RIVER SYSTEMS

Summary: Rivers carry sediment and logs and other floating debris as well as water. They also provide habitat and transportation corridors for fish. Log jams form on rivers in forested regions. These persist for years and tend to trap logs and floating debris, preventing them form reaching culverts and bridges. Culverts in particular are very vulnerable to blockage from floating debris. However, from time to time, at intervals of about 30 years and up, very large floods occur in an area. These “clean out” logs, log jams and sediment from the stream beds and allow the logs and the bed load to reach the culverts and bridges and damage or destroy them. This suggests that culverts and bridges should be designed to carry floods in the 30 to 50 year range, with no damage and also that the design should minimize damage in the event of a major flood with its accompanying sediment and debris load.

River systems

Rivers carry not only water but also sediment and woody debris, such as logs, leaves, branches and whole trees. In most of British Columbia and certainly in areas where there are logging roads, there is a considerable amount of woody debris in the stream channels. When one looks at the debris in most stream channels and realizes the vulnerability of culverts and, to a lesser extent bridges, to blockage from floating debris one wonders how culverts and bridges can continue to function as well as they do.

The amount of sediment and debris, that a stream can carry, varies with the flow and with the slope of the channel. As the flow increases, the sediment and debris load increases much more rapidly than the flow. For example, a 25% increase in flow can double the “carrying capacity” of a stream. This also works on the downside, in that as the discharge falls, the carrying capacity of a stream decreases quite quickly. As a result, the vast majority of sediment and debris is moved during the relatively short periods, when flows are much higher than normal. The rest of the time, the sediment and woody debris load is very low or zero. Also in a stream with a varying slope, there may be erosion leading to high sediment/debris load in a steep reach, followed by sediment deposition where the slope flattens.

In British Columbia, streams have distinct seasonal patterns of streamflow and flows vary considerably. High flows can easily be more than 100 times larger than low flows. In the South West coastal area, flows are typically low in summer and the highest flows occur in fall or winter, as a result of winter rainstorms, often augmented with snowmelt. In the interior, the highest flows usually occur in summer, as a result of the melting of snow, which has accumulated during the winter, often augmented by rain storms during the melt period. In other areas, such as the North Coast, floods can result from both fall/winter rainstorms and spring snowmelt.

Since the amount of sediment, that a stream can carry, varies with the flow, there is also a seasonal pattern to sediment/woody debris load, with erosion and increased sediment/debris loads during flood times and deposition of sediment as the flows decrease. Over a typical year, in a stream reach, erosion may occur at times of high flow and sediment deposition at other times. If these balance out, the reach of river, is said to be stable or “in equilibrium”. In some reaches there may be net deposition of sediment over the year and in others net erosion. Stable reaches, where erosion and deposition balance, are, relatively rare. Where there is net erosion, or the river is trying to erode a resistant channel bed, such as a rock bed, the river channel looks reasonably stable. However, where there is net deposition, the river tries to “run around” the sediment is has deposited – and in the process may attack the banks, resulting in a wide unstable reach of channel. A good example is the alluvial fan, where a steeply sloping channel bed, flattens as it reaches the flood plain. Because of the flatter slope, the river can no longer carry the same sediment load as in the steeper section and deposits the material in its channel through the alluvial fan. Then, when the next flow, which is too large for the partially filled in channel arrives, the flow can no longer be accommodated in the channel. The river breaks out of its channel and opens up a new channel through the fan. Any settlements or facilities, such as roads crossing the fan, are vulnerable to damage during such channel “break outs”.

Log jams are important features in stream channels in British Columbia. As documented by Hogan (1989, 1991), log jams are surprisingly stable and long lived – over 50 years in some cases - and have a reasonably well defined life history. New jams tend to trap most of the logs, trees, other woody debris and sediment, brought to them by the stream. As a result, there tends to be sediment deposition in the channel upstream of the jam, which causes the bed to rise and the slope to flatten. The stream then tries to “run round” this newly deposited sediment, in the process becoming laterally unstable, attacking the banks and becoming wider. Downstream, on the other hand, the stream, which has been deprived of its “normal” sediment load, tends to erode/downcut its bed. Eventually, in the process of running round the sediment upstream of the log jam, all or part of the channel runs round the side of the jam, initiating downcutting first at the jam and then progressively upstream. Meanwhile the increased sediment load resulting from this local downcutting, restores the river’s sediment load and this reduces the downcutting downstream of the jam.

Despite their longevity and stability, log jams do break up or “fail” from time to time. Generally this occurs during a time of unusually high flow, when the stream will have many times it normal carrying capacity for sediment and woody debris. When there are unusually high flows in an area, there can be very widespread damage, when many log jams break, stream channels are “cleaned out” and culverts and bridges become choked with debris and/or overtopped and fail. In recent years, there have been such widespread “cleanouts” in the tributaries along the Skeena River valley, in the East Kootenays the Coquihalla River basin and, this year, the area from Prince George to Dawson Creek.

Culverts in particular and bridges to a lesser extent are vulnerable to blockage by logs and other floating debris at times of high flow. Fortunately, log jams, which occur in almost all channels, are very effective in trapping floating debris. But, at times of unusually high flows, log jams break and release large volumes of debris, which overwhelms most culverts and most bridges. These “cleanouts” occur at intervals of about 30 years or more. This suggests that culverts and bridges should be designed for about the 30 year flood. But designers should also take into account the likelihood of their being overwhelmed by debris from time to time and design the stream crossings for minimal damage under such circumstances. For example, the road should dip at a stream crossing, such that the crossing is at the low point in the road surface. Then, should the culvert or bridge fail, the stream would stay in the same channel, which, in turn, would minimize erosion and the generation of a sediment load, which could damage fish habitat downstream.

Although log jams tend to filter out many logs and other floating debris, that could damage or block culverts and bridge openings, there are always some that get through, or that get into the stream between the stream crossing and the next logjam upstream. These can best be dealt with by having a good maintenance program. This may involve the fostering of a “corporate culture” in which all staff members are encouraged to be on the lookout for potential problems at culverts and bridges and there is a system in place to deal any problems that are identified.

Fish

The river systems are of crucial importance to the fish that inhabit them, whether on a permanent basis, in the case of resident fish, or part time, in the case of anadramous fish, such as salmon. Salmon live part of their lives in fresh water and part in salt water – and have to use the rivers for migration, from and to their spawning grounds, as well as for spawning and for habitat during parts of their lives. Obviously if a bridge, or a culvert constitutes an impassable barrier to fish migration, this seriously interferes with the fish involved. Bridges do not usually pose too much of a problem to fish passage, but culverts do in many cases. This is because the inside of a culvert is hydraulically much smoother than most natural channels, particularly in small steep streams. As a result, water velocities at a typical culvert outlet are much higher than they would be under natural conditions; and this, in turn, causes erosion downstream of culvert exits.

It is quite common to see a large “hole” just downstream of a culvert, with a “drop” between the culvert invert and the surface of the water in the pool downstream. This drop is frequently impassable to fish; and even if fish do make it into the culvert, the water velocities there can easily be too high to allow them to swim upstream through the culvert. In theory, culverts can be designed for safe fish passage, but it requires attention to detail, that would be hard to justify in most cases; and a level of skill that is generally not available to culvert designers. Partially buried culverts, where the culvert invert is buried below the bed of the stream and the streambed is, in effect, carried through the culvert, are used in some circumstances. Opinions about their performance and acceptability vary from enthusiastic acceptance to total rejection. Thus, as a general rule, it is better not to use culverts in fish bearing streams, particularly where there are anadramous fish that have to use the stream for migration – with the possible exception of the buried culverts, in areas where they are acceptable to the local fishery managers.

Fish are affected by sediment transport. Salmonids spawn in gravel, and since the eggs are living organisms, they need oxygen. Water flowing through the gravel carries the dissolved oxygen necessary for life. Thus fish need clean gravel for spawning and the eggs need a continuous supply of oxygen rich water until the fry hatch. Hazards to the eggs come from high flows that may wash away the gravel and the embedded eggs, low flows that may strand the eggs and fine sediment that may blanket the streambed and slow the flow of water through the gravel, below that necessary for life support. Culverts and bridges do not affect high or low flows, but if they fail and in the process release fine sediment, or if there is fine sediment washed off adjacent sections of road, this can adversely affect spawning areas in the channel downstream. Thus care must be taken to prevent or minimize the release of fine sediment, during and after construction of culverts and bridges.

Log jams affect fish (Hogan et al, 1989), usually in a negative way, when the log jams are new, but later in a positive way, as the jams age. A new log jam can provide a barrier to fish migration and by trapping sediment can worsen conditions both upstream and downstream. Upstream, where sediment is being deposited, it can blanket existing gravel areas. And, as the stream flows round it newly deposited bedload, the channel becomes unstable, the banks are attacked and additional sediment is released, some of which can be quite fine and deleterious to the spawning areas. Downstream of the jam, the stream, which has been deprived of its bed load, may down cut its bed and, in the process, carry away gravel that has been used for spawning along with the embedded eggs. Later, as the log jam matures and the stream finds a way round it, the stream can be restored to a condition similar to its original one. At this time, the original log jam can also help provide good habitat for fish. At one time, it was thought that large woody debris in river channels was harmful to fish. But now they are considered beneficial – to the point where there is now an active “industry” designing and installing artificial log jams to improve fish habitat.

Conclusions

Forest road stream crossings are at the intersection of river systems and forest transportation systems and they can have a great influence on fish systems. All three “systems” should be taken into account in designing appropriate culverts or bridges for the crossings.

Log jams form in a way that makes the channels surprisingly stable over long periods of time. However, when really large floods occur, as they inevitably do from time to time, they can completely re-arrange the river channel over long reaches, in the process “taking out” many of the stream crossings in the reach.

Culverts and bridges should be designed for “safe fail” – such that failure, when or if it occurs, causes minimal damage to the road, the crossing and the environment.

Maintenance is important to roads and stream crossing structures. A corporate culture dedicated to good construction practices and to effective maintenance should be fostered by the forest companies and the Ministry of Forests.

References

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