IRRIGATION STRUCTURES

Selecting an appropriate design

Stream form and function

- Diversions should accommodate natural stream geometry and channel dynamics.
- Evaluate stream width-to-depth ratio, and match these dimensions if possible.
- Diverting water leaves less water in the stream to carry the same sediment load, likely leading to aggradation and channel instability.

Careful design helps reduce impacts to the stream and cuts maintenance costs on irrigation diversions.

Channel stability and capacity considerations

- Ensure that vertical and lateral channel stability is adequate.
- Evaluate effects of permanent rock weir versus removable structure (permanent structures may aggrade).
- Permanent instream structures should not restrict channel capacity when not diverting water.

Period of diversion

- High Water Operation – ability to regulate peak intake rates is important to prevent ditch failures.
- Low Water Operation – maintaining sufficient head to fill ditch can be challenging as stream drops.
- Year Round Diversion – icing and regulation of flows may make year-round diversions difficult.
- Type of Structure – permanent and temporary structures each have advantages.

Headwater elevation required

- Required ditch operating elevation and high/low water elevations in the stream should be estimated.
- "Checking up" of water should be kept to the minimum height required to divert adequate irrigation water.
- Diversions requiring minimal checking of stream elevation include rock weirs, barbs, and temporary cobble berms.
- High head installations require structural methods, and may have greater impacts on channel stability.
- High head and even low head structures can pose a hazard to boaters and anglers.

Fish passage

- Fish passage can be impeded by structures with drops exceeding 1 foot, or drops with poor entrance conditions and staging pools.
- Flat sills or diversion floors downstream of drop structures impede fish passage.
- Low head structures promote good fish passage.
- High head structures require some modification to facilitate fish movement.
- Fish ladders can be incorporated into the design if water availability is adequate to allow a flow of several cubic feet per second to continue past the diversion.
- In some cases, a "wasteway" ditch for return of excess diverted water can provide fish passage around an irrigation structure.
- Fish screens can be used at irrigation inlets to prevent fish from entering.

CONCRETE / WOODEN PIN & PLANK DIVERSIONS

Formed concrete diversions are generally similar in form and function to standard wooden pin and plank type structures.

Applications

- High head check structures (greater than 3 feet).
- Low width-to-depth ratio channels.
- Concrete is preferred when frost heaving could damage a wood structure, or a special shape or function is required (pneumatic spillway gates, fish ladder, or a combination bridge crossing and diversion).

Concrete may be preferred to wood for longevity. This structure is not fish friendly because of the height of the drop and the flat slab downstream.

IRRIGATION STRUCTURES

Design and construction techniques

- The open area of an unchecked diversion should accommodate the bankfull width of the stream.
- Structures should not impede floodplain function.
- Collapsible or removable braces are recommended in streams that carry significant amounts of woody debris or have a history of ice jams.
- Keep stopboards under 4 feet in length for ease of handling.
- Wingwalls must be of adequate length to retain fill materials.
- Provisions for fish passage should be considered.
- A sluiceway can be designed in the floor to enhance fish passage at low flows (post and irrigation season).
- Standard designs are available throughNRCS offices.

Wooden diversion structures have a limited life but are easily constructed.

CAUTION:

- Backwater can cause bedload gravel to accumulate, destabilizing the stream channel.
- Icing and spring peak flow can damage the structure if flashboards are left in place.
- It may be difficult to adjust or remove stop boards during spring floods.
- Fish passage may be impeded unless mitigation measures are designed into the structure.
- Avoid restricting the channel cross section with abutments.
- Avoid placing a sill or slab above or below the grade of the existing stream channel.
- Avoid creating boating hazards, if possible.

ROCK V AND W WEIRS / VANES

Rock V and W weirs are used for grade control and can provide a means of diverting irrigation water in situations where a permanent structure will not cause problems with channel stability.

Rock weirs are appropriate on wide shallow channels where adequately sized rock is available. Use a "V" shape in narrow channels and a "W" shape in larger channels. Do not use weirs if a permanent change in bed elevation will adversely impact channel stability.

This weir has a relatively flat profile (without "cap" rocks) typical of an installation to check water at irrigation diversions. **Caution:** sediment transport can be reduced, causing channel instability in high bedload rivers.

Applications

- Control channel bed elevation.
- Help guide water to ditch entrance.
- Promote bank stability by reducing grade and focusing flows to the center of the channel.

Design and construction techniques

- Rule of thumb: maintain a 1 foot drop or less over each structure.
- Large angular boulders are best to prevent movement during high flows.
- Use footer rocks to prevent scour and undermining.
- Increased weir length means less fluctuation in water height with changes in discharge.
- Pools will rapidly fill with sediment in streams transporting heavy bed loads.
- Channel stability in meandering, gravel bed rivers can be very sensitive to weir design (shape, alignment, elevation, etc.).
- Boulder weirs are generally more permeable than other materials and might not perform well for directing low flows.
- Voids between boulders can be chinked with smaller rock and cobbles to maintain flow over the crest. **Caution:** this reduces sediment transport capacity and can severely impact the channel.
- With center at lower elevation than the sides, weirs will maintain a concentrated low-flow channel. ***Note: See weir description under "Hard Engineering Methods" (pages 6.2 and 6.3).***

IRRIGATION STRUCTURES

GRAVEL BERM DIVERSIONS

Annual construction of gravel berms for irrigation diversions in rivers using heavy equipment has generally been discouraged by permitting agencies. Impacts on channel stability and fisheries can be significant.

Gravel berms may be appropriate:

- When impacts to channel stability and fisheries are judged to be minimal.
- On larger braided rivers where permanent structures are not feasible.
- When alternative practices are unavailable.

Alternatives

- Ditch cleaning to improve capacity.
- Low head rock V or W weirs and barbs.
- Relocation of ditch entrance upstream.
- Conversion to pumping station.
- Infiltration galleries (generally less than 5 cubic feet per second).

Design and construction techniques

- The gravel berm should be constructed to the minimum level needed to divert water.
- No gravel should extend above low water elevation.
- The length of berm and encroachment into the channel should be kept to a minimum.
- The berm should be knocked down or removed after the irrigation season to reduce impacts to the river channel.
- Minimize disturbance of streambanks and vegetation when using heavy equipment.
- Consider hauling gravels to site rather than excavating to avoid destabilizing the streambed.

Gravel berms are essentially an extension of the ditch. Relocating the ditch entrance upstream may reduce the need for instream berms.

Berms, like barbs, can direct flow against the opposite bank and cause erosion on the other side of the river.

CAUTION:

- Leaving permanent berms in place can destabilize stream channels.
- Construction of berms can disturb incubating eggs and spawning fish.
- Alternatives to berms should be considered whenever feasible.

INFILTRATION GALLERIES

Infiltration galleries are constructed by burying rings, perforated pipe, or well screen in or adjacent to the stream channel, and daylighting the pipe in an open ditch downgradient.

Infiltration galleries make use of buried screens or perforated pipe.

Infiltration galleries may be appropriate for:

- Cobble and gravel bed rivers with low silt accumulation (Rosgen B and some C channels).
- Smaller (less than 15 cubic feet per second) diversion rates.
- Preventing entrapment of fish.
- Laterally unstable channels where conventional structures fail.
- Debris-laden channels.

Design and construction techniques

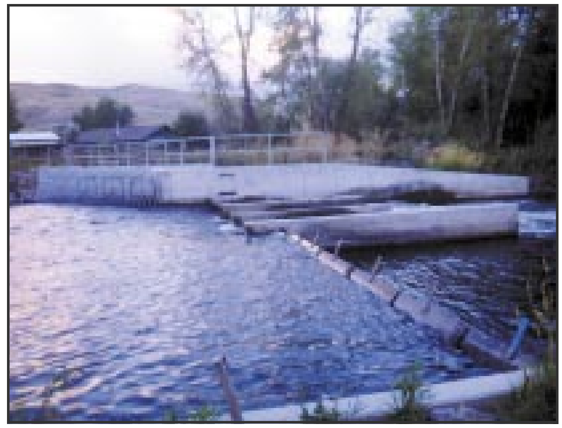
- Infiltration galleries require adequate hydraulic gradient (ditch-water slope).
- Engineering calculations are required to size the length and diameter of screen.
- Size of slots or perforations depends on riverbed gravel sizes.
- Provision must be made to prevent scour exposure of buried screen.
- Must provide access to allow backwashing (cleaning) of screens.

CAUTION:

- Annual maintenance is generally required with air or water backwashing to remove silts from the system.
- Channel downcutting, scour and fill, or migration can expose and damage the pipe.
- Design by an experienced engineer is recommended.

INFLATABLE GATE DIVERSIONS

Inflatable rubber or fabric bladders are most common as spillway control structures on dams. Water inflatable bladders can also be used alone without permanent structures for temporary diversions at construction sites or to control flooding. Both structurally supported and unsupported bladders may serve as irrigation diversions.



Inflatable bladder gates are generally used in specialized applications where precise control of water is important.

Use inflatable bladders:

- When precise control of headwater conditions is needed.
- When automatic control is desired.
- As an alternative to berms.
- To allow the release of diversion during flooding or emergencies such as debris jams.
- To help prevent ditch failures by improving control over diversion rates.

Design and construction techniques

- The base structure is similar to a concrete diversion structure.
- Precise concrete forming is required.
- Steel assembly is bolted to concrete.
- Steel panels fold nearly flush with structure when deflated.
- The compressor system requires electricity, but can be solar powered.
- Available in sizes suitable for small diversions.
- Engineering design recommended.

CAUTION:

- Bladders are sturdy, but can be damaged by debris, ice scouring, or excessive gravel deposition.
- Maintenance and electrical requirements may limit applications.
- Hire an experienced engineer to design the structure.

FISH PASSAGE

Fish passage is often impeded by irrgation structures, especially check board structures that span the width of the channel. Fish passage is especially critical during spring and fall spawning runs.

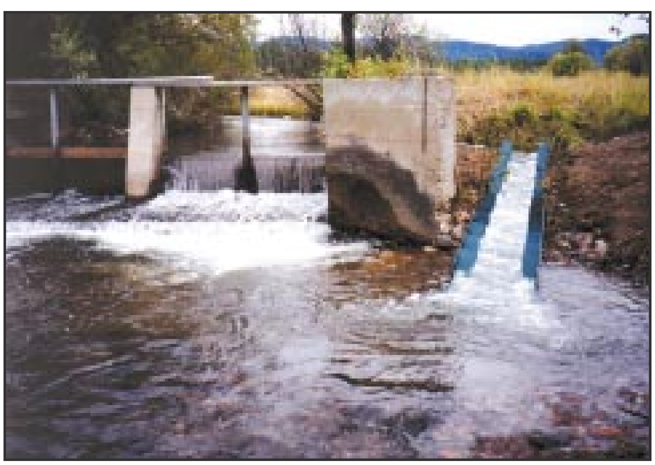
Fish passage is promoted by low head diversions such as rock weirs, but is limited by high head diversions (flashboard structures), unfavorable velocity, or approach conditions (a common problem with culverts). Trout are detered by drops over 1 foot, especially if there is no approach pool. Types of fish ladders include baffles, pool and weirs, and controlled side channels.

Pool and weir structures can be made of natural materials or engineered structures.

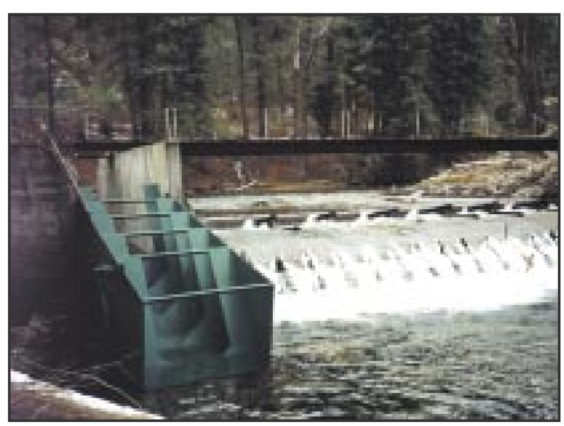
Design considerations

- Maintain drops of less than 1 foot per structure.
- Provide an entrance pool before a drop, and an exit pool after a drop.
- A series of stop boards in 0.5- to 1-foot steps through wood floor structures offer adequate passage if flows are sufficient (more than 1 cfs).
- Fish passage requires allowing several cfs to flow past a diversion during spawing runs.
- Constructed channels or waste ditches can provide passage around irrigation structures.

The flat floor and high drop of a pin and plank structure limits fish passage unless fitted with a fish ladder.



Denil fish ladders have a series of baffles to allow fish passage for small diversions.



Denil fish ladders should be long enough to ensure that the outlet end is submerged during operation.

FISH SCREENS

Fish screening

Using fish screens on diversions prevents the loss of both juvenile and mature fish in irrigation ditches. Almost any size diversion can trap significant numbers of fish. Reducing flows to 25 percent and then closing ditches gradually over several days may allow fish to migrate back to the main channel. Although flow rates cannot be regulated under the 310 Law, voluntarily avoiding excessive diversion rates can help reduce fish losses throughout the irrigation season.

Fisheries agencies can help with design and funding for fish screens. Standard designs include flat screens with brushes and rolling drum screens. Infiltration galleries also can provide excellent fish protection.

Design considerations

- Screen mesh size is typically 1/8-inch to 5/32-inch to protect fry.
- Approach velocities to screen should not exceed 0.4 feet per second.
- A bypass pipe (commonly 10-inch diameter) or channel is needed before the screen to redirect fry to main channel.
- The bypass may require 0.5 to 2 cfs of water.
- Leakage around screens must be prevented with well-maintained rubber gaskets.
- Self-cleaning screens may include a paddle wheel, electric power grid, or solar power.
- Costs vary depending on design, but range from $1,000 to $3,000 per cfs of diverted water.

CAUTION:

- Screening should be designed by an experienced professional.
- Icing, peak flows, debris, and vandalism can readily damage screens.
- All screens require periodic maintenance including debris removal, lubrication, seal replacement, and protection from ice damage.
- Carefully control the diversion rate to avoid over-loading the screen capacity.

Portable drum screens are suitable for small flows (less than 3 cfs).

Large drum screens can accomodate a wide range of flows (from 5 to 50 cfs or more).

Fish screens are effective for preventing fish loss in irrigation ditches. A by-pass channel is needed to redirect fry to the main channel. A flat screen relies on brushes to clear debris.

HEADGATES

Standard headgates

Waterman C-10 and R-5 slide gates

Waterman gates are standard for small to medium diversions on all stream types.

C-10 gates work well when:

- Round culvert meets diversion needs.
- Positive seal for control of diverted water is needed.
- Adjustable diversion rates are important.

R-5 gates may be preferred when:

- Using squash pipes, or wood headwalls in medium to large diversions.
- Some leakage is acceptable and ice formation is not a problem.

Wooden gates

- Constructed with a dimensional lumber box and flashboards to control the diversion rate.
- Use on small diversions needing an inexpensive inlet gate.
- Some leakage occurs through the stopboards, which can cause icing problems

Design considerations

- Place headgates in a protected position to avoid damage by ice or debris.
- Placement on the outside of stable meanders more easily captures flows, but also more fish.
- Placement on inside of meanders results in sediment deposition at the gate.
- Use adequate fill to bed and bury the pipe.
- Headwalls are often required to retain fill.
- Headgate should be sized in accordance with the water right for that diversion.
- Consider installing fish screens (see page 4.8).

A C-10 gate generally benefits from a headwall to stabilize fill. Rock can work, but the slope leaves the gate frame exposed to ice and debris.

Typical prefabricated metal R-5 headgate structure used for squash or arch pipes.

This is a well-constructed gate with wingwalls and positive control at high flows.

DAMS AND DAM SPILLWAYS

Dams, berms, and dikes must be designed to be stable during saturated conditions. All dams and impoundments, whether on-stream or off-stream, require an emergency spillway to safely pass peak flows without eroding.

Design considerations

- Dams generally require engineering design to ensure that fill materials and foundations are appropriate.
- All dams must include emergency spillways capable of safely carrying the 25- to 100-year flood.
- Spillways must be designed with adequate freeboard to prevent overtopping of unprotected areas of the dike or dam.
- Earthen dam slopes must generally be shallower than 2:1 slopes (commonly 3:1 or less).
- Dam spillways can be rock, concrete, wood, or geotextile-lined vegetated swales.
- Consult with a qualified professional before constructing dams and spillways.

CAUTION:

- Construction of new dams on perennial streams may be limited by fisheries, floodplain, water rights, or other environmental considerations.
- On-stream dams tend to accumulate silt, impede fish passage, and may raise water temperatures.
- Many small dams do not have adequate spillways and are prone to failure during flood conditions.
- The appearance of leaks on the dam face or at the toe may mean failure is imminent, especially if seeps are muddy or turbid.
- Dam designs should be reviewed by qualified professionals.
- Also, see concerns listed under “Ponds (Impoundments),” page 2.3.

This unique drop structure is a concrete channel studded with rock to slow velocities. Structures are more commonly large rock or formed concrete.

Canal checks, or outflow pipes, are commonly used on small ponds to control water elevations. Canal checks and standpipe structures do not substitute for emergency spillways.

FLOW MEASUREMENT DEVICES

Water rights and flow measurement

The Montana Department of Natural Resources and Conservation or irrigation districts may require measurement devices on diversions and ditches to verify correct water diversion rates. Flumes located in ditch channels do not require the 310 permit for installation.

Parshall and Montana flumes

- Are most common in larger ditches and flat gradient applications where backwater needs must be kept to a minimum.
- Allow passage of sediment and debris.
- Can be designed to measure both high and low flows with an insert.
- Are available in pre-fabricated steel and fiberglass.
- Require suitable bedding material or concrete to prevent leakage around the structure.
- Become inaccurate if not level.

Rectangular, V-Notch, and Cipoletti weirs

- Are common in smaller diversions.
- Create backwater in the ditch because an upstream pool is required.
- Can catch sediment or debris.
- Can block fish passage out of a ditch if no entrance pool is present below the drop.

Design considerations

- Select the size of device based on both minimum flows and maximum capacity.
- Flat gradient ditches require devices (such as flumes) that create minimal backwater.
- Proper installation is required for accuracy. The device must be level, with no leakage or settling.
- Approach conditions for weirs require low velocities and "contracted" conditions for accuracy.
- Locate the device away from the ditch entrance to prevent damage by ice and debris.
- Design assistance is available from NRCS and water resources professionals.

Parshall flumes cause minimal backwater, and work well in low-gradient applications.

The Montana flume is a shortened, less accurate version of the Parshall.

Types of flumes

- **Parshall Flume**—less drop required, larger diversions.
- **Montana Flume**—inexpensive version of Parshall, less accurate.
- **Trapezoidal Flume**—lower backwater over range of flows than Parshall.
- **H Flume**—requires significant drop, best for canal turnouts.
- **Adjustable A Flume**—similar to Parshall but can be adjusted once installed for proper drop through flume.

FLOW MEASUREMENT DEVICES (*continued*)

Many types of specialized flow measurement devices are available beyond the more common types of flumes and weirs mentioned here. NRCS or other water resources professionals can help select and site appropriate devices for flow measurement.

Open channel flow

- Stage-discharge measurements can be used to develop a rating curve for an open channel with a staff gage.
- Rating curves are developed by taking flow measurements with a velocity meter at several different flow rates.
- Weed growth can shift the stage-discharge relationship during the irrigation season (especially in low-gradient ditches).
- Culverts can be used to estimate flow if conditions are "inlet controlled." This condition occurs when flow is constricted and it drops as it enters the pipe.
- Open channel rating curves developed for staff gages are not always an acceptable technique for water rights purposes.

CAUTION:

- Sizing a measurement device (or headgate) smaller than the water right could eventually forfeit the water right.
- The device must not restrict the channel if placed in natural stream.
- Access to the ditch easement for installation may be limited, making maintenance of structures difficult.

This large concrete structure functions as a cipoletti type weir.

Stage-discharge relationships can be developed for open channels (or culverts) to monitor flow in ditches.

Rectangular weirs can be used to estimate flow if pooling of water behind structure is acceptable.