Channel maintenance in hydropower relicensing
Channel Maintenance Considerations in Hydropower Relicensing
by J.P. Potyondy & E.D. Andrews

Over 250 hydroelectric projects were licensed and constructed on the National Forests during the 1940s and 1950s. Although hydropower has played an important role in economic development, many projects have caused significant unanticipated adverse impacts to National Forest resources. During the next 10 years, many of these projects will be relicensed by the Federal Energy Regulatory Commission (FERC). The forthcoming relicensing will be especially important because the standards and rules governing new operating license were changed by the Electric Consumer Protection Act of 1986. In the future, the operation of hydropower facilities must consider impacts to federal lands and resources when a license is issued. The relicensing process affords the Forest Service a unique opportunity to assess and possibly eliminate or mitigate the negative environmental impacts of these facilities.

A thorough understanding of the impacts that the existing and alternative flow regimes may have on the downstream physical characteristics of the channel is essential during consideration of a new license. Channel morphology, especially the stability of channel banks and riparian vegetation, bed-material composition, water table influences, and bedload transport can be important issues. Understanding channel change is important because the condition of the channel directly influences the biological sustainability of aquatic and riparian ecosystems.

Existing channels below hydropower facilities are frequently damaged due to either too much or too little water. Although the impact to a given site is highly variable and site dependent, a desired goal for the downstream channel is to reestablish proper channel function and thus assure channel maintenance. On National Forests, a key objective is to manage regulated rivers to mimic natural geomorphic processes to the greatest extent feasible.

Proper channel function enables the Forest Service to meet in part the "favorable conditions of water flows" reservation purpose of the Organic Administration Act. Forest Land and Resources Management Plans provide additional guidance for protecting and improving resource values. These plans often identify resource objectives that may require modifications to regulated flow regimes to achieve multiple use purposes such as sustaining fisheries, providing recreational opportunity, or maintaining riparian vegetation. Channel maintenance flow regimes must meet the following criteria to achieve the desired properly functioning condition:

- Move bed-material to maintain a long-term sediment balance;
- Maintain streamside vegetation and the structural stability of streambanks;
- and
- Prevent vegetation encroachment in the channel.

In summary, an analysis of flow and bedload sediment must be conducted to assure sufficient sediment is conveyed to maintain channel capacity and prevent adverse impacts to banks and riparian vegetation from sediment accumulation in the channel.

The objective of geomorphic analysis during the relicensing process, therefore, is to analyze the existing sediment and flow regime to understand the existing condition and predict changes to the downstream channel under a variety of alternative flow regimes. Major factors to consider include: (1) Channel characteristics, (2) the operational hydrology (flow regime), and (3) the sediment regime.

Channel Characteristics

A stream classification system is beneficial to begin to understand the physical characteristics of stream channels involved in a relicensing project (Figure 1). Classification schemes developed by Rosgen (1996) or Montgomery and Buffington (1997) are examples. Mapping the spatial distribution of stream types allows for a focused analysis of sensitive reaches.

Many hydropower projects are situated on bedrock-controlled reaches of streams. Such channels are inherently stable and are less susceptible to alteration. Under certain circumstances, however, impacts on bedrock stream channels can be quite dramatic, e.g., where the hydroelectric facility significantly reduces peak discharges while tributaries continue to supply large quantities of coarse sediment. Alluvial channels by contrast are more adjustable. Nevertheless, gradients of adjustability exist for different stream types. For example, sand-bed channels are inherently more sensitive to change than gravel or cobble-bed rivers, while a different suite of channel processes operate in alluvial channels with cohesive clay banks.

Recognizing the major channel types and materials is especially important for the selection of appropriate sediment transport models. For example, the Ackers and White bedload transport equation (Ackers and White, 1973) is appropriate for sand-bed channels while the Parker equation (Parker, 1990) is best suited for gravel-bed rivers. A procedure for applying the Parker equation to the design of channel maintenance flows in gravel-bed rivers is illustrated in Andrews and Nankervis (1995).

Operational Hydrology

The water impounding structure and operational hydrology will typically have a significant effect on downstream impacts (Figure 2). In general, unregulated flows (run-of-the-river projects) will have fewer significant impacts and are more easily analyzed for channel maintenance flows. In contrast, projects which divert flows frequently have severe impacts. In such schemes, flow in the natural channel is diverted off-stream to the power generating facility with a diversion dam. These designs generally utilize flow from the diversion for as long as possible, limited by plant hydraulic capacity and energy demand. The impact of regulated flow systems is directly related to the size of the dam and the operation of the facility. Larger dams have the capacity to store almost all of the flow while smaller structures generally store and regulate a smaller percentage of the annual volume. Dams used for power peaking have the potential to be most destructive and issues related to ramping rates need to be carefully evaluated.

In all cases, the operational hydrology needs to be understood and analyzed. The "stop-and- go" nature of the flow regime compared to natural conditions changes flood hydrographs, sediment transport regimes, and alters channel morphology. It is crucial to understand when, how, and what magnitude of flows are diverted and recognize the range of usable flows that the facility accommodates. Streamflow data are essential during the consideration of a new hydropower license. If streamflow data is unavailable, stream gages should be established as soon as possible. Streamflow data may be available from the project proponent. Streamflow analysis typically relies on developing existing and pre-project flow duration curves based on mean daily flows and analyzing low flow and peak flow frequencies. The Indicators of Hydrologic Alteration (IHA) analysis approach and software (Richter et al., 1996; see also STREAM NOTES, January 1999) is a tool for summarizing numerous hydrologic flow parameters and displaying changes to the hydrologic regime.

Sediment Regime

The several landforms, e.g., riffles, pools, point bars, etc., that make up a floodplain and river channel are composed of various sediment particle sizes. Typically, a hydroelectric facility will alter the supply and transport of the relatively fine sediment sizes differently than the coarse sediment sizes. The extent and stability of a landform will be impacted when the transport of the associated particle sizes is altered. The magnitude of channel response is largely a result of coarse sediment (bedload) trapped by the dam (Figure 3).

On the one extreme are run-of-the-river facilities that allow passage of all of the bedload sediment in the river. This is a common situation for small hydropower projects. The most probable response in the diverted reach with water removal is a decrease in channel size (aggradation) and an increase in surface/subsurface fines.

At the other extreme are structures that trap all of the bedload. The most common response with water removal is the "hungry water" phenomenon where clean water picks up sediment resulting in an increase in channel size (incision) and/or removal of gravels and fines (armoring).

Between these extremes are a vast array of complex, highly variable responses. These are due to the many possible combinations of altered sediment (changes in volume or size) and water discharge (changes in duration, timing, peak flows or volumes of flow) that are possible at hydropower facilities. While general response may be predicted, every river is unique. In the majority of instances, the site-specific circumstances of a project must be analyzed in detail. Numerous independent watershed variables (e.g., rainfall, geology, vegetation type, land use) combine in countless ways to produce different flow and sediment regimes. Numerous dependent channel variables (e.g., width, depth, bedforms, sediment transport) also adjust in many different combinations to any given regime. In addition, hydropower plant operating schemes and the physical layout of the facility and the stream environment are extremely variable.

A final important consideration in analyzing the sediment situation is the influence of downstream tributary inflow of water and sediment to the by-pass reach. Generally, the critical location is the first major tributary below the dam. Other important factors to consider are the location of the tributary input with respect to accretion flows, the amount and size of material coming from the tributary, and the desyncronization of tributary inflow with the mainstem. It is important to recognize that it is often impossible to restore channels to their pre- project condition simply by changing the flow regime. Novel approaches may be necessary to achieve satisfactory sediment balance. For example, lack of sediment input immediately below the dam may severely limit the rebuilding of channel banks and floodplains. Likewise, a goal of recapturing spawning habitat may be unattainable without artificial, annual introductions of gravel into the system.

Analysis Process

The technical analysis for hydropower relicensing can be very complicated. The following basic steps are suggested:

1. Determine unimpacted (baseline) conditions (flow, sediment, channel conditions) above project or pre-project.
2. Evaluate existing (current) conditions (below project).
3. Consider alternative post-project conditions.

Detailed flow and sediment information is essential to support any changes to the flow regime that might be proposed by the Forest Service to FERC. Three years of continuous streamflow record and at least 20 samples of bedload and suspended sediment over the full range of flows, including those above bankfull, are typically the minimum required during the relicensing process. This basic information is needed to validate any sediment transport modeling, understand local hydrology, and support flow change recommendations that may result. In many cases, specialized technical skills in sediment transport measurement and analysis will be required.

The need to build an adequate administrative and scientific record which contains "substantial evidence" of the facts supporting requested flow changes was reinforced by the Bangor Hydro decision on FERC relicensing (Pizzi, 1997). Well designed studies that link scientific evidence to management decisions are increasingly important for agencies to successfully recommend and implement flow changes designed to improve the adverse channel conditions that exist at many hydropower facilities.

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