and leading to the threat of lack of native stabilizing riparian vegetation.

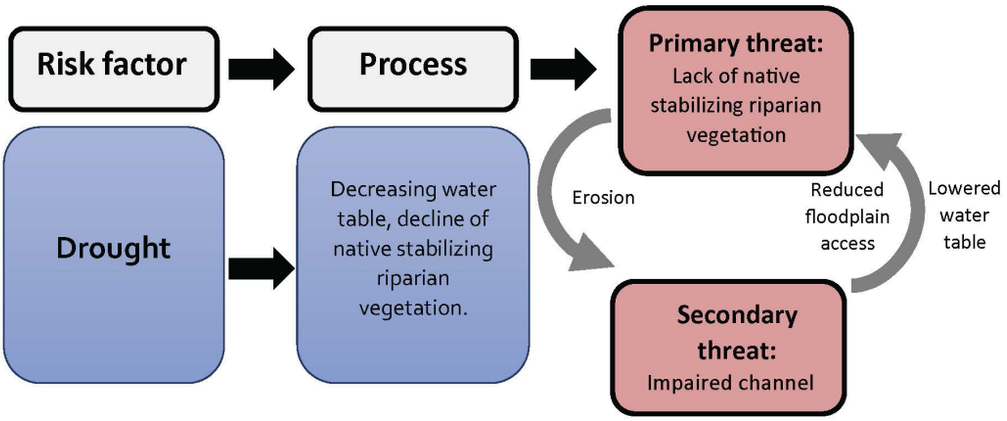

Figure D.3. Drought is a risk factor that can lead to the process of lowering water tables, and if extreme enough, a decline of native riparian vegetation. The primary threat expressed is a loss of native stabilizing riparian vegetation. Adequate native riparian vegetation provides stream-bank stability and creates a "rough or textured" surface adjacent to the stream. During overbank flow events, vegetative texture creates friction which decreases the flood water velocity and erosion capability, thus allowing for increased water infiltration into the floodplain soil and sediment to drop out of the water. Thus, the loss of vegetation can result in secondary processes such as increased flood water velocity resulting in increased erosion, reduced access to the floodplain and ultimately the threat of an impaired channel.

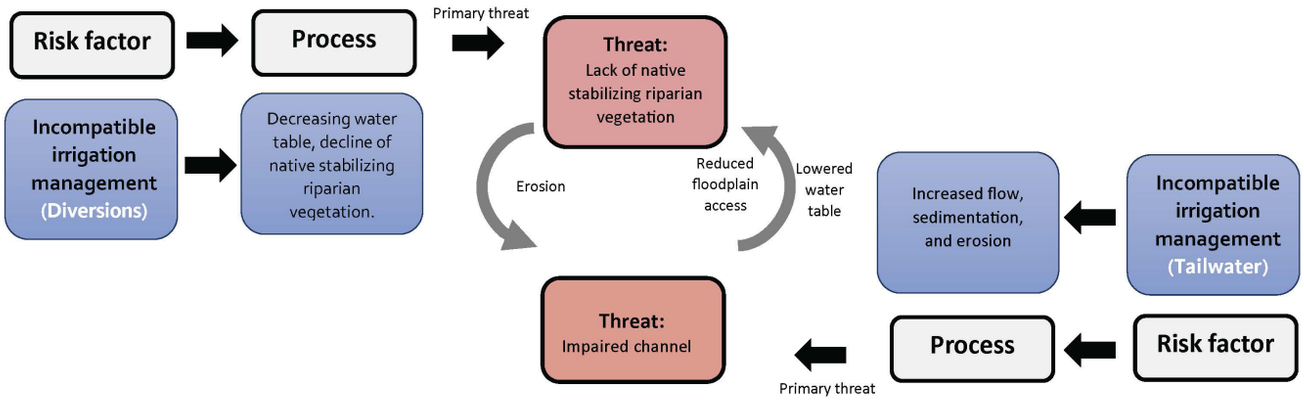

Figure D.4. Incompatible irrigation management is a risk factor that alters stream flow, resulting in destructive processes that lead to the expression of threats. Irrigation diverts stream flows, decreasing the amount of water in a stream or creek, and can lead to dewatering, setting into motion the process of a decreasing water table and loss of vegetation. The primary threat expressed is a lack of native stabilizing riparian vegetation. Additionally, tailwater returning to the stream can carry excess sediment from irrigated fields, and areas where it rejoins the channel can become unstable, leading to the process of erosion and localized degradation of the channel (threat), which can reduce access to the floodplain (secondary process), continuing the degradation cycle between the two threats.

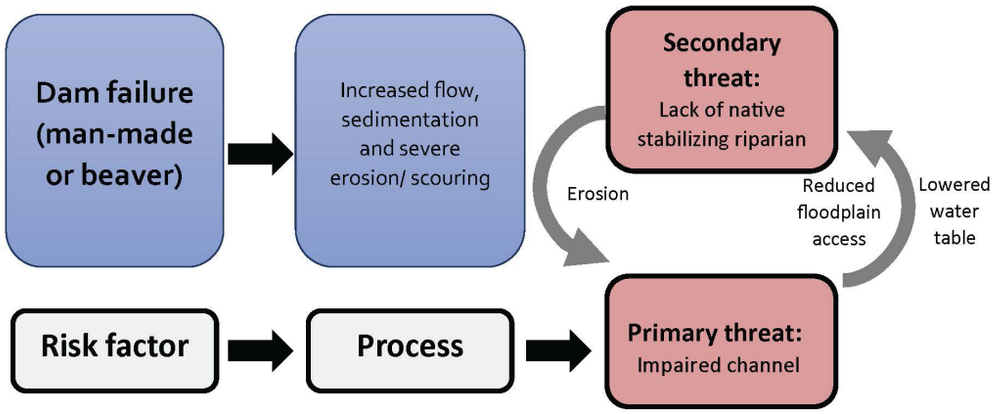

Figure D.5. Dam failure (risk factor) releases large amounts of water and sediment into the downstream channel(s). This can result in both severe erosion and sediment loads that exceed the capacity of the system (primary processes). Dam failures can lead to impaired channels (primary threat) and a subsequent drop in the water table (secondary process). This can reduce access to the floodplain (secondary process) and ultimately deprive native riparian vegetation of moisture which may cause the secondary processes of plant mortality, reduced plant diversity and recruitment, and ultimately a loss of stabilizing riparian vegetation (secondary threat). When native stabilizing riparian vegetation is lost in a stream system, it is typically replaced by less stabilizing species that are more tolerant of lower water tables and dry soil conditions.

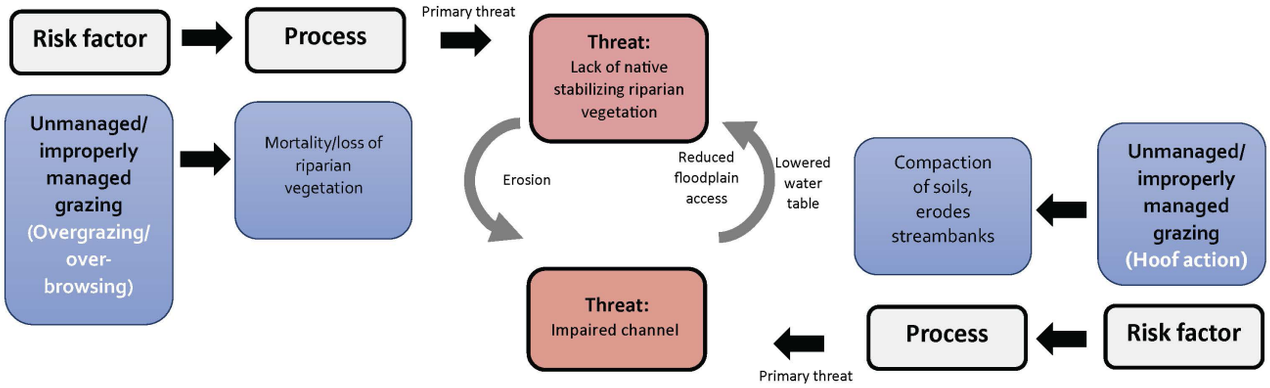

Figure D.6. Unmanaged or improperly managed herbivory can lead to the expression of either primary threat. First, overgrazing/overbrowsing can decrease the vigor of riparian vegetation, which can initiate the processes of plant mortality/loss, reduced plant diversity and recruitment, and ultimately the primary threat of insufficient stabilizing riparian vegetation and its replacement with less stabilizing species that are more tolerant of lower water tables and dry soil conditions. The loss of native riparian vegetation also creates a smoother ground surface for water to flow over, leading to increased water velocity. This facilitates the secondary process of erosion, leading to a loss of floodplain connectivity and the threat of an impaired channel. The threats continue to perpetuate each other, and the channel impairment leads to the secondary processes of reduced water table and access to floodplain, further stressing any remaining vegetation or preventing its re-establishment. Additionally, the hoof action of ungulates can destabilize streambanks, damage established plants and cause erosion, all of which are processes that can lead to the primary threat of an impaired stream channel. If not addressed, associated erosion widens the channel which can disconnect the stream from its floodplain leading to the secondary threat of insufficient riparian vegetation.

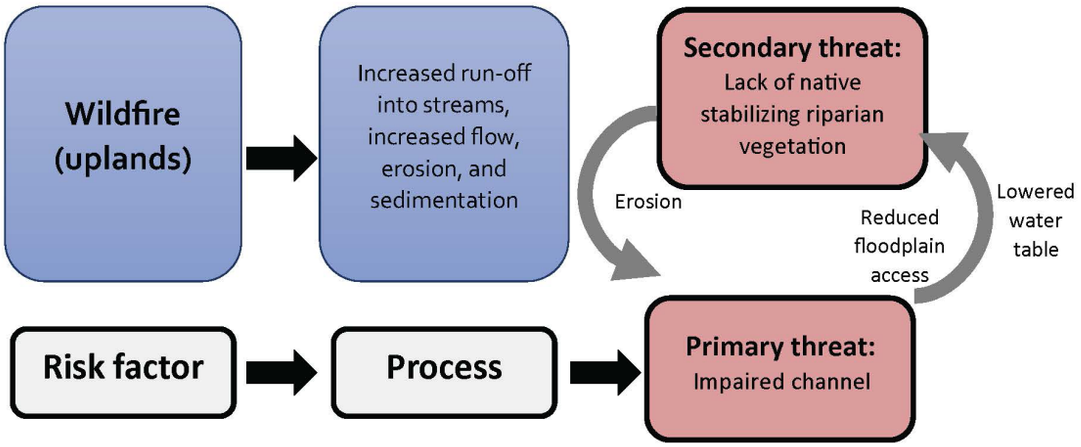

Figure D.7. Wildfire in the surrounding upland watershed removes stabilizing upland vegetation and may result in hydrophobic, water-resistant soils. When combined with precipitation, water that would otherwise be absorbed runs off into the streams (primary process), carrying increased sediment loads and altering stream deposition patterns. Increased stream volume and velocity accelerate bank and streambed erosion, which results in the primary threat of an impaired channel. As the channel continues to erode and degrade, the stream loses its access to the floodplain, subsequently lowering the water table and starving native stabilizing vegetation of the moisture needed to survive. The mortality of vegetation eventually can lead to a lack of sufficient stabilizing vegetation (secondary threat), furthering the process of erosion and loss of floodplain connectivity and exacerbating the channel impairment (primary threat).

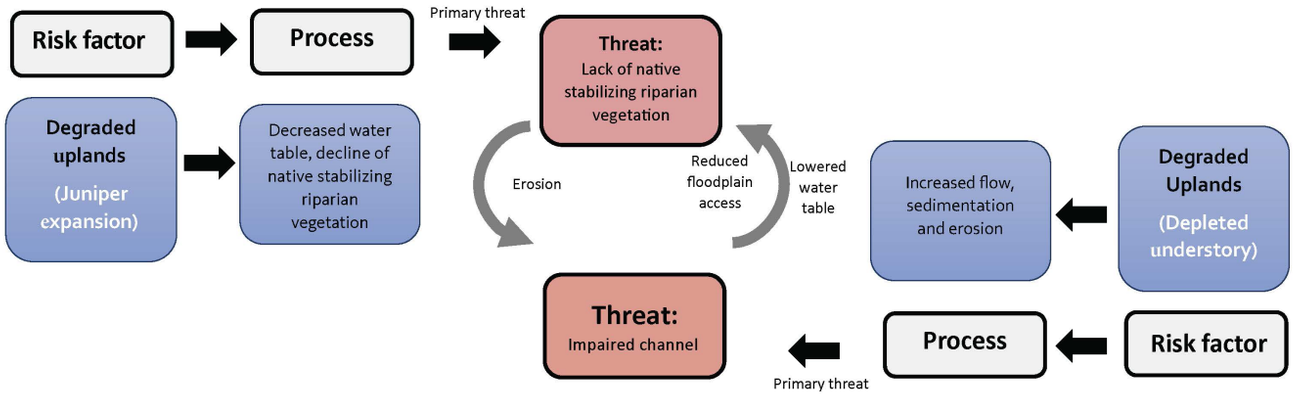

Figure D.8. Degraded uplands can increase or decrease stream flows, resulting in destructive processes that lead to the expression of both threats. Juniper expansion intercepts surface water for groundwater recharge, subsequently decreasing stream flows, lowering the water table and negatively affecting native vegetation vigor and density (processes). The primary threat expressed is a lack of native stabilizing riparian vegetation. Uplands with depleted understories lacking in native upland bunchgrasses can increase erosion of upland soils leading to “flashy” riparian systems that experience sudden inputs of sediment and surface water (processes). More water moving at higher velocities through the existing channel results in incision and may create headcuts, leading to channel impaired streams. This can then reduce access to the floodplain (secondary process), continuing the degradation cycle between the two threats.