
Part I
Hydroelectric Project Effects Matrix

This matrix (Table 1) is intended to provide a fairly comprehensive accounting of potential effects at a generic hydropower project, and does not prioritize certain effects as being more important than others. The matrix includes only those potential effects with a nexus to hydropower facilities or operations, and those that may typically warrant study. Depending on the characteristics of a specific hydropower project, many of these effects may not be manifest, while others may be significant and warrant assessment. This matrix is intended as a tool to examine the effects of an existing hydropower project (typically during relicensing), and is not intended for assessing proposed construction (although many of the same effects could be considered).

A given project feature may have a positive or negative effect on a specified resource. For example, diversion dams can alter river temperatures downstream, but study would be needed at a particular project to determine if the temperatures are increased (e.g., via reduced instream flows or epilimnetic releases) or decreased (e.g., via hypolimnetic releases), and whether the altered condition is “good” or “bad” for the affected environmental resources. Therefore, this matrix refers to most effects as “altering the condition” relative to a natural or pre-project condition, and avoids pre-judging site-specific effects as adverse or beneficial.

Only ecological relationships affected directly by hydropower projects were considered for this matrix. For example, indirect effects such as turbidity resulting from road runoff that potentially decreases foraging efficiency for fish were not considered. In addition, interdependent and interrelated effects that would not occur but for the existence of the hydropower projects (e.g., levees as mitigations for flood control projects) were not included, although they can be significant in some projects. Other types of potentially significant effects that were considered outside the scope of this matrix include:

- Catastrophic events, such as failures of dams or canals,
- Cumulative effects of a hydropower project (or multiple projects) within a watershed, and
- Effects on human health, such as those related to a decline in traditional fish-based food resources.

Table 1. Hydroelectric project effects matrix.

Affected resources	Project facilities and features	Pathway leading to potential effect	Potential effect
Water quality	Dams (including structures such as spillways, passage facilities, and sluice gates)	Low-magnitude flow releases from outlet structures	<ul style="list-style-type: none"> • Altered levels of total dissolved gases • Release of hypolimnetic waters with low levels dissolved oxygen and high levels of ammonia • Releases of algae from reservoir to downstream reaches • Altered water temperatures downstream
		High-magnitude flow releases from outlet structures	<ul style="list-style-type: none"> • Altered levels of total dissolved gases • Altered water temperatures downstream • Increased turbidity • Increased levels of tastes and odors in public water supplies
		Spill operations	<ul style="list-style-type: none"> • Increased levels of total dissolved gases • Increased turbidity
		Sediment pass-through operations	<ul style="list-style-type: none"> • Increased turbidity • Release of accumulated metals, nutrients, and other sediment-bound pollutants • Decreased dissolved oxygen
	Reservoirs and forebays	Impoundment of water	<ul style="list-style-type: none"> • Increased algal productivity • Decreased dissolved oxygen levels with depth • Temperature stratification • Mobilization of methyl mercury from submerged vegetation
		Impoundment of sediment	<ul style="list-style-type: none"> • Accumulation of metals, toxic compounds, and nutrients from upstream inputs • Decreased assimilative capacity • Increased sediment oxygen demand • Decreased dissolved oxygen
		Eutrophication	<ul style="list-style-type: none"> • Increased nutrient levels • Increased algal productivity • Reduced water clarity • Hypolimnetic oxygen deficits • Diel fluctuation in dissolved oxygen and pH • Increased exchange of metals and nutrients at sediment/water interface • Increased levels of tastes and odors in public water supplies • Increased instances of aquatic toxicity
		Water surface elevation fluctuations	<ul style="list-style-type: none"> • Increased turbidity from shoreline erosion
	Powerhouses (including turbines and bypass valves)	Increased hydrostatic pressure within penstocks	<ul style="list-style-type: none"> • Increased levels of total dissolved gas • Increased variations in pH levels
		Cooling water contact with turbine generator	<ul style="list-style-type: none"> • Altered water temperatures • Release of oil and grease

Affected resources	Project facilities and features	Pathway leading to potential effect	Potential effect
Water quality	Intake structures and conduits	Cross-basin water and sediment transfer	<ul style="list-style-type: none"> • Altered water temperatures • Transport of sediments, metals, algae, toxic chemicals, nutrients • Introduction of toxic chemicals from maintenance activities
	Project-affected stream reaches	Altered flow regimes	<ul style="list-style-type: none"> • Altered water temperature dynamics • Altered fine sediment deposition due to alterations in flows causing bedload mobility • Altered water column and intra-gravel dissolved oxygen • Altered diel variation in dissolved oxygen and pH • Altered production of attached algae
	Transmission lines near water bodies	Maintenance of transmission line corridor	<ul style="list-style-type: none"> • Decreased stream shading and relative humidity • Increased water temperatures and alterations in water temperature dynamics • Decreased dissolved oxygen and increased variation in diurnal dissolved oxygen levels • Increased runoff of herbicides and fine sediment inputs during storm events
	Roads	Decreased vegetative cover and increased amounts of impervious surface	<ul style="list-style-type: none"> • Increased water temperatures and alterations in water temperature dynamics • Increased runoff and fine sediment inputs during storm events • Increased turbidity from decreased slope stability
	Maintenance and recreational facilities (including equipment storage, campgrounds, boat ramps, trails, picnic areas, and restrooms)	<p data-bbox="625 1268 906 1360">Increased human use near water bodies</p> <p data-bbox="625 1369 906 1629">Decreases in vegetative cover</p>	<ul style="list-style-type: none"> • Discharge of fuel, oil, and grease • Increased fecal coliform from water contact and restroom facilities • Discharge of fertilizers and herbicides • Increased water temperatures and alterations in water temperature dynamics
Hydrology and geology	Dams (including structures such as spillways, passage facilities, and sluice gates)	High-magnitude flow releases	<ul style="list-style-type: none"> • Bank erosion • Channel bed armoring • Bed scour
		Passage of sediment	<ul style="list-style-type: none"> • Altered sediment transport rates
		Trapping of large woody debris	<ul style="list-style-type: none"> • Reduced large woody debris inputs to downstream reaches

Affected resources	Project facilities and features	Pathway leading to potential effect	Potential effect
Hydrology and geology	Reservoirs and forebays	Impoundment of water	<ul style="list-style-type: none"> • Delta formation • Spatial shifts in groundwater infiltration
		Impoundment of sediment	<ul style="list-style-type: none"> • Sediment trapping and associated change in streambed sediment composition downstream • Decreased delivery of sediment to coastal ecosystems • Decreased reservoir capacity
		Water surface elevation fluctuations	<ul style="list-style-type: none"> • Shoreline erosion
	Powerhouses (including turbines and bypass valves)	High-magnitude flow releases from outlet structures	<ul style="list-style-type: none"> • Scour at outlet • Entrainment of fine sediment near outlet
	Intake structures and conduits	Cross-basin water transfer	<ul style="list-style-type: none"> • Re-sizing of channels to accommodate altered hydrograph
	Project-affected stream reaches	Altered flow regimes	<ul style="list-style-type: none"> • Alterations in channel sediment storage • Alterations in bed mobility • Changes in channel morphology (e.g., pool-riffle frequency and size/depth of pools) • Alterations in stream gradient • Alterations in planform curvature (channel sinuosity) • Bank erosion • Alterations in bankfull width • Channel bed armoring • Alterations to overbank flow and sedimentation • Shift in flood recurrence intervals • Vegetation encroachment • Altered floodplain inundation frequency
	Transmission lines	Maintenance of transmission line corridor	<ul style="list-style-type: none"> • Surface erosion • Increased runoff • Increased hillslope instability
	Roads	Increased amount of impervious surface/decreased vegetative cover	<ul style="list-style-type: none"> • Surface erosion • Increased runoff • Increased hillslope instability • Decreased large woody debris supply to stream reaches near roads
		Construction and use of road/stream crossings (e.g., rolling dips, and culverts)	<ul style="list-style-type: none"> • Accelerated hillslope failure • Increased hillslope instability • Increased sediment delivery to stream
Construction and use of streamside roads		<ul style="list-style-type: none"> • Channel confinement • Rip-rap along channels to protect roads hardens banks and can lead to erosion on opposite banks 	

Affected resources	Project facilities and features	Pathway leading to potential effect	Potential effect
Hydrology and geology	Maintenance and recreational facilities (including equipment storage, campgrounds, boat ramps, trails, picnic areas, and restrooms)	Increased amount of impervious surface	<ul style="list-style-type: none"> • Surface erosion • Increased runoff • Increased hillslope instability
		Creation and use of non-designated trails	<ul style="list-style-type: none"> • Surface erosion • Increased runoff • Increased hillslope instability
Fish and other aquatic species	Dams (including structures such as spillways, passage facilities, and sluice gates)	Passage of water at spillways or sluice gates	<ul style="list-style-type: none"> • Injury or mortality from entrainment or impingement on screens or trash racks • Disruptive attraction flows
		Flow releases from outlet structures	<ul style="list-style-type: none"> • Altered quality of rearing and spawning habitat from alterations in water quality • Disruptive attraction flows
		Barrier to aquatic species	<ul style="list-style-type: none"> • Blocked access to upstream and or downstream habitats; reduced habitat connectivity; genetic isolation • Delay or elimination of downstream migration
		Barrier to sediment and large woody debris	<ul style="list-style-type: none"> • Degradation of spawning and rearing habitats
		Ineffective passage facilities	<ul style="list-style-type: none"> • Delays or reductions in upstream or downstream passage • Injury or mortality during passage
	Reservoirs and forebays	Impoundment of water	<ul style="list-style-type: none"> • Alteration in fish community composition and abundance • Delay in outmigration • Increased habitat for large piscivorous predators • Alterations in food availability • Alterations in quality and quantity of spawning and rearing habitat • Altered access to tributaries • Creation of population "sink" for stillwater breeding amphibians
Reservoirs and forebays	Water surface elevation fluctuations	<ul style="list-style-type: none"> • Stranding • Alterations in available habitat • Reduced access to tributaries • Decreased habitat stability and therefore increased predation/stress due to fish continually having to move to remain within preferred habitats • Alteration of benthic macroinvertebrate assemblage • Desiccation of amphibian egg masses at perimeter 	
Fish and other		Fish stocking (not	<ul style="list-style-type: none"> • Increased fishing mortality on native

Affected resources	Project facilities and features	Pathway leading to potential effect	Potential effect
aquatic species		always a project effect)	fish from increased angling effort for stocked fish <ul style="list-style-type: none"> • Disease introductions • Increased competition and predation on fish and amphibians • Alteration in fish community composition and abundance • Hybridization
	Powerhouses (including turbines and bypass valves)	Passage of water through turbines and bypass valves	<ul style="list-style-type: none"> • Injury or mortality from entrainment or impingement on screens or trash racks
		Discharge from turbines and bypass valves	<ul style="list-style-type: none"> • Upstream migration delay from false attraction • Injury or mortality from swimming up draft tubes, including turbine strike
	Intake structures and conduits	Water intake	<ul style="list-style-type: none"> • Injury or mortality from entrainment or impingement on screens or trash racks
Cross-basin water transfer		<ul style="list-style-type: none"> • Introduction of non-native species • Alterations of species composition and abundance • Genetic mixing • Alterations in available habitat 	
Project-affected stream reaches	Altered flow regimes	<ul style="list-style-type: none"> • Alterations in available habitat • Reduced access to side channels, upstream habitat, tributaries, and floodplain habitat • Alterations in food productivity and delivery due to changes in macroinvertebrate community and/or due to reduced frequency of floodplain inundation • Alterations in intra-gravel oxygen supply in redds • Alterations of species composition and abundance • Alteration of benthic macroinvertebrate assemblage 	

Affected resources	Project facilities and features	Pathway leading to potential effect	Potential effect
Fish and other aquatic species	Project-affected stream reaches	Flow fluctuations	<ul style="list-style-type: none"> • Alterations in available habitat • Reduced access to side channels, upstream habitat, tributaries, and floodplain habitat • Alterations in food productivity and delivery due to changes in macroinvertebrate community • Alterations in intra-gravel oxygen supply in redds • Alterations of species composition and abundance • Alteration of benthic macroinvertebrate assemblage • Forced movement or migration • Stranding of fish or their redds • Dewatering of redds • Stranding, desiccation, or scour of larval amphibians and egg masses • Displacement of amphibians
	Transmission lines	Maintenance of transmission line corridor leading to increased solar radiation	<ul style="list-style-type: none"> • Decreased habitat availability resulting from reductions in water quality
	Roads	Runoff of fine sediment	<ul style="list-style-type: none"> • Changes to water quality and gravel permeability affecting fish habitat and survival
		Decreased vegetative cover leading to increased water temperatures and decreased large woody debris and leaf litter inputs	<ul style="list-style-type: none"> • Decreased habitat quality
Road/stream crossings		<ul style="list-style-type: none"> • Limiting or blocking fish passage to upstream habitat 	
Recreational facilities (including campgrounds, boat ramps, trails, picnic areas, and restrooms)	Angling, including introduction of bait fish	<ul style="list-style-type: none"> • Injury or mortality to fisheries • Poaching • Degradation of spawning and rearing habitat • Alterations in species composition and abundance 	
	Travel of recreationists and use of recreational equipment	<ul style="list-style-type: none"> • Introduction and dispersal of non-native and invasive species 	

Affected resources	Project facilities and features	Pathway leading to potential effect	Potential effect
Special-status plants, lichens, and fungi, and plant communities	Reservoirs and forebays	Impoundment of water	<ul style="list-style-type: none"> • Alterations in aquatic and reservoir perimeter species abundance and community composition • Alteration of wetland hydrology and communities • Establishment of aquatic weeds
		Water surface elevation fluctuations	<ul style="list-style-type: none"> • Alteration of plant species abundance and community composition • Alteration of wetland hydrology and communities • Drowning or desiccation of special-status plant species
	Intake structures and conduits	Cross-basin water transfer	<ul style="list-style-type: none"> • Spread of noxious/non-native invasive plant species (e.g., aquatic weeds or reservoir margin weeds that can be dispersed by water)
	Project-affected stream reaches	Altered flow regimes and sediment supply/transport	<ul style="list-style-type: none"> • Encroachment of riparian vegetation into the channel (due to decreases in scouring flows) • Alteration of riparian plant community composition and structure • Impacts on special-status aquatic or riparian plant communities or species (distribution, abundance, and composition/structure) • Alteration of wetland hydrology and communities • Altered sediment supply to wetlands
	Transmission line and roads	Maintenance of transmission line corridor	<ul style="list-style-type: none"> • Alterations to plant community composition and structure • Impacts on special-status plant species and fungi and their habitats • Increased edge effects (e.g., changes in microclimate) • Corridor for introduction and spread of noxious/non-native invasive plant species • Dispersal of noxious/non-native weeds and disease-carrying fungi to new locations
	Powerhouses, switchyards, and maintenance facilities	Ground-disturbing activities and vegetation clearing	<ul style="list-style-type: none"> • Degradation of habitat and/or eradication of populations of special-status plants, fungi and their habitats

Affected resources	Project facilities and features	Pathway leading to potential effect	Potential effect
Special-status plants, lichens, and fungi, and plant communities	Recreational facilities (including campgrounds, boat ramps, trails, picnic areas, and restrooms)	Ground disturbing activities and vegetation clearing (e.g., during trail maintenance), use of non-designated areas, travel of recreationists	<ul style="list-style-type: none"> • Dispersal of noxious/non-native weeds and disease-carrying fungi and introduction to new locations • Degradation of habitat and/or eradication of populations of special-status plants, fungi and their habitats
Wildlife	Dams and canals	Barrier	<ul style="list-style-type: none"> • Blocked movement and migration by terrestrial species
	Reservoirs and forebays	Impoundment of water	<ul style="list-style-type: none"> • Increased foraging habitat for bird species • Increased habitat for stillwater species (e.g., some amphibians, waterfowl) and decreased habitat for riverine species (e.g., other amphibians, dippers) • Increased foraging habitat for bats
		Water surface elevation fluctuations	<ul style="list-style-type: none"> • Disturbance of turtle and waterfowl nesting
	Project-affected stream reaches	Reduction or fluctuation of flows	<ul style="list-style-type: none"> • Altered habitat availability and food productivity for amphibians • Altered invertebrate production and foraging habitat for bats • Altered riparian and floodplain habitat may affect habitat suitability and use as movement corridors
	Transmission lines	Presence of transmission lines	<ul style="list-style-type: none"> • Altered nesting and foraging habitat for forest birds • Altered habitat for forest mammals and terrestrial amphibians • Decreased bat roosting habitat • Habitat fragmentation • Reduction in large tree snags and down wood habitat (e.g., for woodpeckers, forest carnivores, and bats) • Alteration of wetland habitat
	Transmission lines	Raised structures within flight corridor	<ul style="list-style-type: none"> • Electrocution and collision risk for bird species
	Roads	Decreased vegetative cover	<ul style="list-style-type: none"> • See discussion under effects of maintenance of transmission line corridors
Road density		<ul style="list-style-type: none"> • Habitat fragmentation • Increased access for hunting and poaching 	

Affected resources	Project facilities and features	Pathway leading to potential effect	Potential effect
Wildlife	Recreational facilities (including campgrounds, boat ramps, trails, picnic areas, and restrooms)	General use of recreational facilities	<ul style="list-style-type: none"> • Disruption and displacement of wildlife • Trampling and removal of downed wood reduces habitat for salamanders and small mammals
		Presence of buildings and other raised structures	<ul style="list-style-type: none"> • Increased habitat availability for birds and bats that roost in structures
Recreation	Dams (including structures such as spillways, passage facilities, and sluice gates)	Flow releases from outlet structures	<ul style="list-style-type: none"> • Altered quality of fishery • Danger to recreationists
		Emergency flow releases	<ul style="list-style-type: none"> • Danger to recreationists
	Reservoirs and forebays	Impoundment of water	<ul style="list-style-type: none"> • Increased opportunities for reservoir-based activities (e.g., fishing, power boating, jet skiing, shoreline hiking) • Decreased opportunities for whitewater boating and stream fishing
		Water surface elevation fluctuations	<ul style="list-style-type: none"> • Alterations in fishing opportunities • Alterations in shoreline access during reservoir drawdown • Loss of waterfront access (stranding of docks)
	Powerhouses (including turbines and bypass valves), intake structures, and conduits	Water intake	<ul style="list-style-type: none"> • Danger to recreationists
	Project-affected stream reaches	Altered flow regimes	<ul style="list-style-type: none"> • Alterations in opportunities for boating • Alterations in fishing opportunities and success • Alterations in opportunities for riparian hiking and wildlife viewing
	Roads	Access to remote areas	<ul style="list-style-type: none"> • Increased recreational opportunities • Decreased wilderness experience

Affected resources	Project facilities and features	Pathway leading to potential effect	Potential effect
Recreation	Recreational facilities (including campgrounds, boat ramps, trails, picnic areas, and restrooms)	High use of recreational facilities/inadequate capacity	<ul style="list-style-type: none"> • Loss of recreational opportunities from competition and conflicting activities • Increased use of dispersed (undeveloped) areas • Overcrowding at recreational facilities • Dissatisfaction with recreational experience due to human disturbance • Improper waste disposal
		Inadequate facility upkeep	<ul style="list-style-type: none"> • Loss of recreational opportunities • Improper waste disposal
		Improper campfire use or use of non-designated areas for fires	<ul style="list-style-type: none"> • Fire hazard
Aesthetics	Dams (including structures such as spillways, passage facilities, and sluice gates)	Raised structure penetrating landscape	<ul style="list-style-type: none"> • Diminished scenic integrity
	Reservoirs and forebays	Impoundment of flowing water	<ul style="list-style-type: none"> • Enhanced scenic integrity from open water
		Water surface elevation fluctuations	<ul style="list-style-type: none"> • Diminished scenic integrity from exposed bank areas
		Eutrophication	<ul style="list-style-type: none"> • Diminished visual and olfactory appeal from increased algal production
	Powerhouses (including turbines and bypass valves)	Turbine and bypass valve operation	<ul style="list-style-type: none"> • Noise disturbance
		Raised structure penetrating landscape	<ul style="list-style-type: none"> • Diminished scenic integrity
	Intake structures and conduits	Raised structure penetrating landscape	<ul style="list-style-type: none"> • Diminished scenic integrity
		Water intake at surface level	<ul style="list-style-type: none"> • Noise disturbance
		Open canals visible across landscape	<ul style="list-style-type: none"> • Diminished scenic integrity—linear feature
		Penstock visible across landscape	<ul style="list-style-type: none"> • Diminished scenic integrity—vertical linear feature
Project-affected stream reaches	Altered flows regimes downstream of dams	<ul style="list-style-type: none"> • Diminished scenic integrity 	
Transmission lines	Raised structure penetrating landscape	<ul style="list-style-type: none"> • Diminished scenic integrity 	

Affected resources	Project facilities and features	Pathway leading to potential effect	Potential effect
Aesthetics	Transmission lines	Maintenance of transmission line corridor	<ul style="list-style-type: none"> • Diminished scenic integrity—linear feature
	Roads	Decreased vegetative cover	<ul style="list-style-type: none"> • Diminished scenic integrity—network of linear features
	Maintenance and recreational facilities (including equipment storage, campgrounds, boat ramps, trails, picnic areas, and restrooms)	<p>Raised structures penetrating landscape</p> <p>Increased facility use</p>	<ul style="list-style-type: none"> • Diminished scenic integrity • Diminished scenic integrity • Noise disturbance • Exhaust from cars and motorboats
Cultural resources	Dams (including structures such as spillways, passage facilities, and sluice gates)	Maintenance/new construction	<ul style="list-style-type: none"> • Disturbance or destruction of archaeological and historic sites
	Reservoirs and forebays	Water surface elevation fluctuations	<ul style="list-style-type: none"> • Exposure of archaeological sites to vandalism • Erosion/destruction of archaeological sites by water action • Altered availability of plant materials used for ceremonial regalia and crafts
		Impoundment of water	<ul style="list-style-type: none"> • Possible submergence of archaeological or historic resources
	Powerhouses (including turbines and bypass valves)	Maintenance/new construction	<ul style="list-style-type: none"> • Disturbance or destruction of archaeological and historic sites

Affected resources	Project facilities and features	Pathway leading to potential effect	Potential effect
Cultural resources	Project-affected stream reaches	Reduction or fluctuation of flows downstream of dam	<ul style="list-style-type: none"> • Erosion/destruction of archaeological sites by water action • Alteration of fisheries and other traditional food resources • Decreased ability to float ceremonial canoes • Decreased ability to catch fish for ceremonial use • Altered availability of plant materials used for ceremonial regalia and crafts
	Transmission lines	Maintenance/new construction	<ul style="list-style-type: none"> • Disturbance or destruction of archaeological and historic sites
	Transmission lines	Maintenance of transmission line corridor	<ul style="list-style-type: none"> • Decreased availability of plant materials used for ceremonial regalia and crafts
	Roads	Maintenance/new construction	<ul style="list-style-type: none"> • Disturbance or destruction of archaeological and historic sites • Increased access to archeological/historic sites
	Maintenance and recreational facilities (including equipment storage, campgrounds, boat ramps, trails, picnic areas, and restrooms)	Maintenance/new construction Increased human use	<ul style="list-style-type: none"> • Disturbance or destruction of archaeological, historic, and modern cultural sites through increased use or through vandalism • Disturbance of traditionally used wildlife • Decreased availability of plant materials used for ceremonial regalia and crafts