IRRIGATION DIVERSION STRUCTURES

Irrigation diversions are an important tool to ensure access to surface water rights. By ensuring proper siting and construction of diversions, irrigators can ensure that their activities will limit the impacts to natural stream function and to native fish populations. This chapter addresses design considerations, different types of diversion structures, and fish passage issues. Each structure is unique to the stream context and the needs of the irrigator as well as their allocated water right. Therefore, consultation with a professional is encouraged to ensure structures function efficiently and effectively to meet the needs of landowners and natural resources.

Contents

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

Fish screens on diversion structures prevent the loss of fish in irrigation ditches (entrainment)

DESIGN CONSIDERATIONS FOR IRRIGATION STRUCTURES

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.
- A peak flow capacity for a 100-year event is recommended for most diversions.
- Diverting water leaves less water in the stream to carry the same sediment load, and can lead to aggradation and channel instability.
- Changes in irrigation diversion location (or place of use) may require filing a change with the DNRC.

Channel Stability and Capacity Considerations

- Ensure that vertical and lateral channel stability is adequate for long-term stability.
- Evaluate effects of a permanent rock weir vs. 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 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. Different fish species and age classes have varying requirements.
- Flat sills or diversion floors downstream of drop structures impede fish passage.
- Low head structures can be more successful for fish passage.
- High head structures can require 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 when biologically relevant.

CONCRETE / WOODEN PIN & PLANK DIVERSIONS

Traditional pin and plank diversions are common in Montana, but often impede fish passage, and can adversely impact channel process. Nevertheless, they find application under certain circumstances.

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.

Applications

- High head check structures (greater than 3 feet)
- Low width-to-depth ratio channels
- Locations where water cannot be checked up to needed elevations year round (e.g., excessive back-water/flooding, icing, debris).

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 braces are recommended in streams that carry substantial 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.
- Standard designs are available through NRCS offices.

Wooden diversion structures have a limited life but are easily constructed. These type of diversions often form fish barriers because of the stopboards and flat floor.

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 is likely to 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.
- Potential alternatives are engineered riffle diversion or rock weirs.

ENGINEERED RIFFLE DIVERSION

Engineered riffle as an Alternative to Pin & Plank

A engineered riffle structure can provide an alternative to pin and plank diversion structures. In lieu of vertical stop boards, a rock structure can be constructed across the channel. This can be a long riffle or sequence of riffles and weirs or boulders.

Ideally, diversions should be designed to accommodate the transport of flow, sediment, and aquatic organisms. This requires an understanding of the sediment and flow regime of the stream/river, and fish passage requirements for the target species.

The photographs show replacement of a pin and plank structure with a engineered riffle and rock weir. The engineered riffle is self-maintaining and does not require adjustment as river stage increases or decreases. In addition, a mechanical paddle wheel fish screen was installed with a sediment sluice to keep the forebay clean of sediment. A fish return pipe was designed to prevent fish entrainment in the irrigation ditch.

Design Considerations

- Understand the sediment and flow characteristics of stream.
- A engineered riffle or weir is a permanent rise in channel bed elevation. Effects on flood elevation and sediment transport must be considered.
- Diversion should accommodate natural stream geometry and channel dynamics.
- Required ditch operating elevations and high/low flow elevations in the stream channel should be evaluated.

Original stopboard structure and Denil ladder did not provide adequate fish passage.

The diversion in the photo above was replaced with a engineered riffle structure, which allows fish passage and maintains natural stream processes.

View of the diversion weir, engineered riffle, new radial headgate and flat panel fish screen.

ROCK WEIRS & VANES

Rock 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. They can perform comparably to engineered riffle diversions. Like engineered riffles, weirs and vanes need to be evaluated for potential effects on flood elevations and sediment transport.

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.

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
- Raise water elevation at ditch intake
- Promote bank stability by reducing grade and focusing flows to the center of the channel

Design and Construction Techniques

- Rule of thumb is to 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.
- 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.
- With center at lower elevation than the sides, weirs will maintain a concentrated low-flow channel.
- Permitting on streams and rivers with mapped floodplains may require detailed hydraulic analyses to comply with no-rise requirements.
- Changes in the base flood elevation may trigger CLOMR/LOMR process, particularly if the diversion was not included in the FEMA floodplain study.

CAUTION

- In-stream structures can reduce sediment transport capacity and can severely impact the channel.
- Potential effects on flood elevations must be evaluated in jurisdictional floodplains.
- Elevation drop of more than several feet increases the risk of scour and structural failure.

GRAVEL BERM DIVERSIONS

Annual construction of gravel berms for irrigation diversions in rivers using heavy equipment has generally been discouraged by permitting agencies. Depending on how much site disturbance is needed, impacts on channel stability and fisheries can be substantial.

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 weirs
- Relocation of ditch entrance upstream
- Use of concrete diversion blocks
- 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 after the irrigation season to reduce impacts to the river channel.
- Minimize disturbance of streambanks and vegetation when using heavy equipment.

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

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

Small temporary berms may be appropriate in some locations as a low-impact alternative to permanent structures.

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.

DIVERSION BLOCKS

Concrete diversion blocks provide an alternative to permanent structures in the river bed or temporary gravel berms. Concrete blocks are placed on the river bed for the irrigation season, and removed in the fall. Blocks can be placed with a backhoe or loader using a lifting eye. Blocks are typically oriented in the upstream direction – not across the channel - effectively extending the "ditch bank" and point of diversion upstream on the river.

Concrete diversion blocks have a lifting ring and when placed in the streambed, the broad base keeps the block from tipping. Some site preparation may be necessary.

In high width to depth channels (i.e., wide and shallow), concrete blocks may eliminate the need for excavation and disturbance of the channel bed with annual construction and removal of berms. Not all locations are suitable for this style of structure, and depending on the location and channel alignment/morphology, some preparation of the stream bed may be needed. Gravel bed rivers (Rosgen C and D channels) can lend themselves well to this application.

Blocks can reduce the need for streambed disturbance associated with gravel berms. Blocks should be removed following irrigation season.

One advantage of removable concrete blocks is that floodplain permitting for diversions with FEMA mapped floodplains may be expedited by virtue of the temporary installation that leaves flood elevations unaffected. Bedload also passes freely during peak flows, which reduces the potential for aggradation and channel instability. Finally, the orientation of the blocks can be modified each year to accommodate shifts in channel orientation and low flow pathways.

Design and Construction Techniques

- Diversion blocks should be placed in the upstream direction, not across the channel.
- The channel bed will need to be prepared (smoothed/leveled) with backhoe or excavator.
- The length of blocks and encroachment into the channel should be kept to a minimum.
- The blocks must be removed after the irrigation season to reduce impacts to the river channel.
- Minimize disturbance of streambanks and vegetation when using heavy equipment.
- Storage of blocks within the floodplain may be acceptable if they do not create hazards during flood.

CAUTION

- Blocks should not be left in place year-round because of the potential for channel impacts.
- Scour and fill during high flow may bury blocks in the streambed.

INFLATABLE GATE DIVERSIONS

Inflatable rubber or fabric bladders are most common as spillway control structures on dams. 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

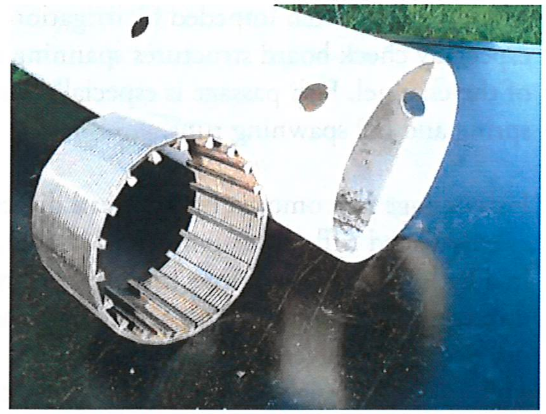
- The base structure is similar to a concrete diversion structure.
- Precise concrete forming is required.
- Steel assembly is bolted to concrete.
- Steel panels fold nearly flush with structure when deflated.
- The compressor system requires electricity, but can be solar powered.
- Available in sizes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

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 (B and some C channels)
- Smaller (less than 5 cubic feet per second) diversion rates
- Preventing entrainment of fish
- Laterally unstable channels where conventional structures fail

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.
- The size of slots or perforations depends on riverbed gravel sizes.
- Provision must be made to prevent scour exposure of buried screen.
- Provide access to allow backwashing (cleaning) of screens.

Concrete rings can make excellent pumping vaults when buried adjacent to a gravel bed stream channel.

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.

FISH PASSAGE AT DIVERSIONS

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

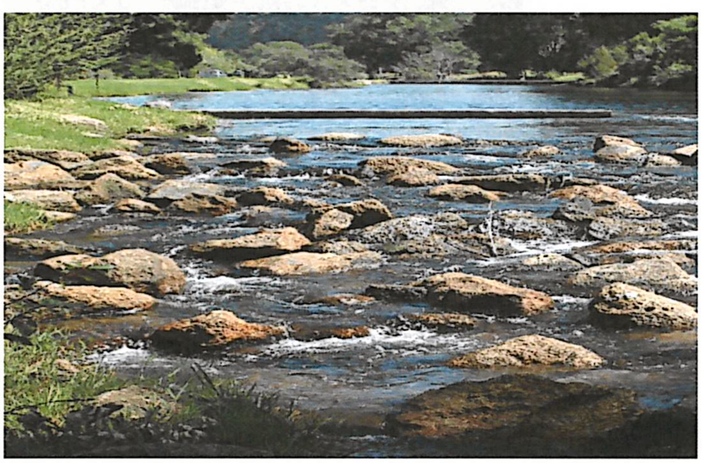
Fish passage is promoted by low head diversions (such as engineered riffle diversion or rock weirs), and limited by high head diversions (flashboard structures) or unfavorable velocity or approach conditions (a common problem with culverts). Trout are deterred by drops over 1 foot, especially if there is no approach pool. Types of fish ladders include baffles, pool and weirs, and controlled side channels. In some case, it may be best to replace diversions with a pump to access water.

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

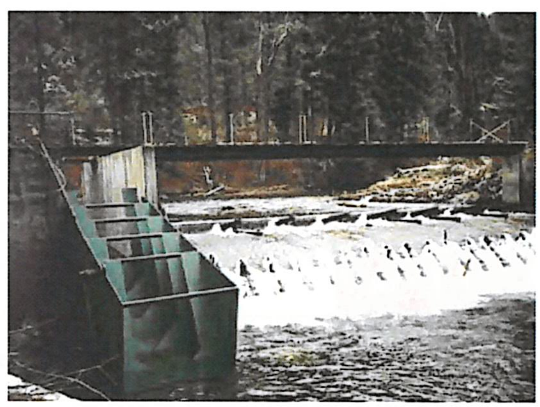
Design Considerations

- Low head rock weirs or engineered riffles can provide excellent passage when they can be accommodated in the channel.
- Constructed bypass channels around irrigation structures are preferred to Denil or other structural fish passage devices where feasible.
- Fish passage requires allowing streamflow to flow past a diversion during spawning runs.
- If in-channel rock weirs are used, maintain drops of less than 1 foot per structure.
- Provide an entrance pool before a drop, and an exit pool after a drop.

The flat floor and high drop of a pin and plank structure limits fish passage.



Engineered riffle diversions (armored riffle) are preferable to pin and plank structures.



Denil fish ladders can function but are less desirable than constructed bypass channels. These are not recommended for bull trout passage.

FISH PASSAGE AT DIVERSIONS (continued)

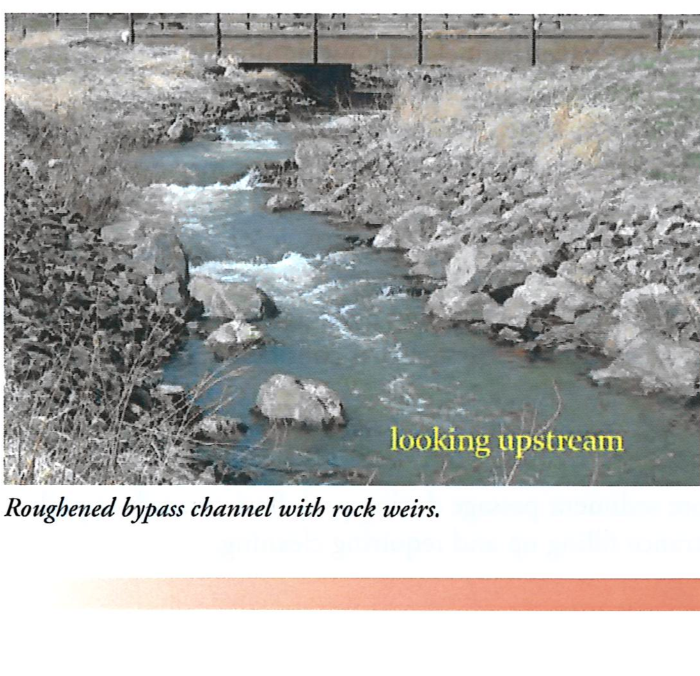
Bypass channels are preferred fish passage around irrigation structures if there is sufficient room. Channels are designed to meet stability criteria and provide fish passage over a desired range of flows. Bypass channels can be effective on small diversions but limited bypass flows may reduce effectiveness of this technique.

Irrigation dam prior to retrofit with engineered riffle bypass.

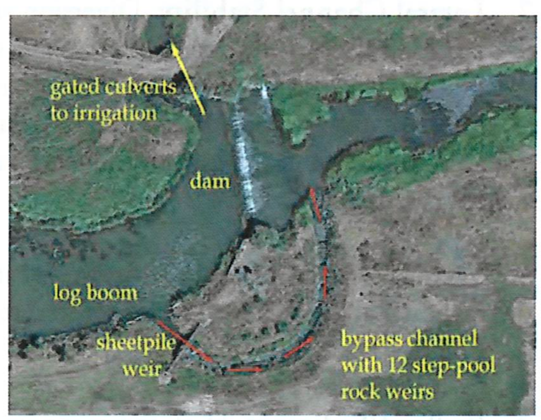
Design Considerations

- Channel hydraulics must be evaluated to ensure velocities and resting pools are sufficient for fish.
- Channel stability criteria must be defined to ensure bypass channel can withstand high flows.
- A weir or other flow regulating structure will be needed to control flows entering the bypass.
- Minimum bypass flow should be defined for critical time periods for fish passage.
- Location of the entrance below the diversion must be carefully selected to ensure fish will find the bypass.
- Attracting fish to the bypass entrance requires augmented flows.
- Designing the channel to have as many natural characteristics as possible (woody debris, vegetation, overhead cover, hydraulic diversity, resting pools, etc) aids with attracting fish.

Engineered riffle bypass provides fish passage.



Roughened bypass channel with rock weirs.



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

GUIDELINES FOR SMALL DIVERSION DESIGN

Diversion and headgate design needs to consider: 1) the ability to "check up" low water elevation to required operating level; 2) the ability of the diversion to pass peak flows, sediment and fish when not in use; 3) the ability of structures to withstand scour, icing, debris, and erosion; and, 4) provisions for fish/ aquatic organism passage when diverting water as required by agencies.

The following design criteria reference the figure following these pages:

1. **Channel Width**. Diversion structures should generally span the entire bankfull width to allow passage of fish, peak flow, sediment, debris and ice. Constricting the channel during spring runoff can result in adverse channel adjustments.

2. **Bankfull Depth**. Identifying bankfull depth from the channel bottom can help define the width of channel that will be expected to flood every 1.5 to 2 years. In general, irrigation structures should allow free passage of flood events when not in use.

3. **Low Water Elevation**. The low water elevation relative to the required ditch operating elevation will determine how high the water needs to be "checked up," or raised by the irrigation diversion.

4. **Required Ditch Operating Level**. The desired operating level is the water elevation required to maintain a full ditch during the irrigation season.

5. **Headwater Requirement**. Headwater is the amount of water elevation gain required to "turn out," or divert water into the ditch. Note that this elevation requirement is increased if the headgate is at right angles to the stream flow, and minimized if the headgate is more parallel to the flow because of the momentum of the flowing water. The tradeoff is that momentum also carries sediment and debris, so a balance and compromise is needed. The orientation/configuration of the intake is an important factor in diversion design. Small differences can have huge effects on performance.

6. **Maximum Ditch Diversion Rate**. This is the full ditch capacity as defined by the water right. This may be greater than the seasonal or typical water diversion rate, but diversion design should consider both typical and maximum diversion rates.

7. **Lateral Channel Stability**. Diversion structures in stable channels without significant lateral bank erosion or sediment deposition are less sensitive to design criteria such as bankfull dimension or flood passage criteria. If significant lateral instability or large sediment deposits are present, design should carefully consider channel hydraulics. In some cases, permanent structures may not be advisable due to potential impacts and probability of failure. Professional assistance is recommended for these structures.

8. **Vertical Channel Stability**. If the stream channel bed is downcutting or aggrading (filling up), professional assistance may be warranted to select an appropriate design that considers restoring channel function.

9. **Bedload/Sediment**. High sediment stream channels often make for high maintenance irrigation diversions. Designing the diversion to promote sediment passage during peak flow can reduce problems with channel instability or the ditch entrance filling up and requiring cleaning.

GUIDELINES FOR SMALL DIVERSION DESIGN (continued)

10. **Diversion Structure Type**. Structures commonly include temporary gravel berms and tarps, wooden pin and plank/stop boards, rock weirs and vanes, concrete boxes with stop boards, and sometimes more sophisticated diversions with radial gates or inflatable bladders. In general, permanent structures that raise the stream water level year-round are not encouraged, as are temporary structures that result in annual streambed and bank disturbance. Ideally, a structure should minimize stream impacts and provide both diversion of water and allowance for passage of floods, debris, ice, and aquatic organisms.

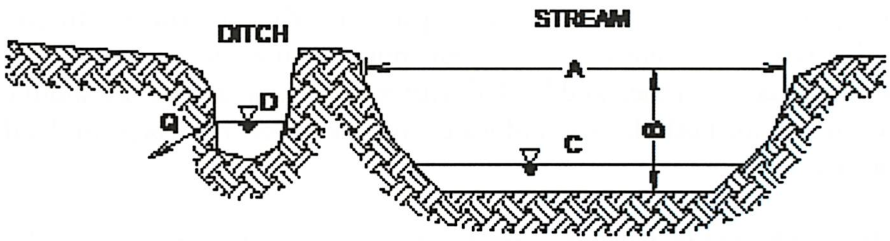
11. **Headgate**. The headgate helps control water and debris flowing into the ditch system, and a good design will help reduce the amount of headwater required to fill the ditch. Orienting the headgate to avoid damage by logs and ice sometimes requires a tradeoff between optimal water appropriation.

12. **Bank Protection**. Diversion structures and headgates often require some bank stabilization measures. Minimizing the extent of channel alterations can help expedite permitting review.

13. **Provision for Fish Passage**. Irrigation diversions should consider providing a means of fish passage when diverting water, and allow fish passage when not in use outside the irrigation season. This is particularly important in high value fisheries including tributaries that provide spawning and rearing habitat. Alternatives include a engineered riffle bypass, low rock weirs or riffles in lieu of pin and plank structures, Denil or other fish passage structures, porous tarps/poles instead of gravel berms, and pumps. The MFWP fish biologist that consults on the 310 permit can help select options and provide information on available funding sources to help cover the costs.

Older diversions that require maintenance or reconstruction offer opportunities for improvement in terms of functionality, fish passage, and stream function.

Diversion Design



CROSS SECTION A

1) CHANNEL WIDTH (ft) A = ________

2) BANKFULL DEPTH (ft) B = ________

3) LOW WATER ELEVATION (ft) C = ________

4) REQUIRED DITCH OPERATING LEVEL (ft) D = ________

5) HEADWATER REQUIREMENT (D–C, ft) ________

6) MAX. DITCH DIVERSION RATE (CFS) ________

7) CHANNEL STABILITY LATERAL GOOD / FAIR / POOR

8) CHANNEL STABILITY VERTICAL GOOD / FAIR / POOR

9) BEDLOAD/SEDIMENT LOW / MODERATE / HIGH

LOW <--EXPERTISE--> HIGH

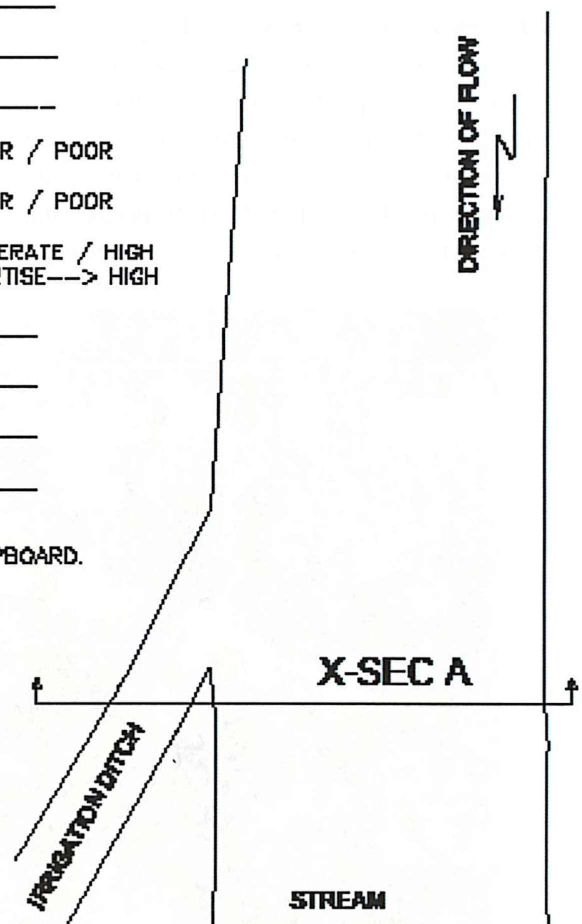
DIVERSION STRUCTURE TYPE (A) ________

HEADGATE TYPE (B) ________

BANK PROTECTION TYPE (C) ________

PROVISION FOR FISH PASSAGE (D) ________

A) TARPS / GRAVEL, ROCK STRUCTURE, PIN/PLANK/STOPBOARD.
B) SLIDEGATE, STOP BOARDS, CHANNEL TURNOUT.
C) ROCK, BIO-ENGINEERING, NONE.
D) BYPASS CHANNEL, STEP POOL, DENIL LADDER, OTHER.



PLAN VIEW
(SKETCH DETAILS)

	PERMIT NO:	DATE:	LOCATION:	PROJECT NAME: CD Manual
	PROJECT MANAGER:	NOT TO SCALE	FILENAME:	DRAWING TITLE: Diversion Design
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HEADGATES

Common 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 (no ice 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

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.

An R-5 Headgate is a flat plate which slides in front of round or arch pipes.

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.

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

FISH SCREENS

Fish Screening

Installing fish screens on diversions prevents the loss of both juvenile and mature fish in irrigation ditches (entrainment). Fish tend to go with the majority of the flow. Any sized diversion can trap substantial numbers of fish.

FWP and Trout Unlimited can help with planning, design, and funding of fish screens. Screens generally fall into two categories: active (moving parts) or passive (no moving parts). Passive screens can require less maintenance, but all fish screens require some level of perpetual maintenance.

Fish screens are typically used to protect important fish populations, where entrainment is negatively affecting a fishery. Without a screen, irrigators may reduce fish losses when closing a ditch by reducing flows to 25% and decreasing flow gradually over several days to allow fish to move back to the main channel or working with FWP to conduct fish rescue after irrigation season.

Farmers screens operate with no moving parts and provide good fish protection characteristics.

Large drum screens can accommodate 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 normally needed to redirect fry to the main channel. A flat screen relies on brushes to clear debris.

Design Considerations

- Screen design considers velocities to prevent fish and debris from getting impinged on the screen (approach velocity) and moving downstream (sweeping velocity).
- Mesh size is important to protect fry and clear debris.
- A bypass pipe or channel is needed to redirect fish to main channel. The bypass may require 5% of diverted flow.
- Active screens may be driven by a paddle wheel, solar, or an electric motor on line.
- Costs vary widely depending on design and size of installation, but range from $5,000 to $10,000 per cfs of diverted water.

CAUTION

- Not all irrigation ditches require fish screens. It is best to consult with a biologist before considering a project.
- All fish screens should be designed and installed by an experienced professional.

FISH SCREENS (continued)

Fish screens can be helpful in excluding fish from irrigation systems, which can reduce fish mortality and improve fish populations. Before starting a project, it is important to consult a local fisheries biologist to discuss the potential improvements. Once all stakeholders decide a fish screen is warranted, project designers must consider a variety of project components, including:

- Will screened flow return to the stream?
- What is the water right and maximum diverted flow?
- Is there power to the site?
- What is the grade of the stream or ditch and the available water surface drop (head)?
- What is the allowable footprint for a screen?
- How much and what is the size of debris and/or sediment that will encounter the screen?
- What fish species and sizes are you protecting?
- Who will be maintaining the screen, and what are their preferences?

Many stakeholders should be involved when considering a fish screen.

Fish screens can be installed in a stream, side channel, or ditch. Individual site constraints will dictate options that can be considered.

Location

In Montana, diversions are typically small and fish screens are often located in the irrigation ditch or instream.

In-ditch installations are downstream of control structures. This allows for easier inspection or maintenance, as well as protection from large debris and the public. Flow conditions are also more consistent and predictable. However, a bypass channel or pipe is necessary, meaning extra water will need to be diverted.

Instream structures allow fish to avoid a diversion altogether and does not require a bypass. However, maintenance may be more difficult, large woody debris may be damaging, and flow conditions may be more variable. Instream installations may not be feasible in larger waterbodies.

CAUTION

- Icing, peak flows, debris flows, 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 overloading the screen capacity.

SCREEN TYPES - ACTIVE

Active fish screens manage debris with a cleaning method that is mechanical. These screens require some form of power, which can include electric, solar, or paddlewheel. They are typically operated seasonally, as the mechanical components do not tolerate icing. These screens include the Rotating Drum Screen, Vertical Flat Plate Screen, Vertical or Horizontal Traveling Belt Screen, or Cone Screen. The most common active fish screens in Montana are the Vertical Flat Plate screen and Rotating Drum Screen.

Vertical Flat Plate Screen

The self-cleaning mechanism is typically a set of vertical brushes driven by a paddle wheel, or motor drive where electricity or sufficient solar is available.

- Generally used for screening larger flows
- Requires a bypass pipe
- Screen typically cleaned with wiper brushes, but air bursts or spray jets are options
- Flow capacity is not limited, typically >10 cfs
- Head requirement approximately 0.2 to 0.6 ft
- Operating ditch depth is >8 inches
- Large screens may require access to pour concrete slab and stem walls

Vertical flat plate screens rely on paddle wheels to power the cleaning brushes. Bypass water returns young fish to the river channel.

Rotating Drum Screen

The self-cleaning mechanism requires power and is often used in conjunction with a paddlewheel. The drum rotates continuously, filtered water flows through the screen, and a portion of the diverted water (bypass water) carries debris off the screen face and back to the stream.

- The water level on the drum must be 65-85% of the drum diameter to clean effectively
- Screens are typically installed at 15-45 degree angles from the flow
- Can be designed for small to large flows (multiple screens)
- Water surface drop requirements is 0.3 to <0.5 ft depending on the design
- Bypass can be piped or open channel
- Operating ditch depth is >8"
- Large screens may require access to pour concrete slab and stem walls

Drum screens can be configured with multiple bays to accommodate a wide range of flows.

SCREEN TYPES - PASSIVE

Passive fish screens manage debris through screen design and flow that sweeps along the screen and downstream. These screens include the horizontal flat plate screens (Farmers Screen, Watson Screen), the Coanda Screen, Corrugated Water Screen, and the Turbulent Fountain Screen. Passive screens are becoming increasingly popular due to the reduced maintenance requirements. The most popular passive screens in Montana have been the Farmers Fish Screen and the Coanda Screen.

Farmers Fish Screen

Farmers screens fit a variety of flows but screen size gets much bigger with larger capacity screens. They are constructed of a horizontal perforated stainless steel plate suspended in a pre-fabricated steel box. Filtered water drops through the screen, and a portion of the diverted water (bypass water) carries debris off the screen face and back to the stream with the fish.

- Requires appropriate entrance hydraulics
- Needs fairly steady diversion streamflows
- Good for shallow flow
- Flow capacity 1 to 25 cfs for modular screens
- Requires head of approximately 1 ft
- Consider access to place pre-fabricated steel or pour close-tolerance concrete slab and stem walls

The screen entrance is in the background; foreground shows screened water on the right and bypass channel (fish return) on the left.

Coanda Screen

Coanda fish screens are installed instream or in a side channel or ditch. Water pours over the top of the screen and screened water drops into the screen and out of a pipe. Fish and debris are transported over the screen.

- High flow capacity.
- Difficult to adjust bypass flow. Possible dewatering of screen toe and bypass during low flow periods.
- Plan to allow at least 0.25 cfs per linear of screen for bypass flow.
- Screen likely to create backwater or impoundment behind the screen.
- Requires a head greater than 1 ft.

In a Coanda, water flows down and out of a pipe, while fish and debris pass over the screen.

FLOW MEASUREMENT DEVICES

Water Rights and Flow Measurement

The Department of Natural Resources and Conservation or your local irrigation district may require measurement devices on diversions and ditches to verify correct water diversion rates.

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:

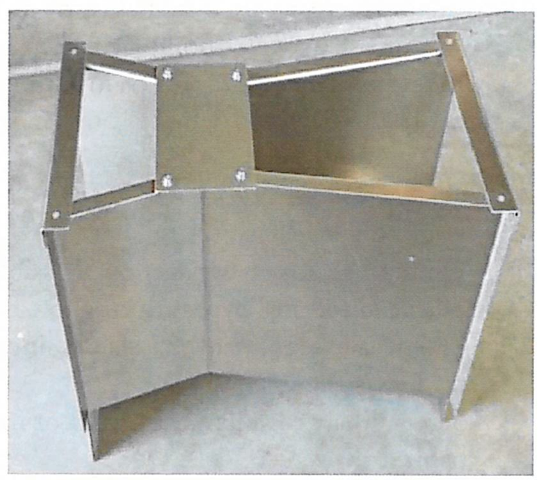
- Are common in smaller diversions
- Create backwater in the ditch because an upstream pool is required
- Can catch sediment or debris
- Can block fish passage out of a ditch if no entrance pool is present below the drop

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

The Montana flume is a shortened version of the Parshall and must be free flowing (not backwatered).

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.



The cutthroat flume has similar characteristics to the Montana flume but can be corrected for submergence.

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 gauges are not always an acceptable technique for water rights purposes.

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.

Numerous commercial water level/telemetry systems are available to measure flow remotely, including ultra-sonic and other sensors.

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

CAUTION

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

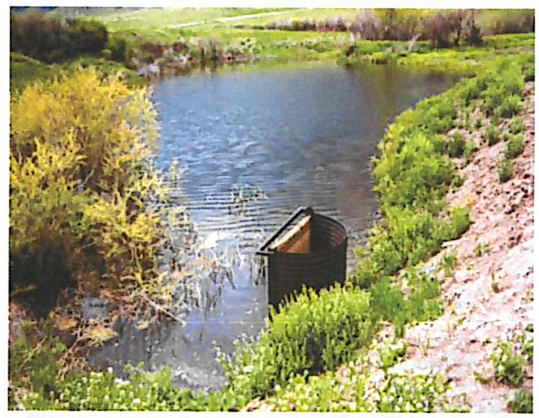
DAMS AND SPILLWAYS

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.

Dam spillway structures are commonly large rock or formed concrete and should be designed to withstand expected flood flows.

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.
- Contact Montana DNRC's Dam Safety Program for additional information regarding permitting, construction and/or maintenance associated with a new or an existing dam



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