Water Commissioner Training Manual

MONTANA DEPARTMENT OF
NATURAL RESOURCES AND
CONSERVATION
1424 9TH AVENUE P.O. BOX 201601
HELENA, MT 59620-1601

MONTANA DNRC

WATER CONVERSION TABLE

VOLUME UNITS

The standard unit of volume is acre-feet (ac-ft)

1 acre-foot is equivalent to:
- 325,851 gallons
- 43,560 cubic feet

FLOW RATE (DISCHARGE) UNITS

The legal unit for flow rate or discharge is cubic feet per second (cfs).

1 cfs is equivalent to:
- 40 miner's inches in Montana
- 448.8 gallons per minute (gpm)
- 1.983 acre-feet per day

A commonly used unit for flow rate or discharge is miner's inches (often referred to as just inches).

1 miner's inch in Montana is equivalent to :
- 1/40 cubic foot per second (cfs)
- 11.22 gallons per minute (gpm)
- 1/20 acre-foot per day

Water Commissioner Training Manual

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PREFACE

This training manual was compiled by the Montana Department of Natural Resources and Conservation (DNRC) as a training tool and field book to assist Montana water commissioners. DNRC is authorized and obligated to provide an educational program for water commissioners and mediators (section 85-5-111 Montana Code Annotated or MCA). The DNRC is working in cooperation with the District Courts of Montana and other appropriate state and federal agencies to develop an annual water commissioner training seminar, a training manual, and an outreach program that identifies persons who might serve as water commissioners.

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INTRODUCTION

This Water Commissioner Training Manual will be used in conjunction with Water Commissioner Training Seminar(s) presented annually in Montana. It has been assembled to provide water commissioners with supplemental educational and reference materials to assist them in distributing the waters of Montana within their jurisdictions according to prior appropriation law.

This manual is distributed in various water commissioner workshops held throughout the state. Your comments and suggestions for improving this manual would be greatly appreciated. Please submit your suggestions to the Water Commissioner Training Program, DNRC, P.O. Box 210601, Helena, Montana, 59620-1601. It is DNRC's goal to assemble valuable materials that will assist water commissioners with their daily duties of water measurement and distribution.

WATER COMMISSIONER DUTIES and RESPONSIBILITIES

WATER COMMISSIONER APPOINTMENT

On any stream, ditch, extension of ditch, watercourse, spring, lake, reservoir, or other water supply with water rights that have been determined by a decree, a water commissioner in the state of Montana can be appointed by the district court system. They become appointed through a petition process that requires at least 15% of the water rights or flow rate affected by the decree. Commissioners, by statute, are considered independent contractors and not employees of the court, the state of Montana, or the water users.

Upon appointment, the water commissioner is required by the district court to file an oath, a bond, and proof of worker's compensation insurance with the clerk of district court. Fulfillment of these obligations is to ensure the faithful discharge of their duties. An order signed by the judge and assigning the water commissioner to a stream or stream reach, setting salary, and other necessary provisions, is sent out to water users.

Water commissioners are generally appointed for one season at a time. Once appointed, all water users affected by the decree should be notified by the clerk of courts office.

Water commissioners are required by state law to attend at least one water commissioner training provided by the state of Montana.

GETTING STARTED

Once a water commissioner has been notified of appointment or potential appointment, the following must take place:

1) Attend DNRC Water Commissioner Training (call Montana DNRC Water Resources Division, 406-444-2074).

Once petition is filed with District Clerk of Court:

2) Purchase Worker's Comp insurance.

3) Meet with Clerk of Court:
   - File Oath and Bond
   - Get copy of Order
   - Get copy of the decree (list of water users, flow rates, etc.)
   - Set up billing protocol for payment.

4) Meet with previous water commissioner, if possible, to gather logistical information and practical advice.
5) Meet with water users, either individually or as a group, to review your duties, responsibilities, access, billing, and communication protocol.
6) Plan daily travel routes for administering water efficiently and accurately.
7) Upon commencement of duties, inspect headgates and measuring devices to ensure proper functioning condition.

RECORD KEEPING AND BILLING

The water commissioner is required to keep detailed records of the daily distribution of water. Payment for services are reliant upon such reporting. The frequency of payment is generally left up to the discretion of the district court and can be covered by the order of appointment.

Water commissioners are paid by the water users. Water users pay for the delivery of the water they receive and for expenses such as mileage, training, worker's compensation, and in some cases gaging equipment. While payment is divided proportionately among water users based on the percentage of water delivered, individual water users may also get billed for tasks that are specific to their operation such as infrastructure repair.

Water commissioners are responsible for tracking costs, recording the daily distribution of water and other expenses, and submitting records to the district clerk of court. District clerks of court are responsible for notifying water users of the amount owed to the water commissioner.

There is no standardized system for tracking costs. It is a common practice, however, for clerks of court to either have the commissioners submit billing information as a spreadsheet or to transpose water commissioners’ field notes into a formatted excel spreadsheet. This practice provides an easy way to track billing and provides transparent documentation for the public or district court hearings. DNRC can help water commissioners or clerks develop spreadsheets for tracking water deliveries and bills.

Montana state law, outlined in MCA 85-5, dictates water commissioner, District Court, and water user duties and responsibilities.

TITLE 85. WATER USE
CHAPTER 5. WATER COMMISSIONERS AND WATER MEDIATORS

Part 1. Appointment and Duties

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Part 1
Appointment and Duties

85-5-101. Appointment of water commissioners.

(1) Whenever the rights of persons to use the waters of any stream, ditch or extension of ditch, watercourse, spring, lake, reservoir, or other source of supply have been determined by a decree of a court of competent jurisdiction, including temporary preliminary, preliminary, and final decrees issued by a water judge, it is the duty of the judge of the district court having jurisdiction of the subject matter, upon the application of the owners of at least 15% of the water rights affected by the decree or at least 15% of the flow rate of the water rights affected by the decree, in the exercise of the judge's discretion, to appoint one or more commissioners. The commissioners have authority to admeasure and distribute to the parties owning water rights in the source affected by the decree the waters to which they are entitled, according to their rights as fixed by the decree and by any certificates, permits, and changes in appropriation right issued under chapter 2 of this title. When petitioners make proper showing that they are not able to obtain the application of the owners of at least 15% of the water rights affected or at least 15% of the flow rate of the water rights affected and they are unable to obtain the water to which they are entitled, the judge of the district court having jurisdiction may appoint a water commissioner.

(2) When the existing rights of all appropriators from a source or in an area have been determined in a temporary preliminary decree, preliminary decree, or final decree issued under chapter 2 of this title, the judge of the district court may, upon application by both the department of natural resources and conservation and one or more holders of valid water rights in the source, appoint a water commissioner. The water commissioner shall distribute to the appropriators, from the source or in the area, the water to which they are entitled.

(3) The department of natural resources and conservation or any person or corporation operating under contract with the department or any other owner of stored waters may petition the court to have stored waters distributed by the water commissioners appointed by the district court. The court may order the commissioner or commissioners appointed by the court to distribute stored water when and as released to water users entitled to the use of the water.

(4) At the time of the appointment of a water commissioner or commissioners, the district court shall fix their compensation, require a commissioner or commissioners to purchase a workers' compensation insurance policy and elect coverage on themselves, and require the owners and users of the distributed waters, including permittees, certificate holders, and holders of a change in appropriation right, to pay their proportionate share of fees and compensation, including the cost of workers' compensation insurance purchased by a water commissioner or commissioners. The judge may include the department in the apportionment of costs if it applied for the appointment of a water commissioner under subsection (2).

(5) Upon the application of the board or boards of one or more irrigation districts entitled to the use of water stored in a reservoir that is turned into the natural channel of any stream and withdrawn or diverted at a point downstream for beneficial use, the district court of the judicial district where the most irrigable acres of the irrigation district or districts are situated may appoint a water commissioner to equitably admeasure and distribute stored water to the irrigation district or districts from the channel of the stream into which it has been turned. A commissioner appointed under this subsection has the powers of any commissioner appointed under this chapter, limited only by the purposes of this subsection. A commissioner's compensation is set by the appointing judge and paid by each district and other users of stored water affected by the admeasurement and distribution of the stored water. In all other matters, the provisions of this chapter apply so long as they are consistent with this subsection.

(6) A water commissioner appointed by a district court is not an employee of the judicial branch, a local government, or a water user.

(7) A water commissioner who fails to obtain workers' compensation insurance coverage required by subsection (4) is precluded from receiving benefits under Title 39, chapter 71, as a result of the performance of duties as a water commissioner.

History: En. Sec. 1, Ch. 43, L. 1911; re-en. Sec. 7136, R.C.M. 1921; amd. Sec. 1, Ch. 125, L. 1925; re-en. Sec. 7136, R.C.M. 1935; amd. Sec. 1, Ch. 187, L. 1939; amd. Sec. 1, Ch. 231, L. 1963; amd. Sec. 39, Ch. 452, L. 1973; amd. Sec. 1, Ch. 51, L. 1975; R.C.M. 1947, 89-1001(1) thru (3), (5), (6); amd. Sec. 1, Ch. 444, L. 1979; amd. Sec. 1, Ch. 246, L. 1983; amd. Sec. 1, Ch. 468, L. 1989; amd. Sec. 7, Ch. 604, L. 1989; amd. Sec. 1, Ch. 179, L. 2003; amd. Sec. 37, Ch. 416, L. 2005; amd. Sec. 1, Ch. 92, L. 2007; amd. Sec. 1, Ch. 212, L. 2017.

85-5-102. Appointment of chief commissioner.

When the judge of the district court appoints two or more commissioners to admeasure and distribute the waters mentioned in 85-5-101, the judge may appoint one of them as chief commissioner and empower the chief commissioner to exercise direction and control over the other commissioners in the discharge of their duties. The judge may depose the person appointed as chief commissioner from that position and appoint another as chief commissioner whenever it appears to the judge that better service may be given to the water users by making the change.

History: En. Sec. 2, Ch. 43, L. 1911; re-en. Sec. 7137, R.C.M. 1921; re-en. Sec. 7137, R.C.M. 1935; R.C.M. 1947, 89-1002; amd. Sec. 2770, Ch. 56, L. 2009.

85-5-103. Oath and bond.

Each water commissioner appointed by the court shall subscribe and file with the clerk of the district court an oath of office before commencing the discharge of duties as commissioner and shall file with the clerk a bond executed by the commissioner, with two or more sureties, in a sum that the judge of the court may designate, to ensure the faithful discharge of the commissioner's duties.

History: En. Sec. 3, Ch. 43, L. 1911; amd. Sec. 1, Ch. 12, Ex. L. 1919; re-en. Sec. 7138, R.C.M. 1921; re-en. Sec. 7138, R.C.M. 1935; R.C.M. 1947, 89-1003; amd. Sec. 2771, Ch. 56, L. 2009.

85-5-104. Term of office.

A water commissioner holds office for the time during the irrigation season of each year that may be designated by the judge in the order making the appointment. The judge may fix the date of the commencement of the term and may, in in the judge's discretion or when requested in writing by at least three persons entitled to the use of the waters, change the term for closing of the commissioner's service.

History: En. Sec. 4, Ch. 43, L. 1911; amd. Sec. 1, Ch. 116, L. 1921; re-en. Sec. 7139, R.C.M. 1921; re-en. Sec. 7139, R.C.M. 1935; amd. Sec. 1, Ch. 68, L. 1955; R.C.M. 1947, 89-1004; amd. Sec. 2772, Ch. 56, L. 2009.

85-5-105. Power and duty to distribute water.

Upon the issuance of an order, the water commissioner or commissioners have authority and it is the commissioner's or commissioners' duty to admeasure and distribute to the users of water, as their interests may appear and be required, the stored and supplemental water stored and as released by the department of natural resources and conservation under provisions of Title 85, chapter 1, to be diverted into and through a stream, ditch or extension of ditch, watercourse, spring, lake, reservoir, or other source of supply in the same manner and under the same rules as decreed water rights are admeasured and distributed. The water commissioner or commissioners and the owners and users of the stored and supplemental water are bound by and are subject to the provisions of this chapter. However, the admeasurements and distribution of the stored and supplemental water may not interfere with decreed water rights. The purpose of Title 85, chapter 5, parts 1 through 3, is to provide a uniform, equitable, and economical distribution of adjudicated, stored, and supplemental waters.

History: En. Sec. 1, Ch. 43, L. 1911; re-en. Sec. 7136, R.C.M. 1921; amd. Sec. 1, Ch. 125, L. 1925; re-en. Sec. 7136, R.C.M. 1935; amd. Sec. 1, Ch. 187, L. 1939; amd. Sec. 1, Ch. 231, L. 1963; amd. Sec. 39, Ch. 452, L. 1973; amd. Sec. 1, Ch. 51, L. 1975; R.C.M. 1947, 89-1001(4); amd. Sec. 2773, Ch. 56, L. 2009.

85-5-106. Maintenance and repair of ditches or systems.

Upon written request of the owners of at least 51% of the water rights in any adjudicated ditch or single water system, the judge of the district court may empower the commissioner to maintain and keep in reasonable repair such water ditch or water system at the expense of the owners thereof, and for such purposes the commissioner shall have authority to enter and work upon any ditch, canal, aqueduct, or other source of conveying the waters affected by the decree and the right-of-way thereof and to visit, inspect, and adjust all headgates or other means of distribution of such waters.

History: En. Sec. 6, Ch. 43, L. 1911; re-en. Sec. 7141, R.C.M. 1921; re-en. Sec. 7141, R.C.M. 1935; R.C.M. 1947, 89-1006.

85-5-107. Record of distribution of water.

(1) Each water commissioner shall keep a daily record, unless a different recording schedule is ordered by the district judge, of the amount of water distributed to each water user and shall file a summary of the record with the clerk of the court monthly or seasonally, at the discretion of the district judge during the judge's term of service. The report must show in detail the total amount of water distributed to each water user during the month or the season and the cost of distributing the water, based upon the water commissioner's or commissioners' daily salary, other costs of the water commissioner or commissioners approved by the district judge, and the proportionate amount of water distributed. When two or more water commissioners serve under the same decree or decrees by order of the judge, they may file a joint summary of their records with the clerk of the court, or the chief commissioner, if one has been appointed by the judge, may file a summary on behalf of all of them.

(2) If the district court judge determines that it is necessary to establish a billing cycle prior to a distribution season, as provided in 85-5-204, the report or reports must serve as the basis for the amounts billed.

History: En. Sec. 9, Ch. 43, L. 1911; re-en. Sec. 7144, R.C.M. 1921; re-en. Sec. 7144, R.C.M. 1935; R.C.M. 1947, 89-1009; amd. Sec. 1, Ch. 305, L. 1983; amd. Sec. 1, Ch. 513, L. 2007.

85-5-108. Authority and arrest power.

For the purposes of carrying out the provisions of Title 85, chapter 5, parts 1 through 3, each commissioner appointed by the court has the authority to enter upon any ditch, canal, aqueduct, or other source for conveying the waters affected by the decree and to visit, inspect, and adjust all headgates or other means of distributing the waters and has the same powers as a sheriff or constable to arrest any person interfering with the distribution made by the commissioner, to be dealt with according to law.

History: En. Sec. 8, Ch. 43, L. 1911; re-en. Sec. 7143, R.C.M. 1921; re-en. Sec. 7143, R.C.M. 1935; R.C.M. 1947, 89-1008; amd. Sec. 2774, Ch. 56, L. 2009.

85-5-109. Failure to perform duty as a contempt of court.

If a commissioner fails to perform any of the duties imposed upon the commissioner by the order of the judge of the district court, the commissioner is guilty of contempt of court.

History: En. Sec. 7, Ch. 43, L. 1911; re-en. Sec. 7142, R.C.M. 1921; re-en. Sec. 7142, R.C.M. 1935; R.C.M. 1947, 89-1007; amd. Sec. 2775, Ch. 56, L. 2009.

85-5-110. Appointment of water mediators -- duties.

(1) Except as provided in 85-20-1902, the judge of the district court may appoint a water mediator to mediate a water controversy in a decreed or nondecreed basin under the following circumstances:

(a) upon request of the governor;

(b) upon petition by at least 15% of the owners of water rights in a decreed or nondecreed basin; or

(c) in the discretion of the district court having jurisdiction.

(2) A water mediator appointed under this section may:

(a) discuss proposed solutions to a water controversy with affected water right holders;

(b) review options related to scheduling and coordinating water use with affected water right holders;

(c) discuss water use and water needs with persons and entities affected by the existing water use;

(d) meet with principal parties to mediate differences over the use of water; and

(e) hold public meetings and conferences to discuss and negotiate potential solutions to controversies over use of water.

(3) If the governor requests or a state agency petitions for a water mediator, the governor or agency shall pay all or a majority of the costs of the water mediator as determined equitable by the district court having jurisdiction.

(4) The governor may use funds appropriated under 75-1-1101 to pay the costs of a water mediator.

(5) This section does not allow a water mediator to require any valid water right holder to compromise or reduce any of the holder's existing water rights.

(6) If an appropriator voluntarily ceases to use all or part of an appropriation right or voluntarily ceases to use an appropriation right according to its terms and conditions as a result of the efforts of a mediator appointed under this section, the appropriator may not be considered to have abandoned all or any portion of the appropriation right.

History: En. Sec. 1, Ch. 625, L. 1989; amd. Sec. 1, Ch. 108, L. 1991; amd. Sec. 2776, Ch. 56, L. 2009; amd. Sec. 11, Ch. 294, L. 2015.

85-5-111. Water commissioner and mediator education.

(1) The department of natural resources and conservation, in cooperation with the Montana supreme court, the Montana water courts, the district courts of Montana, the Montana university

system, and other appropriate state and federal agencies, shall develop an educational program for water commissioners and mediators that includes:

(a) an annual seminar on commissioner and mediator duties, mediation techniques, and water measuring techniques;
(b) preparation and, as necessary, revision of a water commissioner and mediator manual; and
(c) an outreach program that identifies persons who might serve as water commissioners or mediators.

(2) Unless a district court judge having jurisdiction determines otherwise, a water commissioner appointed pursuant to 85-5-101 shall complete at least one educational program as provided in subsection (1) prior to administering water.

History: En. Sec. 2, Ch. 625, L. 1989; amd. Sec. 1, Ch. 118, L. 2017.

Part 2
Charges and Expenses

85-5-201. Distribution of water and related expenses.
(1) Each water commissioner appointed by the judge of the district court for the purpose of distributing water has the authority to determine the appropriate quantity and distribute to the parties interested, under a decree, permit, certificate, or change in appropriation right, the water to which those who are parties to the decree or holders of a permit, certificate, or change in appropriation right, or privy to a permit, certificate, or change in appropriation right, are entitled, according to their priority as established by the decree, permit, certificate, or change in appropriation right.

(2) The water commissioner may incur necessary expenses in the making of headgates or dams for the distribution of the waters if the parties fail or refuse to do so. Expenses associated with making headgates or dams for the distribution of water must be assessed against and paid by the party or parties for whom the ditch or ditches were repaired or the dams or headgates were made. In

the discretion of the court, the costs or expenses may be assessed against the land upon which or for the benefit of which the expense had been incurred.

(3)(a) At the district court's discretion, a water commissioner may bill water users prior to the beginning of a distribution season for the purpose of offsetting costs associated with distributing water and water commissioner duties by submitting the information necessary for the billing to the clerk of the district court. A billing issued prior to the beginning of a distribution season:

(i) must be assessed on a per-user basis;

(ii) must be based on the report provided for in 85-5-107 for the prior year; and

(iii) may not exceed 80% of the amount that was provided to the district court pursuant to 85-5-107 for the prior distribution season on a per-user basis.

(b) Upon receipt of the information from the water commissioner, the clerk of district court shall proceed as provided in 85-5-204.

History: En. Sec. 5, Ch. 43, L. 1911; re-en. Sec. 7140, R.C.M. 1921; amd. Sec. 2, Ch. 125, L. 1925; re-en. Sec. 7140, R.C.M. 1935; R.C.M. 1947, 89-1005; amd. Sec. 2, Ch. 246, L. 1983; amd. Sec. 2, Ch. 92, L. 2007; amd. Sec. 2, Ch. 513, L. 2007.

85-5-202. Repair expenses.

The judge may allow as a charge any expenses necessarily incurred by the water commissioner in the discharge of duties in the employment of extra labor for the repair of dams, headgates, ditches, or flumes when immediate action is necessary to preserve the rights of the parties entitled to the waters of a stream or when the judge has, in the order appointing the commissioner, required the commissioner to repair ditches and keep in repair necessary headgates, ditches, or flumes. The water commissioner shall report all expenses, and the cost must be taxed against the party or parties for whose benefit the expenses were incurred. In the discretion of the court, the costs or expenses may be assessed against the land upon which or for the benefit of which the expense had been incurred.

History: En. Sec. 10, Ch. 43, L. 1911; re-en. Sec. 7145, R.C.M. 1921; amd. Sec. 3, Ch. 125, L. 1925; re-en. Sec. 7145, R.C.M. 1935; R.C.M. 1947, 89-1010; amd. Sec. 2777, Ch. 56, L. 2009.

85-5-203. Telephone expenses.

The judge may also allow as a charge reasonable expenses incurred by a water commissioner in telephoning to the judge for instructions in cases of emergency. When there are two or more commissioners acting under the judge's order, reasonable expenses incurred in communicating with each by telephone or with the judge of the district court, in order to carry on the distribution of the waters harmoniously and in accordance with the decree, shall be deemed a necessary expense. These expenses shall be reported by the water commissioner or commissioners at the close of the season and shall be taxed against all the water users affected by the decree or decrees ratably in proportion to the whole amount of water distributed to them during the season.

History: En. Sec. 11, Ch. 43, L. 1911; re-en. Sec. 7146, R.C.M. 1921; re-en. Sec. 7146, R.C.M. 1935; R.C.M. 1947, 89-1011.

85-5-204. Apportionment of fees and expenses.

(1) Upon the filing of the report by the water commissioner or water commissioners, the clerk of court shall notify by letter each person mentioned in the report:

- (a) of the amount the water user is made liable for by the report;
- (b) that objections to the report and the amount taxed against the water user may be made by any person interested in the report or the amount assessed against the water user within 20 days after the date of the mailing of the notice; and
- (c) that, unless objections are filed, an order will be made by the judge of the district court finally fixing and determining the amount due from each of the water users.

(2) The affidavit of the clerk that the clerk has mailed a notice to each person mentioned in the report at the person's last-known post-office address, in the usual manner, must be considered prima facie evidence that the person received the notice provided for in this section.

(3) At the discretion of the district judge, the water commissioner may issue a bill prior to the beginning of a distribution season for the purpose of offsetting costs associated with distributing water and water commissioner duties by submitting the information necessary for the billing to the clerk of the district court. The bill for each water user may not exceed 80% of the amount that was provided to the district court pursuant to 85-5-107 for the prior distribution season.

(4) If the cost of distributing water during a distribution season is less than the amount that was collected through a bill issued prior to a distribution season, the water commissioner shall refund the money to the water user based on the amount of water that the water user received during the distribution season. The water commissioner shall submit a refund report, along with proof that any refunds were issued, to the clerk of district court for filing.

History: En. Sec. 12, Ch. 43, L. 1911; re-en. Sec. 7147, R.C.M. 1921; amd. Sec. 1, Ch. 11, L. 1923; amd. Sec. 1, Ch. 45, L. 1927; re-en. Sec. 7147, R.C.M. 1935; R.C.M. 1947, 89-1012; amd. Sec. 3, Ch. 513, L. 2007.

85-5-205. Objections to expenses -- hearing.

At the expiration of the 20 days' notice, as provided for in the preceding section, if objections to said report have been filed or a motion to retax the same has been made, the court or judge shall fix a time for the hearing of such objections or motion to retax, which time of hearing shall be as soon as the judge or a court can conveniently hear the same. Any person objecting to said report shall be entitled to at least 5 days' notice of the date and time of such hearing. At such hearing the court or judge shall hear and determine the motion or objections and shall make an order fixing and determining the amount found due from each of said water users to such commissioner or commissioners. In case no objections are filed within the 20 days, as hereinbefore provided for, such order shall be made as a matter of course, and in either case said order shall be final determination of the matter.

History: En. Sec. 13, Ch. 43, L. 1911; re-en. Sec. 7148, R.C.M. 1921; amd. Sec. 2, Ch. 11, L. 1923; re-en. Sec. 7148, R.C.M. 1935; R.C.M. 1947, 89-1013.

85-5-206. Effect of order fixing fees.

After the order of the court fixing the fees and compensation and expenses of the water commissioner is final, the order has the force and effect of a judgment against the person to whom the water was or will be distributed and for whose benefit it was used or will be used. When the expenses of a commissioner or commissioners has been assessed against the land for which the service of the commissioner or commissioners has been rendered, the assessment is a lien against the land. The lien has the same effect as a judgment. The lien may be executed in the same manner as a judgment upon order of the court. The water commissioner, at the water commissioner's discretion, may withhold further determinations of quantity or distribution of water to any person entitled to the water until the person has paid all fees, compensation, and expenses of the water commissioner or commissioners fixed by the court and apportioned and charged to the person, including bills sent prior to the beginning of a distribution season. The commissioner may withhold the determination of quantity and distribution of water from any land against which there exists any lien that is the result of lack of payment pursuant to this section until the lien has been fully discharged.

History: En. Sec. 14, Ch. 43, L. 1911; re-en. Sec. 7149, R.C.M. 1921; amd. Sec. 4, Ch. 125, L. 1925; amd. Sec. 1, Ch. 39, L. 1929; re-en. Sec. 7149, R.C.M. 1935; R.C.M. 1947, 89-1014; amd. Sec. 4, Ch. 513, L. 2007.

Part 3
Rights and Duties of Water Users

85-5-301. Complaint by dissatisfied user.

(1) A person owning or using any of the waters of the stream or ditch or extension of the ditch who is dissatisfied with the method of distribution of the waters of the stream or ditch by the water commissioner or water commissioners and who claims to

be entitled to more water than the person is receiving or to a right prior to that allowed the person by the water commissioner or water commissioners may file a written complaint, duly verified, setting forth the facts of the claim.

(2) Upon receipt of the complaint, the judge shall fix a time for the hearing of the petition and shall direct that notice be given to the parties interested in the hearing as the judge considers necessary. At the time fixed for the hearing, the judge shall hear and examine the complainant and other parties who appear to support or resist the claim and examine the water commissioner or water commissioners and witnesses regarding the charges contained in the complaint.

(3) Upon the determination of the hearing, the judge shall make findings and issue an order that the judge considers just and proper. If it appears to the judge that the water commissioner or water commissioners have not properly distributed the water according to the provisions of the decree, permit, certificate, or change in appropriation right, the judge shall give the proper instructions for distribution of the water.

(4) The judge may remove any water commissioner and appoint a new water commissioner if the judge determines that the interests of the parties in the waters mentioned in the decree, permit, certificate, or change in appropriation right will be best served by appointing a new water commissioner. If it appears to the judge that the water commissioner has willfully failed to perform the water commissioner's duties, the water commissioner may be proceeded against for contempt of court, as provided in contempt cases. The judge shall make an order regarding the payment of costs of the hearing that the judge determines is just and proper.

History: En. Sec. 15, Ch. 43, L. 1911; re-en. Sec. 7150, R.C.M. 1921; amd. Sec. 5, Ch. 125, L. 1925; re-en. Sec. 7150, R.C.M. 1935; amd. Sec. 13, Ch. 460, L. 1977; R.C.M. 1947, 89-1015; amd. Sec. 3, Ch. 92, L. 2007.

85-5-302. Maintenance of headgates and measuring devices.
All persons using water from any stream or ditch for which a water commissioner is appointed are required to have suitable headgates at the point where a ditch taps a stream and shall also, at some suitable place on the ditch and as near the head as practicable, place and maintain a proper measuring box, weir, or other appliance for the measurement of the waters flowing in the ditch. If a person fails to place or maintain a proper measuring appliance, it is the duty of the water commissioner not to apportion or distribute any water through the ditch. The commissioner shall notify all parties interested by certified mail or in person 1 week before making the annual repair or cleaning of a stream or ditch or performing necessary labor or expenses to divert water to a ditch. The sending of a certified letter to the last-known post-office address of any interested party is prima facie evidence of the fact that the party was duly notified. Any work in the way of repairing a ditch made necessary by an emergency may be done without notice when injury would result from a delay.

History: En. Sec. 7, Ch. 64, L. 1905; re-en. Sec. 4890, Rev. C. 1907; re-en. Sec. 7151, R.C.M. 1921; amd. Sec. 6, Ch. 125, L. 1925; re-en. Sec. 7151, R.C.M. 1935; R.C.M. 1947, 89-1016; amd. Sec. 4, Ch. 432, L. 1989; amd. Sec. 2778, Ch. 56, L. 2009.

Part 4
Water Ditches Under Joint or Corporate Control

85-5-401. Determination of water rights between partners, tenants in common, and corporate stockholders.
If a water ditch used for irrigating purposes is owned by a partnership, tenants in common, or corporation and there is any dispute between the respective owners, tenants in common, or stockholders respecting the use and division of the waters flowing in the ditch, any partner, tenant in common, or stockholder may commence an action in any court of competent jurisdiction to determine the rights of the respective parties to the use of the waters and may join in the petition a request for the appointment of

a water commissioner to apportion and distribute the waters of the ditch according to the rights of the respective owners, tenants in common, or stockholders during the pendency of the action.

History: En. Sec. 1, Ch. 181, L. 1919; re-en. Sec. 7152, R.C.M. 1921; re-en. Sec. 7152, R.C.M. 1935; R.C.M. 1947, 89-1017; amd. Sec. 2779, Ch. 56, L. 2009.

85-5-402. Appointment of commissioner prior to final decree.

After the filing of the complaint in an action under 85-5-401, the court may, upon 5 days' notice to the other parties to the action, appoint a commissioner to divide and distribute the waters of the ditch to the respective parties, according to their respective rights, during the pendency of the action. The court may, upon good cause shown, appoint a commissioner without notice, and when a commissioner is appointed without notice, any party to the action may, on 5 days' notice to the plaintiff, move the court or judge to vacate the appointment or to modify the order as to the distribution of the waters of the ditch. The court or judge, on hearing, may affirm, vacate, or modify the order previously made. Each water commissioner appointed shall subscribe to an oath of office before commencing the discharge of duties.

History: Ap. p. Sec. 2, Ch. 181, L. 1919; re-en. Sec. 7153, R.C.M. 1921; re-en. Sec. 7153, R.C.M. 1935; Sec. 89-1018, R.C.M. 1947; Ap. p. Sec. 3, Ch. 181, L. 1919; re-en. Sec. 7154, R.C.M. 1921; re-en. Sec. 7154, R.C.M. 1935; Sec. 89-1019, R.C.M. 1947; R.C.M. 1947, 89-1018, 89-1019(part); amd. Sec. 2780, Ch. 56, L. 2009.

85-5-403. Division of water.

It shall be the duty of the water commissioner to divide the waters of said ditch between the owners, tenants in common, or stockholders in proportion to their respective rights, as set forth in the complaint or in such other manner or proportion as the court or judge may direct.

History: En. Sec. 3, Ch. 181, L. 1919; re-en. Sec. 7154, R.C.M. 1921; re-en. Sec. 7154, R.C.M. 1935; R.C.M. 1947, 89-1019 (part).

85-5-404. Authority of commissioner.

Such commissioner shall have authority to enter upon said ditch; open, close, and set headgates; and do whatever else is necessary to apportion and distribute the waters of said ditch to the respective parties according to their respective rights.

History: En. Sec. 4, Ch. 181, L. 1919; re-en. Sec. 7155, R.C.M. 1921; re-en. Sec. 7155, R.C.M. 1935; R.C.M. 1947, 89-1020.

85-5-405. Compensation and expenses.

The court shall fix the compensation of the commissioner and the term of employment and shall make an order apportioning the amount of compensation among the several owners, tenants in common, or stockholders of the ditch, according to their respective rights and interest in the ditch. The amounts apportioned must be taxed as costs in the action against the respective parties.

History: En. Sec. 5, Ch. 181, L. 1919; re-en. Sec. 7156, R.C.M. 1921; re-en. Sec. 7156, R.C.M. 1935; R.C.M. 1947, 89-1021; amd. Sec. 2781, Ch. 56, L. 2009.

85-5-406. Interference with actions of commissioner.

A person opening or closing a headgate after being set by the commissioner or who in any manner interferes with the commissioner in the discharge of the commissioner's duties is guilty of contempt of court and may be proceeded against for contempt of court as provided in contempt cases.

History: En. Sec. 6, Ch. 181, L. 1919; re-en. Sec. 7157, R.C.M. 1921; re-en. Sec. 7157, R.C.M. 1935; R.C.M. 1947, 89-1022; amd. Sec. 2782, Ch. 56, L. 2009.

85-5-407. Appointment of water commissioner after final decree.

When the rights of the respective parties in an action to the use of the waters flowing in a ditch are adjudicated, the judge of the district court having jurisdiction of the subject matter, upon the application of the owners of at least 10% of the waters of the ditch, may, in the exercise of the judge's discretion, appoint a water commissioner to divide, apportion, and distribute the waters of the ditch to the respective parties according to their respective rights as set forth in the decree. When a commissioner is appointed under the provisions of this chapter to apportion and distribute the waters of the stream from which the water flowing in a ditch is taken, the commissioner shall, when directed by the judge or court, apportion and distribute the waters of the ditch according to the decree by which the rights of the respective owners were adjudicated.

History: En. Sec. 7, Ch. 181, L. 1919; re-en. Sec. 7158, R.C.M. 1921; re-en. Sec. 7158, R.C.M. 1935; R.C.M. 1947, 89-1023; amd. Sec. 301, Ch. 42, L. 1997.

85-5-408. Apportionment of costs.

(1) When a commissioner is appointed upon the application of an owner or owners of a ditch, the court may fix the compensation of the commissioner and the term of the commissioner's employment. The court shall make an order apportioning the amount of compensation among the several owner or owners, tenants in common, or stockholders of the ditch according to their respective rights and interest. The order has the effect of a judgment against the person to whom the water was admeasured and for whose benefit it was used. When, in the discretion of the court, an order of apportionment of expense is made against the land for which the water was used, it has the effect of a lien against the land to which the apportionment was made. Execution may issue upon the order as upon a judgment by direction of the court, upon the application of any person interested in the order.

(2) When a commissioner is appointed under the provisions of this chapter to distribute the waters of the stream from which the waters flowing in a ditch are taken and to apportion and distribute the waters of the ditch according to the rights of the respective owners of the waters, the judge, in the judge's discretion, may, in addition to the apportionment taxed against the respective owners of the waters of the stream, apportion and tax the amount, if any, that the owners of the ditch shall pay in addition to the amount taxed under the provisions of this chapter.

History: En. Sec. 8, Ch. 181, L. 1919; re-en. Sec. 7159, R.C.M. 1921; amd. Sec. 7, Ch. 125, L. 1925; re-en. Sec. 7159, R.C.M. 1935; R.C.M. 1947, 89-1024; amd. Sec. 302, Ch. 42, L. 1997.

INFORMATION and RESOURCES

WATER RESOURCES INFORMATION

Information on water resources, water rights, water law, and measuring devices can be obtained from the DNRC Water Resources Regional Offices, websites, and publications listed below. Information resources include:

> Aerial photographs

> Topographic maps

> Water Resource Surveys by county
- information consists of maps
- field notes and narrative histories
- ditch locations
- decree indexes
- irrigated acres

> DNRC stream gaging data

> Water Rights indexes by drainage
- source name by priority date
- owner name
- point of diversion
- water right number
- place of use

> Water measuring assistance

> Original claim abstracts

> General information on water law

> Status of basin adjudication

WEBSITES AND PUBLICATIONS

Montana Code and Constitution
http://leg.mt.gov/bills/mca/index.html

Montana Dept. Natural Resources and Conservation
http://www.dnrc.mt.gov/

DNRC Water Resources Division
http://www.dnrc.mt.gov/divisions/water

Montana State Library's Natural Resources Information System
http://nris.msl.mt.gov/

USDA Natural Resources Conservation Service – Montana
http://www.mt.nrcs.usda.gov/

Water Rights Bureau and Forms
http://dnrc.mt.gov/divisions/water/water-rights

Adjudication
http://dnrc.mt.gov/divisions/water/adjudication

Reservoir Operations
http://dnrc.mt.gov/divisions/water/projects

Water Commissioner Course Information (manual, power point, etc.)
http://dnrc.mt.gov/divisions/water/management/training-education/water-commissioner-information

Web Soil Survey – NRCS
http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

DNRC Water Right Query System
http://wrqs.dnrc.mt.gov/default.aspx

NRCS Montana Snow Survey Program
http://www.mt.nrcs.usda.gov/snow/

NRCS Water Supply and Reservoir Storage
https://www.nrcs.usda.gov/wps/portal/nrcs/mt/snow/waterproducts/supply/

USDI United State Geologic Survey – Montana
http://mt.water.usgs.gov/

DNRC Surface Water Data
https://gis.dnrc.mt.gov/apps/stage/

USGS Real Time Streamflows
http://waterdata.usgs.gov/mt/nwis/current?type=flow

USGS Surface Water Data – Historical
http://waterdata.usgs.gov/mt/nwis/s

Current Drought and Water Supply Conditions – State of Montana
http://drought.mt.gov/default.aspx

Groundwater/Well Information Montana Bureau of Mines and Geology (MBMG)
http://mbmggwic.mtech.edu/

Publications:

Water Rights in Montana, updated biennially, Montana Dept. of Natural Resources and Conservation, Legislative Environmental Quality Council, Water Center – Montana State University.

Title 85, Water Use, Montana Code Annotated, updated biennially, Montana Legislative Services Divisions, Capitol Building, P.O. Box 201706, Helena MT, Phone 444-3036.

A Landowner's Guide to Western Water Rights, ME Wolfe, The Montana Water Course Montana State University, 201 Culbertson Hall, Bozeman, MT.

Water Measurement Manual, U.S. Department of Interior, Bureau of Reclamation, A Water Resources Technical Publication, Third Edition, 1997.

DNRC WATER RESOURCE DIVISION
WATER OFFICES

Billings
Airport Business Park
1371 Rimtop Drive
Billings MT 59105-1978
(406) 247-4415

Bozeman
2273 Boot Hill Court, Suite 110
Bozeman MT 59715
(406) 586-3136

Glasgow
222 Sixth Street South
PO Box 1269
Glasgow MT 59230-1269
(406) 228-2561 or 228-2564

Havre
210 Sixth Ave.
PO Box 1828
Havre MT 59501-1828
(406) 265-5516 or 265-2225

Helena
1424 Ninth Ave.
PO Box 201601
Helena MT 59620-1601
(406) 444-6999

Kalispell
655 Timberwolf Parkway, Ste 4
Kalispell MT 59901-1215
(406) 752-2288

Lewistown
613 NE Main, Suite E
Lewistown MT 59457-2020
(406) 538-7459

Missoula
2705 Spurgin Road
Building C
PO Box 5004
Missoula MT 59806-5004
(406) 721-4284

DNRC Water Resources Division
1424 Ninth Ave.
PO Box 201601
Helena MT 59620-1601
(406) 444-6601

Montana Water Court
601 Haggerty Lane
PO Box 1389
Bozeman MT 59771-1389
1-800-624-3270 or
(406) 586-4364

Montana Watercourse
MSU - Culbertson Hall
Room 332
PO Box 170575
Bozeman MT 59717
(406) 994-6671

WATER DISTRIBUTION and MEASUREMENT

DISTRIBUTION AND FLOW MANAGEMENT

Day to day operation of water commissioners requires attention to the accurate and timely distribution of decreed waters. A thorough understanding of what constitutes accurate delivery and fair distribution of water under all circumstances is needed.

ACCURATE DISTRIBUTION

Proper infrastructure enables the water commissioner to fairly distribute waters, protect water rights, and prevent overcharging of water users. In order to ensure accurate delivery of water, water users are required to have a properly functioning headgate and a properly functioning measuring device located in close proximity of their diversion works.

A properly functioning headgate is easily adjustable by one person, can be completely shut off, and allows for a range of flows that fall within the requirements of the water rights associated with that point of diversion.

A properly functioning measuring device is a recognizable standardized apparatus, usually a weir or flume, that is installed based upon design specifications for that device. More details on properly functioning measuring devices are included later in this chapter in the water measurement section.

Distributed waters are measured at the source as described in the decree. To alleviate the influence of hydraulics that sometimes exist below headgate structures and occasional logistical issues, measuring devices can be located several hundred feet below headgates, but not at a distance so far that accurate measurement of withdrawal would be precluded.

Various types of streamflow require special consideration. Natural flows are administered separate of released stored waters. Instream flow water rights may also require special attention.

Natural flows - The naturally occurring water that creates in-channel flows. Natural flows do not include water imported from other basins, water stored in a reservoir, or artificially added ground water. Natural flows may include tributary streams, springs, bank storage, and return flow.

Stored waters - Water stored in a reservoir that may be released into a natural channel for conveyance. Water stored in a reservoir that is turned into the natural channel of a stream to be withdrawn or diverted at some point downstream for beneficial use must be measured at a minimum, at the original point of diversion (i.e., reservoir outlet).

Instream flow - Water rights to remain instream to provide benefits to flows. Instream flow rights are administered in priority similar to any other surface water right.

TIMELY DISTRIBUTION

Water commissioners are required to distribute waters based on the Prior Appropriation Doctrine. This "priority system" demands the most senior water user receives their appropriated amount of water at their headgate first. As water supply diminishes over the course of the irrigation season, junior priority users are shut off. Water is delivered to the most senior water user as supplies exist. There are no other priority systems in Montana.

SPECIAL CIRCUMSTANCES

While carrying out their duties, water commissioners may encounter circumstances not specifically described in the old decrees.

Carriage Losses

Carriage refers to the quantity of water required during conveyance to deliver a specified amount from a point of diversion to the place of use. Carriage loss is accounted against the water right holder. As stated before, a water user measures their diversion at the headgate on the source, not at the field headgate. Losses from the point of diversion and the place of use cannot be added to the diversion.

In shared ditches, the carriage loss may be allocated proportionally between the water users, at least through the “shared portion of the ditch”; each user jointly shares in the losses.

The same holds true with stored water. While Montana law allows the owner of stored water to convey that water in a natural stream or stream course, the law also places a burden upon the user to be able to account for losses or delays in delivery (section 85-2-411 MCA). Therefore, it is possible that uses of stored water have multiple measuring devices. For example, they may have to measure inflows and outflow of the reservoir, changes in reservoir levels and measure the diversion of water from the carriage stream into the ditch at a secondary point of diversion (POD).

In some cases, stored and natural flow water users may have an informal agreement to share in the carriage losses that occur during transport between the legal and secondary POD. This agreement cannot expand the limitations of the water rights involved including priority date, period of use, flow rate, point of diversion, and place of use.

Road Construction

In 2001 the Montana legislature created provisions that allow the leasing of their water right for road construction without a public notice or administrative proceeding. The period of the lease is limited to 90 days. The quantity of water leased cannot exceed 60,000 gallons per day or the amount of the original appropriation, whichever is less. Any combination of leases for a single construction project cannot exceed 120,000 gallons per day. The lessee is to publish a notice of the proposed use in a newspaper of general circulation in the area of the diversion or mail notice to potentially affected water users 30 days prior to use. A complaint to DNRC will cause a review, temporary discontinuance, and if the other rights can be satisfied, an order to continue (section 85-2-410 MCA, "Short-term Lease of Appropriation Right").

Instream Flow Changes

There are two sections of statute that allow leasing and temporary changes of a consumptive water right to instream flow. One statute limits participation to the Montana Department of Fish, Wildlife and Parks (section 85-2-436 MCA, Water leasing Study,

FWP leasing program). The other section allows a private party to temporarily change their right for a limited period to instream flows (section 85-2-408 MCA). Only the original owner (lessor) of the right can seek enforcement of the instream flow changes. Therefore, the commissioner will be working with the original owner of the right. DNRC uses the provisions for "changes in appropriation right" (section 85-2-402 MCA) to review, condition, and approve such proposals. The "Authorization to Change", issued by DNRC with it's attached conditions is crucial to the water commissioner. Further, the applicant is required to develop a measurement and operation plan that describes the reaches where the water is to be protected by priority date and is to provide mechanisms for water measurement. Since these measurement sites are likely to be on the stream itself and not ditches or man-made canals, it is unlikely that a commissioner will be able to rely upon standard measurement structures. In many of these cases, streamflow measurements are obtained using a staff gage, gaging station, or manual methods.

Authorities – Decrees of Operation

As Montana's general stream adjudication proceeds it will become more clear who has water rights and what those rights are. In many areas of the state water commissioners must still use historic stream reach decrees. These documents are often 50 to 100 years old. The owners listed may bear little or no relationship to those living on the stream today. Further, there may be water rights developed that are not part of that decree. Some of those developed prior to the Water Use Act of 1973 – both *use rights* and *filed appropriations* – are likely to be valid rights but may not be included in the decree. However, at this point, since the commissioner administers water rights under a decree, the commissioner may not be able to deliver those other water rights. A water right developed and authorized by the state's water right system after 1973 and the passage of the water use act can be regulated by a commissioner, even though it is not part of the historic decrees.

WATER COMMISSIONER DO'S AND DON'T'S

Do's

- Measure and distribute water based on priority and decree.

- Inspect headgates and measuring devices.

- Record daily distribution.

- When warranted, shut water off based on:

    > priority

    > lack of payment

    > non-cooperation regarding infrastructure

- Administer water at source unless otherwise ordered by Decree or Judge.

Don'ts

- Change points of diversion (PODs), periods of use, flow rates, place of use, or priority dates.

- Deliver water based on preferred use (must be based on priority).

- Deliver water to non-water right holders.

- Deliver water outside of priority unless senior user asks to be shut off.

- Perform construction in or near a stream without a 310 permit

    (National Streambed and Preservation Act)

WATER MEASUREMENT

The information contained in this section has been assembled from a variety of sources. Personnel at the DNRC Water Resources Regional Offices can provide assistance in using this information and making accurate water measurements.

Standard Units of Measurement

The standard unit of water measurement in Montana is the cubic foot per second or CFS. In reality, many water users describe their use in terms of inches or Miner's inches. The miner's inch is defined as the quantity of water that will flow through an opening 1-inch square in a vertical wall under a given pressure head. Pressure heads ranging from 4 to 7 inches were used by miners and settlers.

Miner's inch as defined in terms of cfs:

> 1/50 cfs = southern California, Idaho, Kansas, New Mexico, North Dakota, South Dakota, Nebraska, Utah, Washington

> 1/40 cfs = Arizona, northern California, Montana Nevada, Oregon

> 1/38.4 cfs = Colorado

> 1/36 cfs = British Columbia

In other words, in Montana, 1 CFS = 40 Miner's Inches.

While flow rates are described in terms of CFS, volume of use is described in acre-feet. An acre-foot is the amount of water it would take to cover a one-acre field one foot deep. One CFS flowing for 24 hrs is equal to approximately 2 acre-feet (1.983 acre-feet).

Multiply:				
Cubic feet per second (cfs) by:	1	40	1.983	448.8
Montana miner’s inch (inches) by:	0.025	1	0.0496	11.22
Acre-feet per day (ac-ft/d) by:	0.504	20.16	1	226.2
Gallons per minute (gpm) by:	0.0022	0.088	0.0044	1
To Get:	cfs	inches	ac-ft/d	gpm

MEASURING DEVICES

To ensure the faithful discharge of their duties, as required by the oath of office and the bond filed with the clerk of district court's office, water commissioners must be able to accurately measure and distribute waters listed in the decree. Water is typically measured by standardized devices such as flumes and weirs but can also be measured manually using current meters.

It is recommended that water users have one of the following standardized devices for distribution of decreed waters.

- parshall or short-parshall flume
- ramp flume (broad crested weir)
- cipoletti, rectangular, or V-notch weir
- submerged orifice
- in-line propeller meter (for pipe flow)

In the case that no water measuring device is apparent, the water commissioner can require one to be installed. The district court judge, if asked, is likely to require the water user to install such a device. Factors which influence the selection of measuring devices include:

- accuracy requirements
- cost
- range of flows needed
- head loss
- approach velocity
- adaptability to site conditions
- ability to pass sediment and debris
- user acceptance
- maintenance requirements
- construction and installation requirements

Current meters can be useful to water commissioners for obtaining an instantaneous flow measurement, or checking the accuracy of a standardized measuring device. Current meters measure the velocity of water. When velocity is applied to the cross-sectional area of a stream, a flow or discharge may be obtained. Standard methodologies have been developed for this procedure. Acceptable current meters include:

- Flowtracker ADV
- Marsh-McBirney electromagnetic meter
- Price AA propeller meter
- Price pygmy propeller meter

The following procedure is based on the recommended standard USGS methodology (see reference below).

1) Select flat, laminar, straight-section if possible, with zero-flow control section below site (generally a riffle).
2) Stretch tape across channel, perpendicular to flow.
3) Set instrument time interval to 40 seconds.
4) Record tape distance and depth of water (to hundredths).
5) Set top-setting rod at 0.6 of depth (from top of water column).
6) Push 'on' button to reset velocity calculation.
7) Record velocity at end of timed interval.
8) Space intervals so no measurement accounts for greater than 10% of volume. Widen interval in slow shallow areas, tighten intervals in deep, fast sections.
9) Take at least 20 measurements.

Measurement of stream discharge by wading. Nolan M.K. and Shields R.R. 2000. U.S. Geological Survey WRIR 00-4036. Download at: http//training.usgs.gov/ntc/courses/cbt-cdrom/cbtindex.html

Measuring Device Inspection

To ensure accurate measurement of water, a measuring device must be functioning properly. Devices can deteriorate and become unusable over time especially if maintenance is neglected. In some cases, they may be improperly installed in the first place. Either way, they will not be accurately reading flows. Regular and careful inspection of measuring device condition will prevent inaccuracies that may affect water distribution at the site in question and at other sites affected by the decree. Considerations when inspecting measuring devices include:

- proper selection of standard device
- approach flow conditions- dependent on device
- exit flow conditions - must have free-flow conditions
- turbulence - not conducive to accurate measurement
- location of staff gage - dependent on device
- level - crest, bulkhead, sidewalls, etc. must be plumb

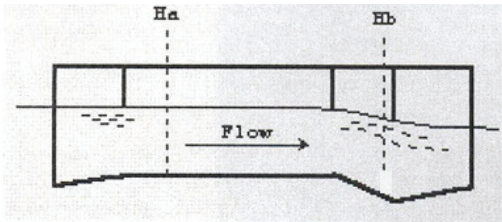
Detailed descriptions of device specifications and installation are provided in the following pages as well as the following references.

Water Measurement Manual, U.S. Department of Interior, Bureau of Reclamation, A Water Resources Technical Publication, Third Edition, 1997.

Irrigation Water Management, Irrigation ditches and pipelines. University of Wyoming Cooperative Extension Service College of Agriculture Bulletin 583R.

Determining Discharge from a Submerged Parshall Flume

A water commissioner approaches a 3-foot parshall flume and sees no standing wave and suspects it is submerged. The regularly mounted staff gage (Ha) reads 0.8 feet. Using another staff gage carried by the water commissioner, a second staff gage reading is taken at the lower end of the throat section. The commissioner is careful to make sure the bottom of the staff gage is level with the floor of the approach section of the flume.



The second staff gage reading (Hb) is 0.6 feet. To determine if the flume is indeed submerged, Hb is divided by Ha:

Hb/Ha = 0.6/0.8 = 0.75 or **75%**

Comparing the percentage to a submergence table like this one from Wyoming's Irrigation Water Measurement Bulletin 583R, shows that 75% is greater than the 68% limit for a 3-foot parshall flume and therefore the flume is submerged.

Table 3: Transition submergences in Parshall flumes.

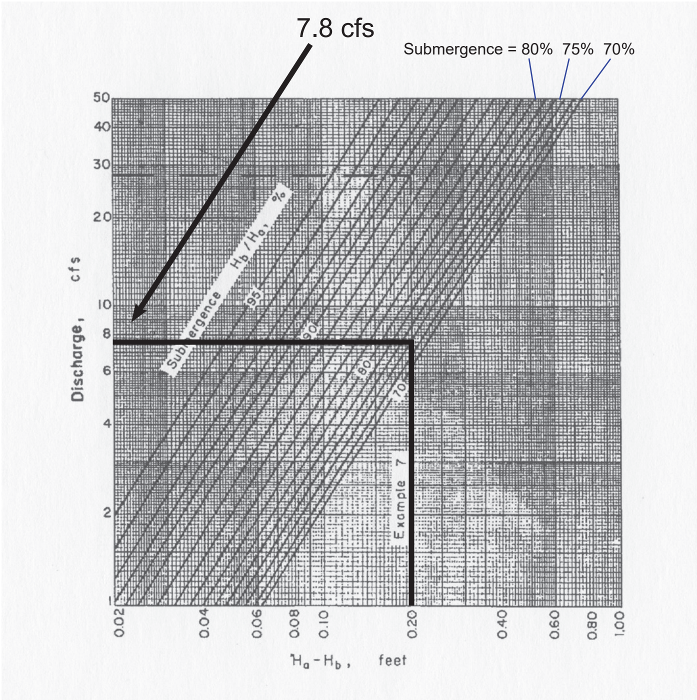
Flume Size	Transition Submerg-ence (H_b/H_a)	Flume Size	Transition Submerg-ence (H_b/H_a)	Flume Size	Transition Submer-gence (H_b/H_a)
3"	56%	18"	64%	4'	70%
6"	56%	24"	66%	5'	72%
9"	60%	30"	67%	6'	74%
12"	62%	3'	68%	7'	76%
				8'	78%
				10' to 25'	80%

If the H_b/H_a ratio is less than shown in Table 3, there is free flow through the flume and Table 8 (p. 36-49) can be used to determine discharge.

The next step for the water commissioner is to determine the adjusted discharge from a chart using the staff gage values. First subtract Hb from Ha:

Ha – Hb = 0.8 – 0.6 = 0.2

Next, find 0.2 on the horizontal axis of an appropriate submergence chart such as those located in Wyoming Irrigation Measurement Bulletin 583R. Draw a line from this point until the diagonal line representing the submergence value, in this case 75%, is intersected then draw another line to the vertical axis. Where this horizontal line intersects the vertical axis is the adjusted submergence in cubic feet per second (cfs). In this case it is 7.8 cfs (note: the non-adjusted discharge would have been 8.46 cfs based on just the Ha staff gage).



Note: If submergence is greater than 95% then this method does not apply and the flume must be raised and reset.

MEASURING DEVICE SPECIFICATIONS

Water Measurement

MT 9129 (AG)

The Parshall Flume (Part 1)

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

This bulletin is composed of two parts. Part 1 should be used by those who are choosing among types of measuring devices, or who need information and tables for flume use. Part 1 describes the flume, gives its advantages and disadvantages, and tells how to measure water. Part 2 (MT 9130) gives flume dimensions, describes sizing and locating the flume, and tells how to measure water under submerged condition. Part 2 is quite technical and intended for use by technicians, contractors, and engineers.

What is a Parshall flume?

A Parshall flume, shown in Figure 1, is a specially shaped structure which can be installed in a channel to measure the water flow rate. The flume was developed and calibrated by Ralph Parshall at Colorado State University early in this century and has been used extensively in Montana and other states. Many people confuse the Parshall flume with weirs. Flumes and weirs are not the same. They should not be confused in discussion or when using tables to determine flow rates. Parshall flumes are difficult devices to set and build. They are, however, an accepted and widely used measuring device. Standard-size commercially made flumes are available and in most situations should be selected over on-site construction unless an experienced contractor is available.

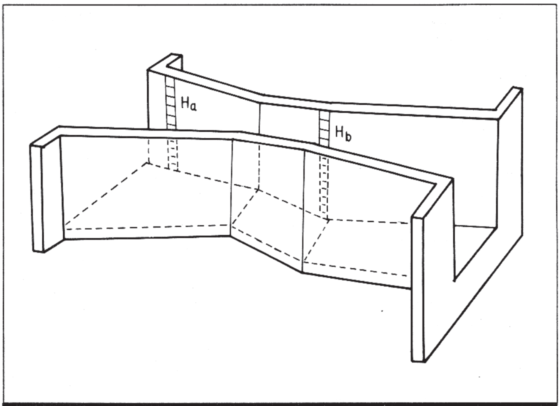


Figure 1. A Parshall measuring flume.

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second x hours}}{\text{area irrigated in acres}}$$

$$= \frac{\text{flow in gallons per minute x hours}}{\text{450 x area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches x hours}}{\text{40 x area irrigated in acres}}$$

The Parshall flume consists of a converging section, the throat (crest), a downward sloping floor, and a rising/diverging downstream section. A short Parshall, also called a Montana flume (discussed in MT 9127 and MT 9128), has only the converging section and crest. The Montana flume cannot be used to measure submerged flow. The portion of the Parshall flume downstream from the crest minimizes erosion and allows measurement when the flow

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Water Should Be Measured Because . . .

Water measurement is the foundation of water management and economical crop production. Measuring and applying the proper amount of water saves you money and protects water resources by decreasing soil erosion, fertilizer leaching, and waste water problems.

Montana law requires measuring devices on all streams for which water commissioners have been appointed. A commissioner cannot deliver water unless measuring devices are in place. Eventually all Montana waters will be decreed. You can protect your water right by accurately measuring and recording flow rates and times of use.

Water measurement also helps conserve energy by enhancing fertilizer use and reducing the need to pump. Optimizing water use can lessen local and regional shortages. And minimizing water and energy use nationally will help decrease dependence on foreign energy and conserve our own water and energy supplies.

is partially submerged (when water is "backed up" into the throat). The flume size corresponds to the throat width which normally is in one-foot increments.

Advantages

• The flume can operate with small head loss which allows use in flatter ditches than a weir.

• The flume is relatively insensitive to the velocity of the inflowing water. Thus it can be located in canals and ditches without a stilling pond immediately upstream.

• Fairly good measurements can be obtained under moderate or even considerable submergence when the proper correction factors are used. Remember, submergence should be avoided by proper installation if at all possible. Measurement under submerged conditions is discussed in Part 2 (MT 9130).

• The water velocity through the flume is high enough to virtually eliminate sediment deposition.

• Prefabricated flumes ready for field installation in sizes ranging from one to four feet are available at commercial outlets.

• Accuracy is plus or minus percent if the flume is carefully constructed, and the flume is accepted as an accurate measuring device in virtually all jurisdictions.

• The flume can be built in different sizes to accommodate a wide range of flow rates. Sizes and dimensions are given in Part 2, (MT 9130).

Disadvantages

• The flume requires meticulous attention to detail in construction. Proper dimensions must be followed exactly if the flume is to measure accurately.

• The flume must be set and located correctly for good measurement. Part 2 (MT 9130) gives details on locating and setting the flume.

• The flume cannot be used to control the flow of water. A separate headgate is required.

• Construction and installation is beyond the capabilities of the average water user. Prefabricated flumes are available but help in installation may still be needed.

Water measurement

Tables are available which are used to convert linear measurements to flow. The steps for using a table to determine the flow rate through a Parshall flume are:

1. Determine the flume size. The size is the width at the narrowest part. This part is the throat or crest of the flume.

2. Measure the upstream head, H_a. H_a is measured two-thirds of the distance from the crest to the flume entrance. For most irrigation measurements, a staff gage attached to the flume wall at this point is satisfactory. When precise measurement is required, stilling wells (a pipe set outside the flume but connected to the water in the flume) should be installed so that minor water fluctuations are dampened.

Units of Measurement

Water is measured in volume and flow rate units. The choice of units depends on what is customary and legal and on how water is purchased or delivered.

Common volume units used in irrigation are: cubic foot (cu. ft., ft^3), gallon (gal.), acre-inch (ac.in.), and acre-foot (ac. ft.). Flow rate units simply add a time dimension to these volume units. These are: cubic feet per second (cu. ft./sec or cfs), gallons per minute (gpm), acre-inches per hour (ai/hr), and acre-feet per day (af/day).

A common flow rate unit in Montana is the miner's inch (M.I.). Water users often refer to a flow rate as a certain number of "inches," when they actually mean miner's inches. Remember that miner's inches are a measure of flow rate, not length.

Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

Head, H_a (feet)	Discharge, Q, for throat widths, W, of__								
	1 foot	1.5 feet	2 feet	3 feet	4 feet	5 feet	6 feet	7 feet	8 feet
0.10	0.11	0.15	——	——	——	——	——	——	——
.15	.20	.30	0.42	0.61	——	——	——	——	——
.20	.35	.51	.66	.97	1.26	1.55	——	——	——
.25	.49	.71	.93	1.37	1.80	2.22	2.63	3.02	3.46
.30	.64	.94	1.24	1.82	2.39	2.96	3.52	4.08	4.62
.35	.80	1.19	1.57	2.32	3.06	3.78	4.50	5.22	5.93
.40	.99	1.47	1.93	2.86	3.77	4.68	5.57	6.46	7.34
.45	1.19	1.76	2.32	3.44	4.54	5.63	6.72	7.80	8.87
.50	1.39	2.06	2.73	4.05	5.36	6.66	7.94	9.23	10.5
.55	1.62	2.39	3.17	4.70	6.23	7.74	9.25	10.8	12.2
.60	1.84	2.73	3.62	5.39	7.15	8.89	10.6	12.4	14.1
.65	2.08	3.09	4.11	6.12	8.11	10.1	12.1	14.1	16.0
.70	2.33	3.46	4.60	6.86	9.11	11.4	13.6	15.8	18.0
.75	2.58	3.85	5.12	7.65	10.2	12.7	15.2	17.7	20.1
.80	2.85	4.26	5.66	8.46	11.3	14.0	16.8	19.6	22.4
.85	3.12	4.67	6.22	9.30	12.4	15.5	18.5	21.6	24.6
.90	3.41	5.10	6.80	10.2	13.6	16.9	20.3	23.7	27.0
.95	3.70	5.55	7.39	11.1	14.8	18.4	22.1	25.8	29.5
1.00	4.00	6.00	8.00	12.0	16.0	20.0	28.0	32.0	
1.10	4.62	6.95	9.27	13.9	18.6	23.3	27.9	32.6	37.3
1.15	4.94	7.44	9.94	14.9	19.9	25.0	30.0	35.0	40.1
1.20	5.28	7.94	10.6	16.0	21.3	26.7	32.1	37.5	42.9
1.25	5.62	8.46	11.3	17.0	22.8	28.5	34.3	40.0	45.8
1.30	5.96	8.99	12.0	18.1	24.2	30.3	36.5	42.6	48.8
1.35	6.32	9.52	12.7	19.2	25.7	32.2	38.7	45.3	51.8
1.40	6.68	10.1	13.5	20.3	27.2	34.1	41.1	48.0	55.0
1.45	7.04	10.6	14.2	21.5	28.8	36.1	43.4	50.8	58.1
1.50	7.41	11.2	15.0	22.6	30.3	38.1	45.8	53.6	61.4
1.55	7.80	11.8	15.8	23.8	32.0	40.1	48.3	56.5	64.7
1.60	8.18	12.4	16.6	25.1	33.6	42.2	50.8	59.4	68.1
1.65	8.57	13.0	17.4	26.3	35.3	44.3	53.3	62.4	71.6
1.70	8.97	13.6	18.2	27.6	37.0	46.4	56.0	65.5	75.1
1.75	9.38	14.2	19.0	28.8	38.7	48.6	58.6	68.6	78.7
1.80	9.79	14.8	19.9	30.1	40.5	50.8	61.3	71.8	82.3
1.85	10.2	15.5	20.8	31.5	42.2	53.1	64.0	75.0	86.0
1.90	10.6	16.1	21.6	32.8	44.1	55.4	66.8	78.2	89.8
1.95	11.1	16.7	22.5	34.1	45.9	57.7	69.6	81.6	93.6
2.00	11.5	17.4	23.4	35.5	47.8	60.1	72.5	84.9	97.5
2.05	11.9	18.1	24.3	36.9	49.7	62.5	75.4	88.4	101.4
2.10	12.4	18.8	25.3	38.4	51.6	64.9	78.4	91.8	105.4
2.15	12.8	19.5	26.2	39.8	53.5	67.4	81.4	95.4	109.5
2.20	13.3	20.2	27.2	41.3	55.5	69.9	84.4	98.9	113.6
2.25	13.7	20.9	28.1	42.7	57.5	72.4	87.5	102.6	117.8
2.30	14.2	21.6	29.1	44.2	59.6	75.0	90.6	106.2	122.0
2.35	14.7	22.4	30.1	45.7	61.6	77.6	93.8	110.0	126.3
2.40	15.2	23.0	31.1	47.3	63.7	80.3	97.0	113.7	130.7
2.45	15.6	23.8	32.1	48.8	65.8	82.9	100.2	117.6	135.1
2.50	16.1	24.6	33.1	50.4	67.9	85.6	103.5	121.4	139.5

Table 1. Free-flow discharge values for Parshall flumes in cubic feet per second.

3. Table 1 gives the free-flow discharge rate for one 1- to eight-foot flumes for upstream heads in 0.05 foot increments. The figures can be interpolated when accuracy requires gage readings to 0.01 feet, or extended tables can be obtained. For example, the discharge rate through a two-foot flume with an H_a reading of 1.10 feet is 9.27 cubic feet per second.

4. If there is any question as to whether the flume is submerged, measure the downstream head (H_b). Locate the H_b gage as shown in Figure 1. For one- to eight-foot flumes this gage point is located two inches upstream and three inches above the lowest part of the flume. The zero point for the gage, however, is at the crest elevation even though the gage point is downstream from the crest. Because the flume's throat section is turbulent, a stilling well should be installed at H_b if submergence is common.

5. Check for submergence by dividing H_b by H_a to obtain a percent submergence value. The flume size (followed by this value in parentheses) is: 1 (62), 1.5 (64), 2 (66), 3 (68), 4 (70), 5 (72), 6 (74), 7 (76), and 8 (78). If the given value is exceeded, the flume is submerged and the free flow discharge rate must be corrected. Seek help or follow the correction procedure given in Part 2, (MT 9130).

Summary

A Parshall flume is an excellent measuring device which has stood the tests of time and use. The flume is difficult to properly locate and construct. Water users should consider obtaining assistance from a qualified specialist or the Soil Conservation Service. When correctly built and located it will measure accurately. The flume is capable of measurement under minimal submerged conditions, but readings must be corrected. If possible the flume should be located and set to operate in a non-submerged condition.

Water Measurement

MT 9130 (AG)

The Parshall Flume (Part 2)

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

This portion of the Parshall flume bulletin gives flume dimensions, describes sizing and locating the flume, and tells how to measure water under submerged conditions. This information is quite technical and intended for use by technicians, contractors, and engineers. For a general description of the Parshall flume and its uses see Part 1, MT 9129.

Flume shape and dimensions

A Parshall flume is shown in Figure 1. The flume consists of a converging section, the throat (crest), a downward sloping floor, and a rising/diverging downstream section. Section and plan views are shown in Figure 2. A short Parshall, also called a Montana flume (discussed in MT 9127 and MT 9128), has only the converging section and crest. The portion of the Parshall flume downstream from the crest minimizes erosion and allows measurement when the flow is partially submerged (when water is "backed up" into the throat). The flume size is designated by the throat width which normally is in one-foot increments.

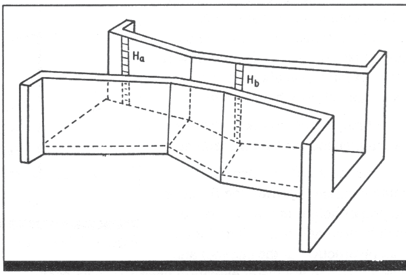

Figure 1. A Parshall measuring flume.

Throat Width	A	B	C	D	Flow rate, cfs Min.	Max.
1 ft	2 ft 9 1/4 in	2 ft	4 ft 6 in	4 ft 4 7/8 in	.11	16.1
1.5ft	3ft 4 3/8in	2ft 6in	4ft 9in	4ft 7 7/8in	.15	24.6
2ft	3ft 11 1/2in	3ft	5 ft	4ft 10 7/8in	.42	33.1
3ft	5ft 1 7/8in	4ft	5ft 6in	5ft 4 3/4in	.61	50.4
4ft	6ft 4 1/4in	5ft	6ft	5ft 10 5/8in	1.3	67.9
5ft	7ft 6 5/8in	6ft	6ft 6in	6ft 4 1/2in	1.6	85.6
6ft	8ft 9in	7ft	7ft	6ft 10 3/8in	2.6	103.5
7ft	9ft 11 3/8in	8ft	7ft 6in	7ft 4 1/4in	3.0	121.4
8ft	11ft 1 3/4in	9ft	8ft	7ft 10 1/8in	3.5	139.5

Table 2. Parshall flume dimensions for various throat widths and flow capacities.

Table 2 gives dimensions for various size flumes and corresponding flows. The letter designations in Table 2 correspond to those in Figure 2. Other dimensions shown in Figure 2 that remain the same for all flume sizes in Table 2 are: X=2 in., K and Y =3 in., H=9 in., E=2 ft., F=3 ft., and G=3 ft. or less depending on the required capacity and flow depth.

Locating and sizing the flume

Choosing a location and size for a Parshall flume is difficult. Seek professional help unless you are trained and experienced in flume installation. A large flume can cost thousands of dollars to build and be

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virtually impossible to move if set improperly. Prefabricated metal flumes up to three or four feet in size can be moved and reset but this takes time and labor. The following should be considered in locating a flume.

• Locate the flume in a straight section of channel so the water will flow smoothly into the converging section.

• Locate the flume where it will not be submerged by backwater from downstream. If submergence can not be avoided, make sure it will not be greater than allowed in the correction tables which follow.

• Provide for easy accessibility for maintenance and measurement.

The most difficult aspect of flume location is setting the flume at the proper height in relation to the ditch bottom and banks. The flume is an obstruction in the channel and causes a rise in the water elevation upstream. The banks must be high enough so that they will not be overtopped. Submerged (backed up) flows can be measured if submergence is not complete, but it is best to avoid them. Choosing a good location and setting the flume at the proper height above the ditch bottom will help avoid submergence.

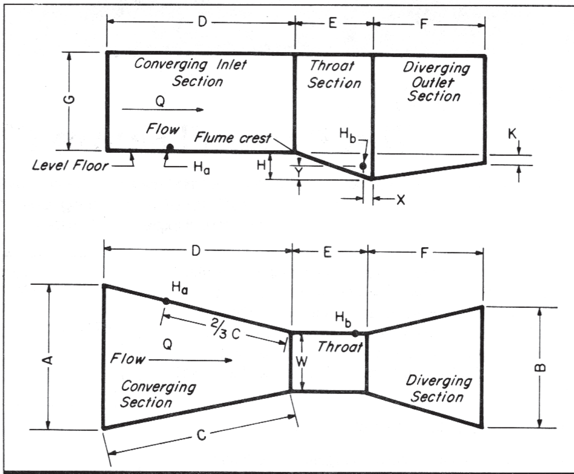

Figure 2. Section and plan views of a Parshall flume.

A flume is considered submerged when the downstream head (water depth) called H_b is a certain percentage of the upstream head (water depth) which is called H_a. These points are shown in Figure 2. The allowable percent value depends on the size (throat width) of the flume. For various size flumes the submergence values of H_b/H_a expressed as a percent and indicated in parentheses are: 1 (62), 1.5 (64), 2 (66), 3 (68), 4 (70), 5 (72), 6 (74), 7 (76), and 8 (78). In other words, a particular size flume should preferably be set so that the water does not back up into the downstream section to a depth greater than the submergence percentage multiplied by the upstream head. On flat ditches the flume may have to be set so that it ordinarily measures in a submerged condition. If this is the case the tabulated values from Table 1 (MT 9129) will have to be multiplied by a correction factor.

The flume size, flow rate, and maximum value of H_a are interrelated. As a general rule the flume size should be about 40 percent of the channel width. Several flume sizes may work in a given setting so several trials may be necessary to choose the best size. It is much easier to make these trials on paper than with steel or concrete. Figure 3 depicts the relationships of flow depths through a Parshall flume and shows an example.

These are the steps in analyzing how the flume should be set:

1. Determine the approximate maximum channel discharge in cubic feet per second.

2. Estimate the desired flume size based on the flow rate and ditch dimensions.

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Units of Measurement

Water is measured in volume and flow rate units. The choice of units depends on what is customary and legal and on how water is purchased or delivered.

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A common flow rate unit in Montana is the miner's inch (M.I.). Water users often refer to a flow rate as a certain number of "inches," when they actually mean miner's inches. Remember that miner's inches are a measure of flow rate, not length.

Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

3. Determine the depth at the maximum flow in the ditch or canal by inspecting the banks or from canal specifications.

4. From Table 2 determine the upstream head (H_a) at the maximum discharge rate. A correction factor for submergence (discussed in the water measurement section of this bulletin) may be necessary.

5. Determine the allowable submergence percentage for the desired flume size. If a greater submergence percentage is being allowed because of site conditions such as a flat ditch, estimate this submergence value and use it in further calculations.

6. Multiply the maximum upstream head (H_a) by the submergence percentage to determine the distance the flume crest should be set below the original maximum flow depth.

7. Subtract the distance calculated in step 6 from the original flow depth to determine the height of the flume floor above the channel bottom.

8. Subtract the distance calculated in step 6 from the upstream head (H_a). Add the result to the original flow depth to calculate the rise in upstream water level after the flume is installed. Verify that the banks upstream can handle this increased depth.

This analysis is reiterated in the following example. Again, refer to Figure 3.

Steps 1, 2, 3. Suppose you are considering a two-foot flume, a maximum discharge of 27.0 cubic feet per second, and an original flow depth of 2.5 feet.

Step 4. Using Table 1 (Part 1) and interpolating, for a two-foot flume with a discharge of 27.0 cubic feet per second H_a equals 2.19 feet.

Step 5. To prevent submergence for a two-foot flume the allowable submergence ratio is 66 percent. Use an alternative submergence ratio if some degree of submergence is being allowed.

Step 6. Thus the flume crest (flume floor) should be set below the original maximum flow depth an amount equal to 2.19 x 0.66 or 1.45 feet. (Use the alternative submergence ratio if some degree of submergence is being allowed.)

Step 7. Subtract 1.45 feet (or an alternative value) from the original flow depth of 2.5 feet to determine that the crest floor should be 1.05 feet above the channel bottom.

Step 8. The increase in flow depth upstream of the flume is 2.19 feet minus 1.45 feet or 0.74 feet. The water flowing at a 2.5 foot depth upstream of the flume prior to installation will rise 0.74 feet to flow at a depth of 3.24 feet after installation. The banks upstream must be able to handle this greater water depth. Allowing greater flume submergence will decrease the upstream flow depth.

Several size flumes can carry the 27.0 cubic feet per second flow rate used in this example. These sizes should be evaluated before construction to see which size would best fit the ditch and situation. The narrowest flume may not always be the most economical because of the wing wall length needed to span the channel and the increased

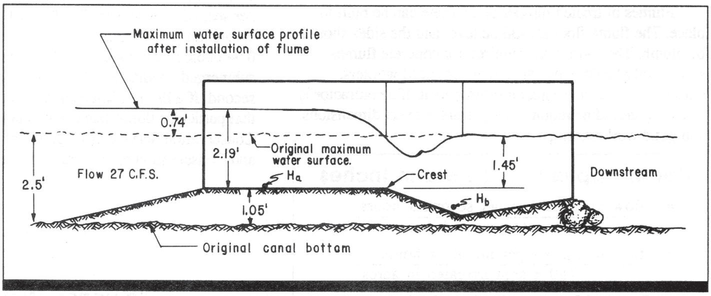

Figure 3. Analysis of upstream and downstream water elevations and crest elevation above the channel bottom.

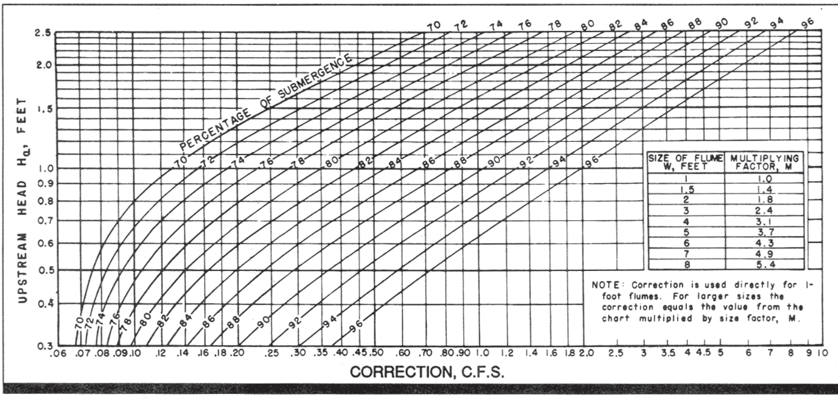

Figure 4.Diagram for determining correction to be subtracted from free-discharge flow to obtain rate of submerged flow through Parshall flumes one to eight fee wide.

upstream water depth. In some situations it will be impossible or too expensive to select a flume which will not submerge. In these cases the above analysis should be done with some percent submergence allowed, and the submergence compensated for during measurement. Correction factors for submergence are discussed in the water measurement section which follows.

Building a flume

Flume dimensions are shown in Figure 2 and Table 2. These dimensions must be followed exactly during construction for water measurements to be accurate. All dimensions given are inside measurements. Prefabricated sheet metal flumes have the advantage of in-shop construction where pieces can be properly jigged and bent or welded. This is difficult in a farm shop when generally only one flume is built. Prefabricated flumes are the best choice for small sizes. Flumes built in place are generally cheaper for larger sizes.

Flumes of treated lumber or concrete can be built in place. The flume floor should be level and the sides should be plumb. The form work required for concrete flumes should only be done by careful, experienced workers. Concrete flumes need steel reinforcement. If a contractor is hired, he should be required to guarantee exact dimensions and good workmanship.

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second x hours}}{\text{area irrigated in acres}}$$

$$= \frac{\text{flow in gallons per minute x hours}}{\text{450 x area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches x hours}}{\text{40 x area irrigated in acres}}$$

Measuring submerged flow

If it appears the flume may be submerged, check for submergence by dividing H_b by H_a and comparing the result against the submergence value for particular size flume that was noted previously. If the flume is submerged the free flow discharge rate must be corrected. Correction values are given in Figure 4.

Figure 4 is used by entering the figure at the H_a value. Read across to the right to the percentage of submergence determined previously. Read the correction for a one-foot flume on the lower scale. Subtract this correction (or a size-modified correction) from the flow rate for an unsubmerged condition. For example, if a two-foot flume has an H_a reading of 1.1 feet and an H_b reading of 0.9 feet, the submergence is 0.9/1.1 or 82 percent. The discharge table in MT 9129 shows that for the 1.1 foot H_a reading for a two-foot flume the free-flow discharge is equal to 9.27 cubic feet per second. From Figure 4 the correction factor for 82 percent submergence and a 1.1 foot head is 0.52 cubic feet per second. Multiply 0.52 cubic feet per second by the correction factor for a two-foot flume, which is 1.8, to give 0.94 cubic feet per second. The true flow rate under this submerged condition is 9.27 - 0.94 or 8.33 cubic feet per second. If a flume often submerges, submergence tables for that particular flume size can be obtained from the Soil Conservation Service or Department of Natural Resources and Conservation to ease this calculation.

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Water Measurement

MT 9128 (AG)

Montana (Short Parshall) Flume (Part 2)

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

A general description of the Montana (short Parshall) flume appears in MT 9127. This bulletin gives flume dimensions and describes sizing, locating and building the flume. This information is quite technical and intended for use by technicians, contractors, and engineers.

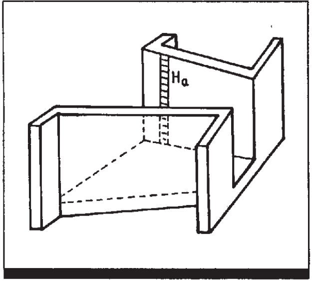

Figure 1. A typical Montana flume.

Flume shape and dimensions

A Montana flume is shown in Figure 1. The flume consists of a converging section and throat also called a crest. The flume size is designated by the crest width and is normally in one-foot increments. Section and plan views are shown in Figure 2. Montana flumes do not protect the channel downstream of the crest from erosion and can not measure partially submerged flows as the Parshall flume can.

Table 2 gives flume dimensions with the letter designation corresponding to those in Figure 2. The height G equals three feet or less depending on the required capacity and flow depth.

Locating and sizing the flume

When installing a flume the following recommendations should be followed.

• Locate the flume in a straight section of ditch so the water will flow smoothly into the converging section.

Water Should Be Measured Because . . .

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Montana law requires measuring devices on all streams for which water commissioners have been appointed. A commissioner cannot deliver water unless measuring devices are in place. Eventually all Montana waters will be decreed. You can protect your water right by accurately measuring and recording flow rates and times of use.

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Funded by the Ag Energy Conservation Program, Montana Department of Natural Resources and Conservation. Sponsored by Gallatin County Conservation District.

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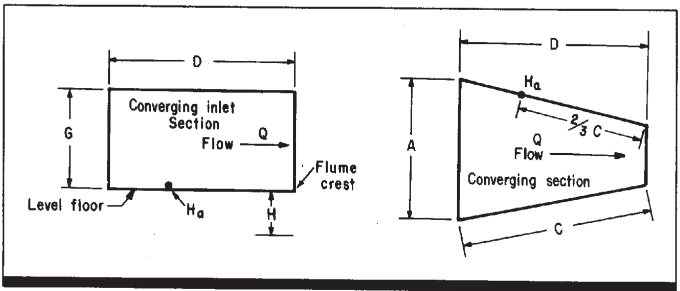


Figure 2. Section and Plan views of a Montana Flume.

• Locate the flume where flow will not be submerged by backwater from downstream.

• Provide for easy accessibility for maintenance and measurement.

The most difficult aspect of flume location is setting the flume at the proper height in relation to the ditch bottom and banks. The flume is an obstruction in the channel and causes a rise in the water elevation upstream. The water must rise from the ditch bottom, pass through the converging section, then drop over the crest. Submerged flows cannot be measured with the Montana flume and must be avoided.

You can avoid submerged flows if you know the downstream water levels at which submergence occurs. A flume is submerged when the depth of water in the throat divided by the flow depth in the converging section exceeds a certain percent. The allowable percent value depends on the size (throat width) of the flume. The flume size in feet with allowable percent shown in parentheses are:

1 (62), 1.5 (64), 2 (66), 3 (68), 4 (70), 5 (72), 6 (74), 7 (76), and 8 (78).

In other words, a particular size flume should be set so that the water does not back up into the throat to a depth greater than the stated percentage multiplied by the upstream head. Submergence can be avoided by setting the flume in a steep section of ditch or at a drop, choosing the proper flume size, and setting the flume at the proper height above the ditch bottom.

For a particular flow rate and channel, it is necessary to determine the flume size and the maximum value of H_a. As a general rule the flume size should be about 40 percent of the channel width. Several flume sizes may be feasible at a given location so check to see which size works best. It is much easier to make these trials on paper than with steel or concrete.

Figure 3 depicts the relationships of flow depths through a flume and shows an example. The analysis of proper flume size and how the flume should be set is hard to

Throat Width	A	B	C	D	Flow rate, cfs Min.	Max.
1 ft	2 ft 9¼ in	2 ft	4 ft 6 in	4 ft 4⅞ in	.11	16.1
1.5ft	3ft 4⅜in	2ft 6in	4ft 9in	4ft 7⅞in	.15	24.6
2ft	3ft 11½in	3ft	5 ft	4ft 10⅞in	.42	33.1
3ft	5ft 1⅞in	4ft	5ft 6in	5ft 4¾in	.61	50.4
4ft	6ft 4¼in	5ft	6ft	5ft 10⅝in	1.3	67.9
5ft	7ft 6⅝in	6ft	6ft 6in	6ft 4½in	1.6	85.6
6ft	8ft 9in	7ft	7ft	6ft 10⅜in	2.6	103.5
7ft	9ft 11⅜in	8ft	7ft 6in	7ft 4¼in	3.0	121.4
8ft	11ft 1¾in	9ft	8ft	7ft 10⅛in	3.5	139.5

Table 2. Parshall flume dimensions for various throat widths and flow capacities.

Units of Measurement

Water is measured in volume and flow rate units. The choice of units depends on what is customary and legal and on how water is purchased or delivered.

Common volume units used in irrigation are: cubic foot (cu. ft., ft^3), gallon (gal.), acre-inch (ac.in.), and acre-foot (ac. ft.). Flow rate units simply add a time dimension to these volume units. These are: cubic feet per second (cu. ft./sec or cfs), gallons per minute (gpm), acre-inches per hour (ai/hr), and acre-feet per day (af/day).

A common flow rate unit in Montana is the miner's inch (M.I.). Water users often refer to a flow rate as a certain number of "inches," when they actually mean miner's inches. Remember that miner's inches are a measure of flow rate, not length.

Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

follow and complicated, but there are no shortcuts. If you don't understand the following, seek help.

The steps in analysis are:

1. Determine the approximate maximum channel discharge in cubic feet per second.

2. Estimate the desired flume size.

3. Determine the flow depth at the maximum discharge rate from inspection of the banks or from canal specifications.

4. From Table 1 in MT 9127, determine the upstream head (H_a) at the maximum discharge rate.

5. Determine the submergence percentage for the desired flume size.

6. Multiply the upstream head (H_a) by the submergence percentage to determine the distance the flume crest should be set below the original maximum flow depth.

7. Subtract the distance calculated in step 6 from the original flow depth to determine the height of the flume floor above the channel bottom.

8. Subtract the distance calculated in step 6 from the upstream head (H_a). Add the result to the original flow depth to calculate the rise in upstream water level after the flume is installed. Verify that the banks upstream can handle this increased depth.

This analysis is reiterated in the following example. Again refer to Figure 3.

Steps 1, 2, 3. Suppose you are considering a two-foot flume, a maximum discharge of 27.0 cubic feet per second, and an original flow depth of 2.5 feet.

Step 4. Using Table 1 in MT 9127 and interpolating, for a two-foot flume with a discharge of 27.0 cubic feet per second, H_a equals 2.19 feet.

Step 5. To prevent submergence for a two-foot flume, the allowable submergence ratio is 66 percent.

Step 6. Thus the flume crest (flume floor) should be set below the original maximum flow depth an amount equal to 2.19 x 0.66 or 1.45 feet.

Step 7. Subtract 1.45 feet from the original flow depth of 2.5 feet to determine that the crest floor should be 1.05 feet above the channel bottom.

Step 8. The increase in flow depth upstream of the flume is 2.19 feet minus 1.45 feet or 0.74 feet. The water flowing at a 2.5 foot depth upstream of the flume prior to installation will rise 0.74 feet to flow at a depth of 3.24 feet after installation. The banks upstream must be able to handle this greater water depth.

Several sizes of flumes can carry the 27.0 cubic feet per second flow rate used in this example. These sizes should be evaluated before construction to see which size would best fit the ditch and situation. The narrowest flume may not always be the most economical because of the wing wall length needed to span the channel and the increased upstream water depth.

Building a flume

Dimensions for the Montana flume are shown in Figure 2 and Table 2. The flume shape is simple but these dimen-

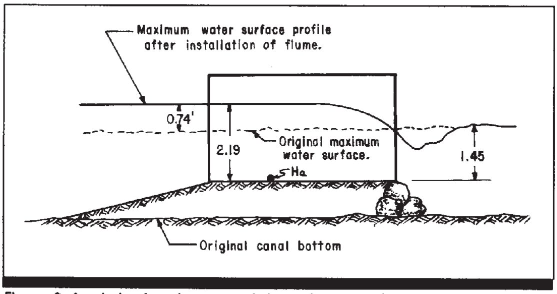


Figure 3. Analysis of upstream and downstream water elevations and crest elevation above the channel bottom.

sions must be followed exactly for the water measurement to be accurate. Prefabricated sheet metal flumes have the advantage of in-shop construction where pieces can be properly jigged and bent or welded. This is difficult in a farm shop when generally only one flume is built. Prefabricated flumes are the best choice for small sizes. Many fabricators only make the Parshall flume. You may be able to have the Montana flume built by special order. Flumes built in place are generally cheaper for larger sizes.

Flumes of treated lumber or concrete can be built in place. The floor should be level and the sides should be plumb. Adequate steel reinforcement should be used. The form work for the Montana flume is relatively simple and can be done by anyone with reasonable carpentry skills. The work cannot be sloppy, however, and a any contractor engaged should be required to guarantee exact dimensions and good workmanship.

The Montana flume usually requires erosion protection downstream of the crest because the water pours through freely and rapidly. A concrete apron, cobble, or other material can be used below the flume. An eddy will develop on each side of the streamflow and erosion protection may be required (depending on the stability of the bank material).

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second x hours}}{\text{area irrigated in acres}}$$

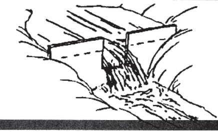
$$= \frac{\text{flow in gallons per minute x hours}}{\text{450 x area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches x hours}}{\text{40 x area irrigated in acres}}$$

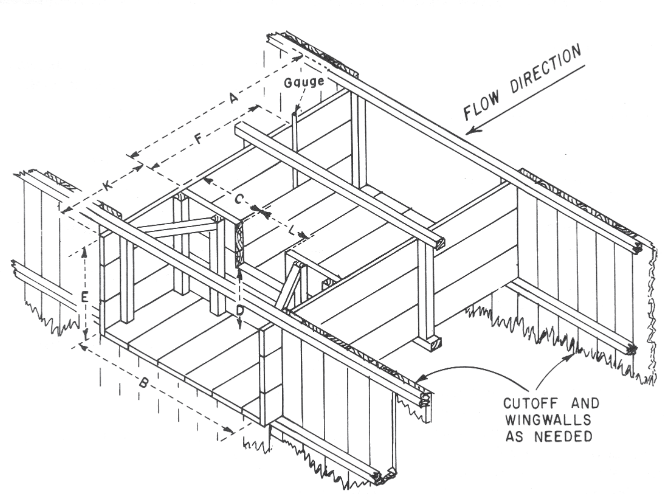
Water Measurement

MT 9123 (AG)

Rectangular Contracted Weirs



Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station



What is a Weir?

A "weir" is one of the oldest, simplest and most reliable structures for measuring water flow in canals and ditches. A weir's operation is easily observable and improper operation can be readily detected and quickly corrected.

A rectangular contracted weir is an overflow structure built across an open channel. The notch through which the water pours is narrower than the width of the channel and is above the bottom. Other types of weirs may have a different notch shape, or the overpour portion may occupy the full width of the channel. Many people refer to Parshall flumes as weirs. The two devices are completely different in construction and measuring technique.

Dimensions in feet for rectangular contracted weirs

	L	A	K	B	E	C	D	F
Flow in C. F. S.	Length of Weir Crest	Length of Box Above Weir Notch	Length of Box Below Weir Notch	Inside Width of Box	Inside Depth of Box	End of Crest to Side	Crest to Bottom	Gauge Distance Upstream
to 3	1	6	2	5 1/2	3 1/2	2 1/4	2	4
2 to 5	1 1/2	7	3	7	4	2 3/4	2 1/2	4 1/2
4 to 8	2	8	4	8 1/2	4 1/2	3 1/4	2 3/4	5
6 to 14	3	9	5	12	5	4 1/2	3 1/4	5 1/2
10 to 22	4	10	6	14	5 1/2	5	3 1/2	6

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Water Should Be Measured Because . . .

Water measurement is the foundation of water management and economical crop production. Measuring and applying the proper amount of water saves you money and protects water resources by decreasing soil erosion, fertilizer leaching, and waste water problems.

Montana law requires measuring devices on all streams for which water commissioners have been appointed. A commissioner cannot deliver water unless measuring devices are in place. Eventually all Montana waters will be decreed. You can protect your water right by accurately measuring and recording flow rates and times of use.

Water measurement also helps conserve energy by enhancing fertilizer use and reducing the need to pump. Optimizing water use can lessen local and regional shortages. And minimizing water and energy use nationally will help decrease dependence on foreign energy and conserve our own water and energy supplies.

Advantages/disadvantages

Weirs will accurately measure water with less than five percent error when carefully installed, maintained and read. Portable weirs can be relocated to spot check flow rates. Weirs do not clog easily, and are simple and relatively inexpensive to build. Because of their accuracy, their readings are accepted by the courts and virtually all agencies.

Careful construction is important or water measurement may not be accurate. Silting-in can be a major problem. Because of the clear overpour required, use will be limited to areas where there is a natural drop, or to channels with a large amount of fall.

Construction

A rectangular contracted weir can be constructed by anyone with fundamental carpentry and/or masonry skills. The base of the notch over which water flows is the weir "crest." The depth of the water flowing over the crest is the "head." Proper dimensions are shown in the chart on the first page of this guide. The length of the weir crest is given in multiples of one foot. For easy water measurement, the lengh of the crest should be an even number of feet. It should be noted that any construction in a natural perennial flowing stream requires an SB 310 permit from the conservation district in that area.

- Use treated rough lumber, concrete, concrete blocks, sheet metal or other durable material.
- Size the weir so that, at maximum flow:
  - a) the crest length is about three times the head depth.
  - b) the distance from the edge of the notch to the channel sides is at least two times the head depth.
  - c) the distance from the channel bottom to the crest is at least three times the head depth.
- Attach a 1/8"-thick metal strip to the crest and sides of the weir.
- Use a cut off wall so water can't go under the weir.
- Provide an underdrain to drain the pool and prevent damage by freezing.

Installation

The weir must be installed and maintained so that its original dimensional relationships remain true.

- Set the weir in a section of the ditch with enough drop so that water can pour freely over the weir's crest.

Units of Measurement

Water is measured in volume and flow rate units. The choice of units depends on what is customary and legal and on how water is purchased or delivered.

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A common flow rate unit in Montana is the miner's inch (M.I.). Water users often refer to a flow rate as a certain number of "inches," when they actually mean miner's inches. Remember that miner's inches are a measure of flow rate, not length.

Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

- Place the weir where the upstream channel is straight for at least ten times the length of the weir crest.
- Set the weir with the crest perpendicular to the water flow so that it doesn't lean upstream or downstream.
- Ensure that the crest is level so water flowing over it will be the same depth at all points.
- Use cobble or concrete to protect the channel below the weir from erosion.

Maintenance

Weir maintenance, while it is important, is relatively simple. If not properly maintained, the life of the structure will be appreciably shortened and the measurements made will not be accurate. Here are some maintenance tips:

- Clear the channel and weir crest of weeds, trash, and other floating debris.
- Keep the weir pond and bulkhead free of sediment.
- Trim the channel and weir pond of vegetation which interferes with the flow of water.
- Make sure the crest does not settle out of level and that leakage is not occurring through and around the structure.

Water Measurement

Two measurements are used to determine flow in cubic feet per second: head and weir crest length.

Head is normally measured upstream, a distance of at least four times the expected maximum head, so the measurements are not affected by the downward curve of water as it approaches the crest.

Head can be easily measured by driving a stake or establishing a reference point upstream which is level with the weir crest. The distance from the top of the stake to the water surface is the head. Head measurement upstream is often done by setting a staff gauge. Gauges are made of metal and calibrated in tenths and hundreths of feet.

If a stake cannot be set upstream, the head can be measured at the crest by using a board (such as a two-by-four) held edgewise to the flow and resting on the crest. The velocity of the water will cause the water to "climb" the board. The distance from the weir crest to the height to which the water climbs is a good measure of the head.

The other measurement, weir crest length, is constant for each weir. Painting the length of the crest on the structure allows quick reference.

Table 1 (see next page) gives the flow for various heads and crest lengths. The flow is given in cubic feet per second (cfs) and must be multiplied by 40 to obtain Montana Miners Inches (M.I.). For weirs of odd sizes, proportional amounts of the stated lengths can be used with little error. The flow can also be calculated using the formula $Q=3.33\ H^{3/2}\ (L-0.2H)$ where Q is the discharge in cubic feet per second, H is the head, and L is the length of the crest in feet. Convert all measurements to feet before using the formula.

Table 1 is read directly. For a head of .85 feet and a 4.0 foot crest length, the discharge is 10.01 cfs. Multiply this by 40 to give 400.4 Miner's Inches. Most water-users would call this a flowrate of 400 inches.

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second x hours}}{\text{area irrigated in acres}}$$

$$= \frac{\text{flow in gallons per minute x hours}}{\text{450 x area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches x hours}}{\text{40 x area irrigated in acres}}$$

Table 1	Discharge values for rectangular contracted weirs in cubic feet per second					
Head in Feet	Discharge, Q, for crest lengths of . . . 1.0 Ft	1.5 Ft	2.0 Ft.	3.0 Ft	4.0 Ft	for each foot in excess of 4 feet
.10	.11	.16	.21	.32	.43	.11
.15	.19	.29	.39	.58	.78	.20
.20	.29	.44	.59	.89	1.20	.30
.25	.40	.61	.82	1.23	1.65	.42
.30	.53	.80	1.07	1.61	2.16	.55
.35	.66	1.00	1.34	2.02	2.71	.69
.40	.80	1.21	1.63	2.46	3.30	.84
.45	.96	1.44	1.94	2.93	3.92	1.00
.50	1.11	1.68	2.26	3.42	4.58	1.16
.55	1.28	1.94	2.60	3.94	5.27	1.34
.60	1.45	2.20	2.96	4.47	6.00	1.52
.65	1.65	2.47	3.32	5.03	6.75	1.71
.70	1.82	2.76	3.70	5.61	7.52	1.91
.75	2.01	3.05	4.10	6.21	8.33	2.12
.80	2.21	3.35	4.51	6.83	9.16	2.33
.85	2.41	3.66	4.92	7.46	10.01	2.55
.90	2.62	3.98	5.35	8.12	10.89	2.78
1.00	3.06	4.64	6.25	9.48	12.72	3.24
1.05	___	4.98	6.71	10.18	13.66	3.49
1.10	___	5.33	7.18	10.90	14.63	3.37
1.15	___	5.69	7.66	11.63	15.62	3.99
1.20	___	6.06	8.16	12.38	16.63	4.25
1.25	___	6.43	8.66	13.15	17.65	4.51
1.30	___	___	___	13.93	18.70	4.78
1.35	___	___	___	14.72	19.77	5.06
1.40	___	___	___	15.53	20.85	5.34
1.45	___	___	___	16.35	21.96	5.62
1.50	___	___	___	17.18	23.08	5.91

File under: Water Measurement
A-1 (Devices and Methods)
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Water Measurement

MT 9132 (AG)

The Replogle Flume (Broad-crested Weir)

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

What is a Replogle flume?

The Replogle flume is named for a U.S. Department of Agriculture researcher who helped develop it. A picture of the flume is shown in Figure 1. The flume usually consists of a section of concrete-lined ditch with a sill and ramp rising from the bottom. The ramp accelerates the water as it passes over the sill. In a typical ditch the sill is about two feet long and is above the bottom about two thirds of the normal water depth. The ramp is built on a slope of about 3:1 on the upstream side of the sill. There is no ramp on the downstream side. The flume is normally made of concrete although wood flumes have been used in a few applications. The flume has been most widely used in concrete-lined ditches. It can be used in earth ditches if a short section of concrete lining is provided.

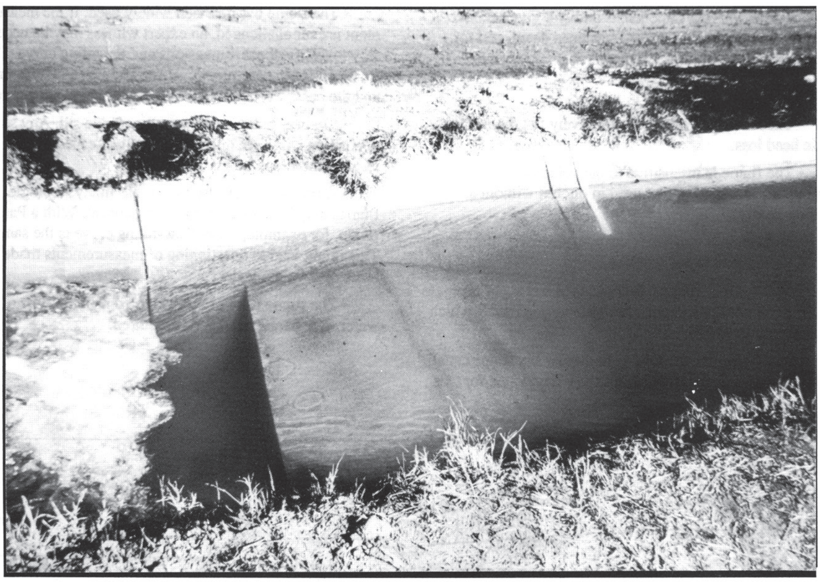

Figure 1. A Replogle flume.

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Water measurement also helps conserve energy by enhancing fertilizer use and reducing the need to pump. Optimizing water use can lessen local and regional shortages. And minimizing water and energy use nationally will help decrease dependence on foreign energy and conserve our own water and energy supplies.

The Replogle flume is virtually the only open channel water measuring device which has evolved during the computer age. Because of the computer and mathematical expertise available, the development of the Replogle flume followed a different approach than was used for previous devices such as the Parshall flume. The Replogle flume can be built to fit a canal or ditch and mathematical modeling can then be used to generate a flow-rating table for that specific facility. The Replogle flume can thus be constructed with varying dimensions and still give accurate measurement. Standard tables have been developed for some small concrete lined ditches.

Advantages

• The flume can operate in relatively flat ditches with little head loss.

• The flume is insensitive to the velocity of the inflowing water and can be used in ditches without a stilling pond.

• The flume is extremely easy to construct. Meticulous attention to detail is not required.

• The flume is rugged. It consists of a mass of concrete in the ditch bottom and does not have vertical walls which are easily overturned.

• The flume can be built to fit almost any shape canal or ditch, and a flow-rating table can be developed for that particular flume.

• Accuracy is about plus or minus two percent if reasonable attention is paid to construction detail.

• The cost is probably the lowest of any measuring device.

Disadvantages•

• Professional help must be obtained to size the flume and develop the rating curve.

• The flume has not been widely used. If the measurement is ever challenged, an expert witness may be necessary to testify about dimensions and the rating curve. The flume has been carefully developed by USDA engineers and the basic workings of the flume should stand any test.

• Silt may build up downstream of the sill. Any silt deposition will have to be periodically cleaned or the measurement will be inaccurate.

• A river or canal system that has many Replogle flumes may have many flow-rating curves. With a Parshall flume, for example, every flow-rating curve is the same. This might lead to questioning of measurements made by users or a water master.

• The flume can not be used to control the flow of water. A separate headgate is required.

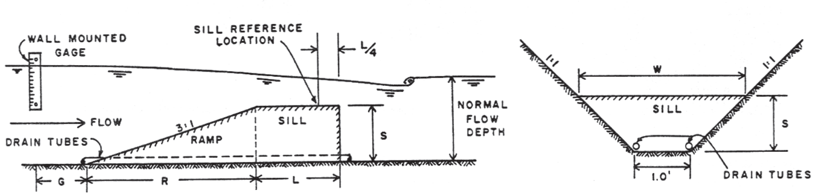

Figure 2. The general shape of the Replogle flume.

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Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

Location and construction

The first step in selecting a flume is to determine the size, shape, and slope of the channel. The expected minimum and maximum discharge also should be determined. The channel section should be straight and uniform. With earth channels it may be necessary to concrete line a section approximately 20 feet long. The sill will be located at the center of this section. The approximate flume shape is shown in Figure 2. Worksheets and/or an existing computer program can be used to evaluate the alternatives of sill height, width, and length. By varying these dimensions, the appropriate criteria involving upstream and downstream freeboard and submergence can be determined. Specific criteria and exact dimensions will be determined during this design process. The process is not difficult but does require specialized knowledge and help should be secured from the Soil Conservation Service or a qualified consultant. When dimensions are determined the water user with only fundamental carpentry and concrete skills can easily build a serviceable flume.

The first step in construction is to cut two identical pieces of plywood to make a form that matches the sill cross section. These pieces will normally be trapezoidal in shape and may have to be reinforced. Notch the bottom corners or center for insertion of one or more drain tubes. Cut spacers the length of the sill to hold the two sides of the form apart. With the spacers between the two sides of the form, use wire ties between the sides to hold them firmly against the spacers. This process makes a sturdy box for pouring the sill. Insert the drain tubes (typically 2-inch PVC pipe) and shim the form so that the top is level. The drain pipes extend through the sill and the ramp.

Remove the spacers as the form is filled with concrete. Use a screed board and the form boards as guides for screeding and troweling the sill to a smooth **level** surface. Any surplus concrete can be placed on the upstream side on the ditch floor as the bottom of the ramp section. When the sill has taken an initial set, remove the upstream side of the form and pour the ramp. The ramp is on a 3:1 slope. Chalk marks on the ditch sides help show the proper slope. The ramp needs to be reasonably smooth but its finish is not critical.

The reference point for the gage is shown in Figure 2. Using this sill point as a reference helps eliminate error resulting from a non-level sill. The gage itself should be located one foot upstream from the beginning of the ramp. The bottom of the gage (zero) should be set level with the sill reference point. Generally it is most convenient to fasten the gage to the side of the ditch, which will require translation of the vertical gage depths to slope distances. The gage can be mounted on the concrete with lead anchors and screws. Care should be taken in setting the gage as a mis-set gage is a common source of error.

Water measurement

When a Replogle flume is properly designed and constructed, the actual water measurement is extremely simple. The rating table generated with the computer after construction matches actual dimensions and conditions. Thus if some error was made during construction in sill width, for example, the computer can compensate for that error. Using the rating table, the water user simply reads the gage and looks up the flow rate. Even this step can be eliminated by marking the gage in flow units and reading the flowrate directly.

Summary

The Replogle flume is extremely easy to use and build. It is a rugged and simple measuring device which is accurate and inexpensive. Expert help is required during design and in the generation of a rating curve.

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second} \times \text{hours}}{\text{area irrigated in acres}}$$

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$$= \frac{\text{flow in Montana miner's inches} \times \text{hours}}{40 \times \text{area irrigated in acres}}$$

Water Measurement

MT 9124 (AG)

The Container Method

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

What is the container method?

The container method of water measurement involves using a watch and a container of known volume such as a one- or five-gallon bucket to determine water flow rates. Flow rates from sprinklers, gated pipe and siphons can be readily determined. For this method a stopwatch is useful but a watch measuring seconds is adequate.

Advantages

- The container method is quick, expedient and requires a minimal amount of equipment.
- Accuracy can be very good, within about five percent more or less, if care is taken and a large enough container is used so that the time interval is reasonable.
- If records are kept of the time and place of the measurement, the records would be acceptable in court.

Disadvantages

- The measurement is good for only a particular time and may have to be repeated under different conditions for the reading to be representative.
- Measurement from siphons or gated pipe may be difficult because the flow emerges from the pipe so close to the ground.

Sprinklers

Measurement of the flow from a sprinkler is easier if the impact arms of the two adjacent sprinklers are held back with small pieces of wire or trash. Then you will not be sprinkled as the adjacent sprinklers rotate. Slip a short length of garden hose over the end of the sprinkler, direct the flow into the container, and measure the time for the container to fill. The method is illustrated in Figure 1.

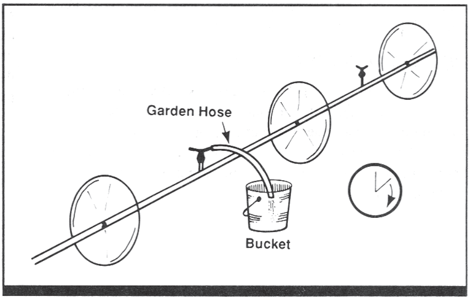

Figure 1. Measuring the discharge from a sprinkler using the container method

Water Should Be Measured Because . . .

Water measurement is the foundation of water management and economical crop production. Measuring and applying the proper amount of water saves you money and protects water resources by decreasing soil erosion, fertilizer leaching, and waste water problems.

Montana law requires measuring devices on all streams for which water commissioners have been appointed. A commissioner cannot deliver water unless measuring devices are in place. Eventually all Montana waters will be decreed. You can protect your water right by accurately measuring and recording flow rates and times of use.

Water measurement also helps conserve energy by enhancing fertilizer use and reducing the need to pump. Optimizing water use can lessen local and regional shortages. And minimizing water and energy use nationally will help decrease dependence on foreign energy and conserve our own water and energy supplies.

MONTANA STATE UNIVERSITY
1893•CENTENNIAL•1993
Extension Service

Funded by the Ag Energy Conservation Program, Montana Department of Natural Resources and Conservation. Sponsored by Gallatin County Conservation District.

The programs of the Montana State University Extension Service are available to all people regardless of race, creed, color, sex, handicap or national origin. Issued in furtherance of cooperative extension work in agriculture and home economics; acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, Andrea Pagenkopf, Acting Vice President for Extension and Acting Director of Montana State University Extension Service, Bozeman, Montana 59717

Units of Measurement

Water is measured in volume and flow rate units. The choice of units depends on what is customary and legal and on how water is purchased or delivered.

Common volume units used in irrigation are: cubic foot (cu. ft., ft^3), gallon (gal.), acre-inch (ac.in.), and acre-foot (ac. ft.). Flow rate units simply add a time dimension to these volume units. These are: cubic feet per second (cu. ft./sec or cfs), gallons per minute (gpm), acre-inches per hour (ai/hr), and acre-feet per day (af/day).

A common flow rate unit in Montana is the miner's inch (M.I.). Water users often refer to a flow rate as a certain number of "inches," when they actually mean miner's inches. Remember that miner's inches are a measure of flow rate, not length.

Conversion factors between the various units are simple. One cubic foot per second (cfs) is equal to 448.8 (often rounded to 450) gallons per minute (gpm). One cfs is also equal to 40 miner's inches (m.i.).

By checking several sprinklers along a line, computing an average, and multiplying by the total number of sprinklers, the total flow from a sprinkler line can be calculated. Doing this measurement also presents an opportunity to check sprinkler nozzles for wear and uniformity. The method works for wheel and hand lines where the sprinkler type and discharge are uniform. It does not work with center pivots as the sprinklers have different flow rates, are usually too high to reach, and the "end gun" flow is usually too high to measure with a container.

Siphons and gated pipe

With water flowing from siphons or gated pipe, it may be necessary to dig a hole to set the bucket in before making the measurement. Several streams should be checked and an average calculated. For measurement, select representative gated pipe or siphons that are operating under uniform pressure.

Calculations

For example, if a five-gallon bucket is filled in 45 seconds, the calculations would be:

45 seconds = 45/60 = .75 minute

Flow rate = 5 gallons /.75 minute = 6.67 gallons per minute (gpm)

This technique can provide valuable information for the producer. For example, if there were 33 sprinklers per line and assuming all sprinklers were uniform, the total flow rate would be 6.67 gpm x 33 or 220 gpm. If the line irrigated a 44-acre field in 11 days or 11 x 24 (or 264) hours the average depth of water applied in inches would be:

$$\frac{\text{flow in gallons per minute} \times \text{hours}}{450 \times \text{area irrigated in acres}}$$

$$\frac{220 \text{ gpm} \times 264 \text{ hours}}{450 \times 44 \text{ acres}} = 2.9 \text{ inches}$$

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second} \times \text{hours}}{\text{area irrigated in acres}}$$

$$= \frac{\text{flow in gallons per minute} \times \text{hours}}{450 \times \text{area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches} \times \text{hours}}{40 \times \text{area irrigated in acres}}$$

File under: Water Measurement
A-2 (Devices and Methods)
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Water Measurement

MT 9125 (AG)

The Float-area Method

Gerald L. Westesen, Professor of Civil and Agricultural Engineering,
Agricultural Experiment Station

What is the float-area method?

In the float-area method of water measurement, the cross sectional area of the channel is measured and a float such as a stick is timed as the water carries it down a measured distance. Combining these measurements and multiplying by an appropriate coefficient gives the flow rate.

Advantages/disadvantages

The float-area method of water measurement gives only an approximate measure of the flow rate. Accuracy within about 10 percent, more or less, is possible. The method is much better than a guess and is useful where a more elaborate installation is not warranted or would be impossible to install, and where high accuracy is not required. If the measurements are made and recorded carefully, they may be accepted by a court.

The accuracy of the method is limited by many factors including difficulty in determining the exact cross sectional area, using stream segments greater than about 10 feet in width on wide streams, changes in stream depth along the channel reach, cross currents, wind forces, and errors in measuring time and distance. There also is a lack of precision in the coefficients (see Table 1.)

Water measurement

Find a straight section of channel about 20 to 100 feet long where the width and depth are fairly uniform, as illustrated in Figure 1. Measure and stake the exact distance between two points. Determine the dimensions of the channel at these points. The dimensions of these upstream and downstream cross sections will be averaged and used in final calculations. If the channel is very uniform it is only necessary to determine the area of one cross section at the center of the reach.

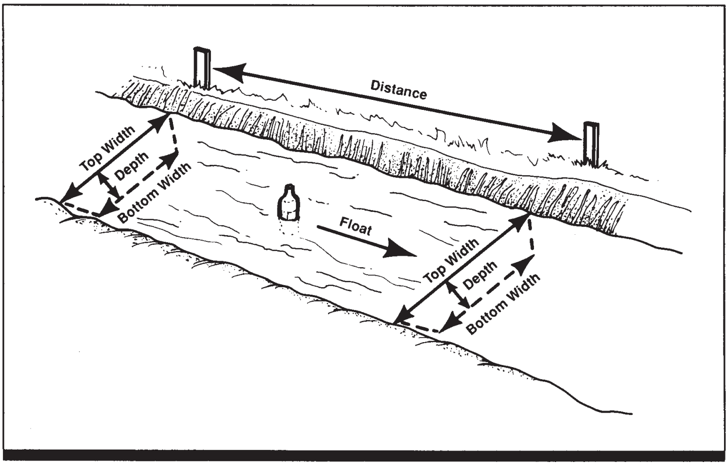

Figure 1. Using the float-area method to measure flow rate

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Water measurement also helps conserve energy by enhancing fertilizer use and reducing the need to pump. Optimizing water use can lessen local and regional shortages. And minimizing water and energy use nationally will help decrease dependence on foreign energy and conserve our own water and energy supplies.

The top width of the channel can be measured by stretching a tape across the stream. Most stream cross sections are roughly trapezoidal in shape, and the bottom corners of the cross sections can be found by probing with a rod or board. When the bottom corners are delineated, the bottom width can be measured and the water depth can be measured at the corners. Some judgement is necessary. For a stream wider than about 10 feet, the depth is also measured at intermediate points. A rope with markers at reasonable intervals (about 10 feet) stretched across the channel and tied in place can be used to delineate the segments. On wide and deep channels you may need boots, waders, or even a boat.

The distance between the upstream and downstream cross sections and the time for the float to travel between them are used to determine the velocity of the water. Place a small float in the channel and measure the time it takes to move through the stretch selected. When there is more than one segment, as on wide streams, make this velocity determination in the center of each segment. The float should be released far enough upstream from the first section so that it is up to speed as it floats through. It is good practice to repeat the entire process in a second nearby stretch of channel.

The float should be something that is partially submerged such as a water-logged piece of wood or a bottle partly filled with water. A leaf or chip is too light and tends to be blown about and restrained by the surface tension of the water.

Because of the drag exerted on the water by the sides and bottom of the channel, the average water velocity is less than the velocity of the float. For this reason the measured float velocity should be multiplied by the appropriate coefficient shown in Table 1. The corrected velocity should then be multiplied by the cross-sectional area of the corresponding stream segment to obtain the flow rate.

The following example illustrates this water measurement method.

A float takes 22 seconds to travel 50 feet. The channel depth in the upstream section is 1.7 feet and in the downstream section it is 1.5 feet, giving an average channel depth of 1.6 feet. For a depth of 1.6 feet, from Table 1, the coefficient is .67. The top widths at the upstream and downstream sections are 3.0 and 3.4 feet giving an average top width of 3.2 feet. The bottom width at the upstream and downstream sections is 1.2 and 1.6 feet giving an average bottom width of 1.4 feet. The flow rate can be calculated by following these steps.

1. Find the cross-sectional area by adding the average top width to the average bottom width, dividing by 2, and multiplying by the average channel depth.

$$\text{Cross-sectional area} = (3.2 + 1.4)/2 \times 1.6 = 3.7 \text{ square feet}$$

2. Determine the float velocity by dividing the distance between cross sections by the time it takes the float to go from the upper to the lower cross section.

$$\text{Float velocity} = 50 \text{ feet}/22 \text{ seconds} = 2.3 \text{ feet per second (fps)}$$

Table 1. Coefficients for Converting Float Velocity to Water Velocity

Average Depth (in feet)	Coefficient
1	.66
2	.68
3	.70
4	.72
5	.74
6	.76
9	.77
12	.78
15	.79
20 and above	.80

3. Adjust the float velocity by multiplying it by the coefficient for the appropriate depth given in Table 1.

Average water velocity = 2.3 fps x .67 = 1.5 fps

4. Find the flow rate by multiplying the cross-sectional area (from Step 1) by the average water velocity (from Step 3).

Flow rate = 3.7 square feet x 1.5 fps

= 5.6 cubic feet per second (cfs)

For larger streams this procedure would be followed for each stream segment measured. The depth would be measured at the upper and lower ends of each segment, then averaged. The total flow rate would then be the sum of the flow rate in each segment. Calculations are simple, but should be carefully checked to avoid mistakes.

Depth Applied to a Field in Inches

$$= \frac{\text{flow in cubic feet per second x hours}}{\text{area irrigated in acres}}$$

$$= \frac{\text{flow in gallons per minute x hours}}{\text{450 x area irrigated in acres}}$$

$$= \frac{\text{flow in Montana miner's inches x hours}}{\text{40 x area irrigated in acres}}$$

Units of Measurement

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GLOSSARY

Acre-foot – The quantity of water needed to cover one acre to a depth of one foot.

Adjudication – Simply stated this means "a court decision". Applied to water law it is the judicial procedure that settles claims and qauntifies rights and priorities.

Annual flood – The highest peak discharge of a stream in a water year.

Approach Velocity – Required velocity of water just upstream of measuring device to ensure proper conditions for accurate measurement.

Appropriated water – Water from a stream, reservoir, or other source reserved for a specific use under state water-right laws.

Aquifer – Rock or sediment which is saturated and sufficiently permeable to transmit economic quantities to wells and springs.

Average annual runoff (yield) – The average of water-year runoff for a total period of record; measured in volume.

Bank storage – The water that infiltrates the banks of a stream channel during high flows or floods, is stored there, and is released to the stream after the high water recedes.

Basin – A physiographic region bounded by a drainage divide; consists of a drainage system comprised of streams and often natural or man-made lakes. (Also called **drainage basin** or **watershed**.)

Beneficial use – The use of water for the benefit of the appropriator, other persons, or the public, including but not limited to agricultural (including stock water), domestic, fish and wildlife, industrial, irrigation, mining, municipal, power, and recreational uses. A beneficial use also includes the use of water for leasing under special provisions of Montana Codes Annotated 85-2-141.

Bond – A sum of money filed by a water commissioner with the clerk of district court to insure the faithful discharge of their duties.

Channelization – The artificial enlargement or realignment of a stream channel.

Cipolleti (trapezoidal) weir – A contracted weir trapezoidal in shape.

Claim – The "statement of existing water right claim" in accordance with Senate Bill 76, the adjudication statute, is a filing made to document an existing (pre-July 1, 1973) water right as ordered by the Montana Supreme Court. The statement of claim is considered prima facie evidence.

Closed basin – 1) A drainage basin having no natural outlet where surface water eventually seeps into the ground or evaporates. 2) A term also used when no more water rights are being granted in the basin in accordance with citizen petition or by legislation mandate.

Closed conduit flow – Flow (pipe flow) that occurs as the result of pressure due to head difference between the ends of the pipe.

Cone of depression – A depression in the potentiometric surface of an aquifer, typically defined or modelled as an "inverted cone" which defines the area of influence of a pumping well.

Confluence – The place where tributaries, streams, or rivers meet.

Conjunctive use – Planned management of surface water and groundwater resources as an interrelated system.

Conservation – The continuing protection and management of natural resources in accordance with principles that assure their optimum long-term economic and social benefits.

Consumptive use – Water removed from available supplies that does not return to the source. For example, water diverted from surface or groundwater that evaporates or transpires to the atmosphere due to plant use.

Continental divide – A drainage divide separating the rivers that flow toward opposite sides of a continent.

Cost allocation – The procedure for dividing total financial cost among the benefiting parties.

Creek – A small stream of water that serves as the natural drainage course for a drainage basin. The term is relative according to size. Some creeks in a humid region would be called rivers if they occurred in an arid area.

Crest – 1) The top of a dam, dike, or spillway. 2) The highest elevation reached by floodwaters flowing in a channel.

Cubic feet per second (cfs) – A unit expressing rate of discharge, typically used in measuring streamflow. One cubic foot per second is equal to the discharge in a stream of a cross section one foot wide and one foot deep, flowing with an average velocity of one foot per second; equals 448.8 gallons per minute.

Current meter – An instrument, typically using mechanical, electro-magnetic or doppler technology, that measures velocity to determine discharge in a stream or ditch.

Dam – A structure of earth, rock, concrete, or other materials designed to retain water, creating a pond, lake, or reservoir.

Dead storage – The volume of water in a reservoir stored below the lowest outlet that cannot be released for downstream use.

Decree – The judgement of a court; an official order or settlement. As related to Montana water law, a court adjudication of pre-July 1, 1973 existing water rights in a particular river basin.

- <u>Temporary preliminary decree</u> – A listing of state-based claims in a particular river basin issued by the Montana Water Court as a temporary listing of rights pending the addition of federal water right claims.
- <u>Preliminary decree</u> – a listing of state-based and federal reserved rights in a particular river basin.
- <u>Final decree</u> – a finalized record and adjudication of all rights in a basin, allowing for sound administration of water rights.

(All decrees are subject to objections and hearings before finalized)

Dike – An embankment to confine or control water. A **levee**.

Discharge – Flow of surface water in a stream or the flow of ground water from a spring, ditch, or flowing artesian well.

Ditch Rider – An employee of an irrigation district, water users' association, or some other private entity that facilitates the measurement and distribution of waters for that entity.

Ditch right – A right that allows someone to bring water through a ditch to their own land across someone else's land. Ditch rights are separate from water rights. One can have a water right without having a ditch right and vice versa, although this occurs infrequently. Ditch rights are obtained either by permission of the landowner, or by condemnation in a court with compensation. Owners of ditch rights can go onto the land of the landowner and repair and maintain the ditch, without notice. However, the access must be reasonable and necessary for maintenance of the ditch and cannot exceed the historical access.

Diversion – The transfer of water from a stream, lake, aquifer, or other source of water by a canal, pipe, well, or other conduit to another watercourse or to the land, as in the case of an irrigation system.

Diversion dam – An artificial barrier designed to enable the transfer of water from a stream into a canal, pipe, or other conveyance mechanism.

Drainage – Downward movement of water through soil or across the land surface.

Drainage area – The land area contributing runoff to a stream or other body of water, and generally defined in terms of acres or square miles.

Drainage divide – A natural ridge on the land surface which divides one drainage area from another.

Easement – A legal instrument enabling the giving, selling, taking, or use of certain property rights such as land use, without transfer of title, such as for the passage of utility lines.

Ephemeral stream – A stream that flows only part-time usually during snow melt periods or following rainstorms.

Evaporation – The process by which a liquid changes to vapor.

Evapotranspiration – The loss of water from the soil both by evaporation and by transpiration from the plants growing thereon.

Existing water rights – As defined by the Montana Water Use Act, water rights that originated before July 1, 1973, the effective date of the Montana Water Use Act.

Float-Area Method – A quick method to approximate flow when other means are not available.

Flood – The temporary inundation of normally dry land areas resulting from the overtopping of the natural or artificial confines of a river or other body of water.

Floodplain – The land bordering a stream or river, built up of sediments from overflow of the stream or river, and subject to inundation when the stream or river is at flood stage.

Flood stage – The stage at which overflow of a stream or body of water begins.

Flow – The rate of water discharged from a source; expressed in units of volume per units of time.

Flow augmentation – The addition of water to a stream.

Flume – A shaped, open-channel flow structure that forces flow to a accelerate and is used to measure flow in a channel.

Flow rate – The volume of water passing by a cross-sectional area per unit time. Typically expressed in cubic feet per second, gallons per minute, or miner's inches.

Freeboard – The vertical distance between a designed maximum water level and the top of a structure.

Free-flow condition – When the flow condition downstream of a measuring device does not influence the stage measurement at the upstream end. Free flow is critical for accurate measurements of flumes and weirs.

Gaging station – A particular site on a stream, canal, lake, or reservoir where hydrologic data is collected.

Gallons per minute – A unit expressing rate of discharge, typically used in measuring well capacity.

Gradient – Degree of incline; the steepness of a slope.

Groundwater – Any water beneath the land surface or beneath the bed of a stream, lake, or reservoir, and which is not a part of the surface water.

Headgate – A structure installed at the point of diversion to regulate flow.

Head – The height of a column of water above a reference point.

Headwaters – The source and upper reaches of a drainage.

Hydrograph – A graph showing the changes in discharge of a stream or river, or the changes in water levels of a well with the passage of time.

Hydrologic cycle – The constant circulation of water from the sea, through the atmosphere, to the land, and back to the sea by overland, subterranean, and atmospheric routes.

Influent stream – A stream that contributes water to the zone of saturation and to bank storage (losing stream).

In-line flow meter – A meter often permanently installed in a pipe or closed conduit that measures the volume of water flowing through the pipe.

Instream flows – The water left in a stream to maintain the existing water quality or aquatic resources and associated wildlife and riparian habitat.

Instream use – Uses of water within the stream channel (e.g., fish and other aquatic life, recreation, navigation, and some types of hydroelectric power production).

Interbasin transfer – The diversion of water from one drainage basin to another drainage basin.

Intermittent stream – A stream or reach of a stream that flows only at certain times of the year because losses from seepage or evaporation are greater than the available streamflow.

Irrigable land – Land possessing favorable soil, topographic, drainage, and climatic conditions, and an adequate water supply capable of economically supporting irrigation.

Irrigation – The controlled application of water to cropland, hayland, and/or pasture to supplement that supplied through nature.

Irrigation district – A quasi-public governmental organization created by petition and court decree to operate an irrigation system in a defined area that includes the operation of works, delivery of water, and administration of the organization. It is overseen by a board that is elected by the members of the district.

Irrigation system efficiency – The ratio of the consumptive use of applied irrigation water to the total amount of water diverted; expressed as a percentage.

Irrigation return flow – Irrigation water not consumed and returned to a surface or groundwater supply.

Lateral Ditch – Lateral ditches normally divert water from a main canal or ditch which has its heading from a river or natural stream channel.

Left or right bank – The left - or right-hand bank of a stream when the observer faces downstream.

Marsh-McBirney – The product name for an electromagnetic current meter commonly used in flow measurements to determine velocity.

Miner's Inches – 40 Montana statutory miner's inches is equivalent to 1 cubic foot of water per second (cfs).

Natural flow – The naturally occurring water that creates in-channel flows. Natural flows do not include water imported from other basins, water stored in a reservoir, or artificially added ground water. Natural flows may include tributary streams, springs, bank storage, and return flow.

Nappe – The falling sheet of water springing from a weir plate.

Net reservoir evaporation – The evaporation from a reservoir after making allowance for precipitation on the reservoir and for runoff that would have occurred if the land area were not covered by the reservoir.

Offstream use – Water withdrawn from a surface water source for uses such as irrigation, municipal water supply, steam electric generation, etc.

Perennial stream – A stream that flows from source to mouth throughout the year.

Period of use – The time period during each year that the holder of a valid water right is allowed to use water.

Place of Use – The location where water is used.

Point of diversion – The location at which water is physically diverted by man-made works from the source of water. Points of diversion are identified by legal descriptions in Montana water rights.

Price AA and pygmy meter – Types of mechanical velocity meters utilizing horizontally aligned "cups" spun by the stream current.

Prior Appropriation Doctrine – A legal theory of water law and a system of water rights management which allocates water between users based upon a priority of water use. It is often defined as a water system where "first in time", is "first in right". An individual's right to a specific quantity of water depends on when the use began and the amount of water used at that point in time. The first person to use the water from a source established the first right, the second person could establish the next right, and so on. During dry years, the person with the first right has the first chance to use the available water. The holder of the second right (a junior right) would have the second chance, and so on. The traditional elements of a valid appropriation are:

1. Intent to apply water to a beneficial use
2. An actual diversion of water from the natural source
3. Application of the water to a beneficial use within a reasonable time
4. The right to conditions as they exist at the time appropriation

Priority date – The date a water right was first established. The priority date is used to disperse water according to seniority.

Rating table – A table listing gage heights with their corresponding discharge values. It is used in obtaining instantaneous discharges.

Reach – Any arbitrarily defined length of a stream.

Reserved water right – A water right created and implied under federal law by the reservation of land by the federal government. The federal court quantifies this as the amount of water sufficient to meet the purposes of the reservation. Federal reserve rights are associated with military reservations, the National Park Service, USFS, and other federal lands such as Indian reservations. The right is not lost by nonuse and its priority date is the date the land was reserved by federal law, executive order or treaty.

Reservoir – A man-made pond, lake, or basin that stores, regulates, or controls water.

Riprap – Rock placed along a streambank, as a protective layer to prevent erosion.

Runoff – The flow of water over the land surface and eventually in stream channels typically as a function of precipitation, snowmelt, spring discharge, or excess irrigation water.

Seepage – Water lost or gained in a stream or ditch as the result of interaction with shallow ground water through porous soils.

Sharp Crested Weir – A weir with a thin plate mounted across the notch to allow for free-flow conditions.

Snowpack – The winter accumulation of snow; measured in inches.

Spring – A naturally occurring source of water issuing from the ground.

Staff gage – Either vertical or inclined. The standard U.S. Geological Survey vertical staff gage consists of porcelain-enameled iron sections, each 4 inches wide, 3.4 feet long, and graduated every 0.02 foot. They are used to measure water-surface elevations.

Stage – The height of a water surface above some established reference point.

Stored water – Water diverted to and retained within a reservoir and then released for some beneficial use.

Stream – Any body of running water moving under gravity flow through clearly defined natural channels.

Streamflow – The discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream.

Submergence – When used to describe the operation of a flume, submerged flow is when the resistance to flow becomes sufficient to reduce the velocity, increase the flow depth, and cause a backwater effect at the flume. When used to describe the operation of a weir, submerged flow occurs when freeflow no longer occurs over the crest and the nappe is not ventilated.

Surface water – Water above the surface of the land including, but not limited to, lakes, rivers, streams, wetlands, wastewater, flood water, and ponds.

Topographic maps – Maps with lines showing equal elevation of a region's relief; also showing natural and man-made surface features, including hills, valleys, rivers, and lakes; and man-made features such as canals, bridges, roads, cities, etc.

Totalizer – A flow meter with the built-in capability to sum or totalize volume continually.

Transpiration – The process by which water absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface, principally from the leaves.

Tributary – A stream that contributes its water to another stream or body of water.

Velocity Head - As it pertains to a weir, when flow approaches the crest, the water surface becomes lower due to acceleration of the flow by the force of gravity.

Volume – The amount of water in terms of gallons, acre-feet, or cubic feet.

Water budget – An accounting of the inflows and outflows of water to and from a system.

Water Master – An attorney or technical specialist employed by the Montana Water Court who is responsible for the organization of and management of objections and issues in a decree.

Water reservation – A water right granted by the Board of Natural Resources and Conservation to public entities, on behalf of the public, for existing or future beneficial uses or to maintain a minimum flow, level, or quality of water.

Water right – A legal right to use a specified amount of water for beneficial purposes.

Watershed (drainage basin) – The land area (or catchment) which captures precipitation and conveys it to a particular waterbody. It is bounded by ridges or divides. A large watershed like that of the Bitterroot River is made up of the watersheds of all its tributaries, such as Mill Creek.

Water table – The upper level of a saturated zone in an aquifer below the soil surface.

Water year – The 12-month period October 1st through September 30th, and designated by the calendar year in which it ends.

Water yield – The surface runoff from a drainage basin; precipitation minus the evapotranspiration; usually measured in cubic feet per second or acre-feet per square mile. For groundwater, the volume of water pumped from a well in a given period of time; usually measured in gallons per minute (gpm).

Weir – A structure placed in a canal, stream, or ditch to measure the rate of flow of water. In its simplest form, a weir consists of a bulkhead with an opening of fixed dimensions cut into its top edge.

Well – A pit, hole, or shaft sunk into the earth to tap an underground source of water.

Wetlands – Lands where water saturation is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the surrounding environment. Other common names for wetlands are sloughs, ponds, and marshes.

NOTES