Water Commissioner Training

Title 85-5
Montana Code Annotated

Helena, Montana
April 9-10, 2015

Department of Natural Resources
and Conservation (DNRC)

Handouts

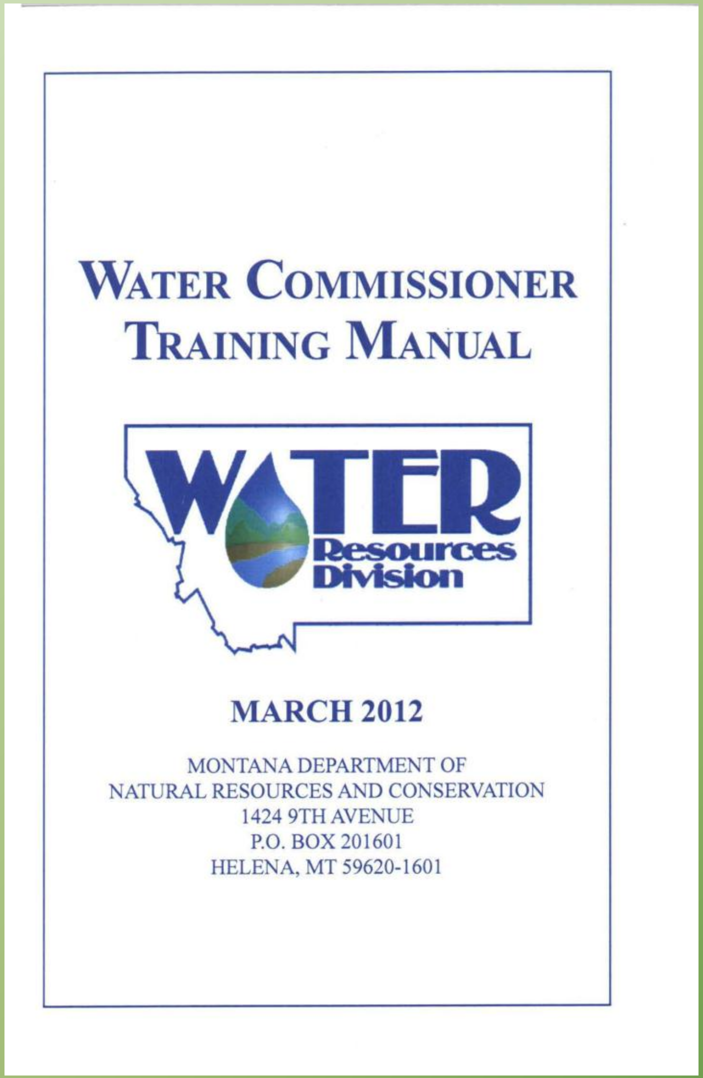
- Water Commissioner Training Manual (2015)
- Water Rights in Montana (2014)
- Irrigation Water Measurement (Wyoming Pocket Guide)
- Problem Sets
- Water trivia!
- Additional Handouts

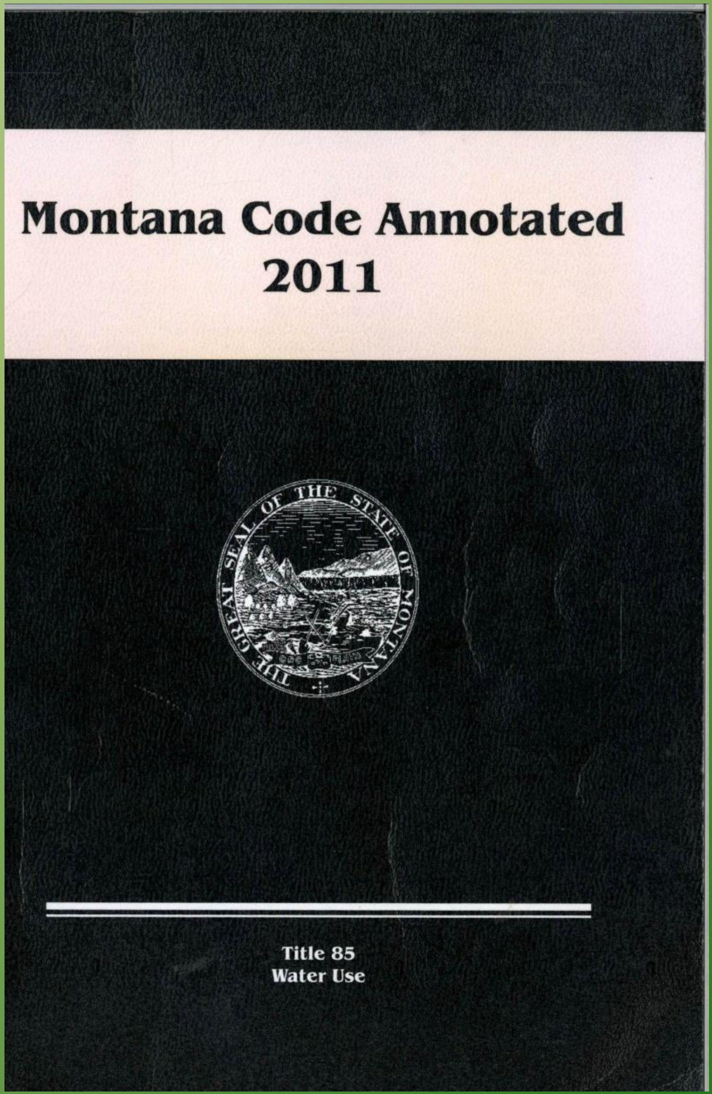
Speakers

Hon. Douglas Ritter, Associate Water Judge, Montana Water Court
Mike McLane, Montana Dept. Fish, Wildlife, and Parks
Jamie Ellis, New Appropriations Manager, DNRC Water Resources Division
Matt Norberg, State Water Projects, DNRC Water Resources Division
Jim Beck, Retired DNRC Water Resource Engineer
Mike Roberts, Hydrologist, DNRC Water Resources Division

Why do we train Water Commissioners?

1989 Montana Legislature MCA 85-5-111





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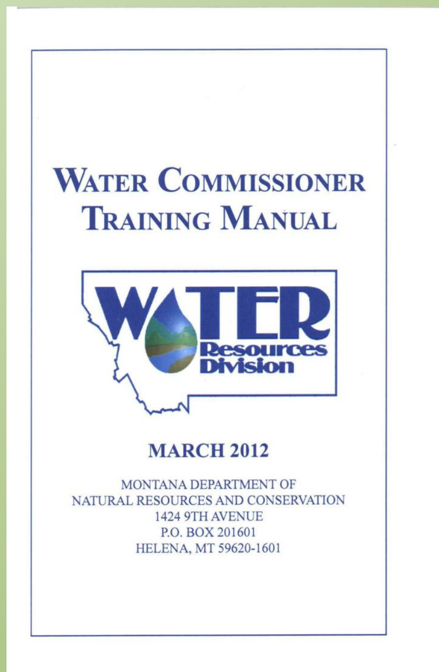
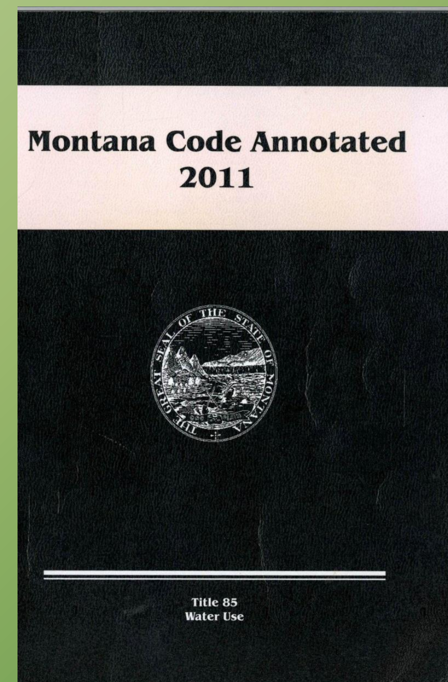




Heightened awareness of water management:

- adjudication – Water Court Decrees
- drought
- water right hearings

Water Mediation Training

MCA 85-5-110
MCA 85-5-111

What is a Water Commissioner?

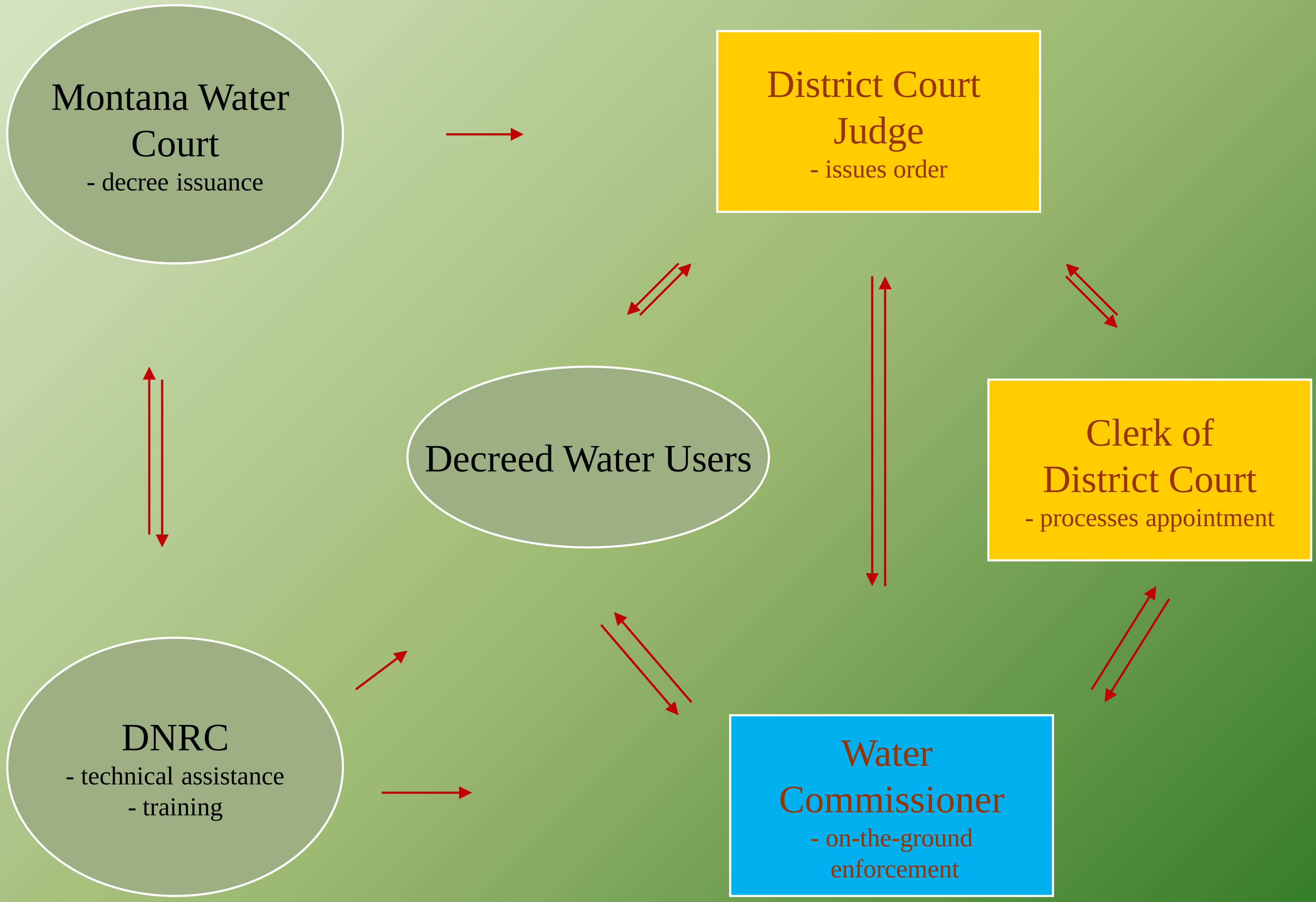
An appointee of the District Court responsible for the measurement and delivery of water based upon the priority of water rights for a specific stream, ditch, reservoir, or other watercourse.

Ditch Rider? Dam Tender? Water Commissioner? Mediator?

MCA 85-5-101 Applies to any stream, ditch, watercourse, spring, lake, reservoir, or other source of supply which has been determined by a decree of a court of competent jurisdiction (including temporary preliminary, preliminary, and final decrees).

Who are these guys?

Key Players

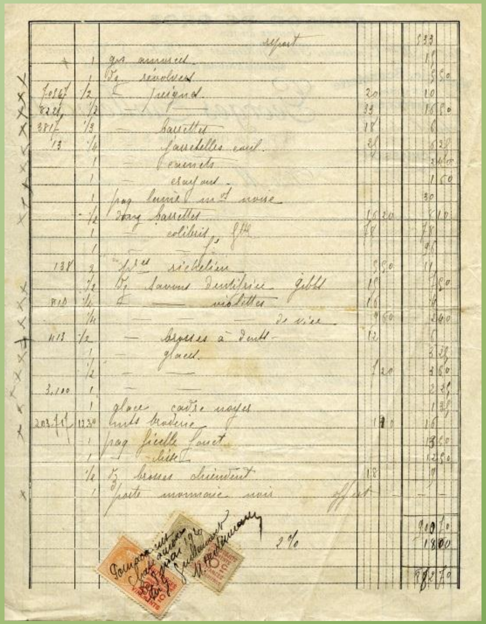


Montana Water Court
- decree issuance
District Court Judge
- issues order
Decreed Water Users
Clerk of District Court
- processes appointment
DNRC
- technical assistance
- training
Water Commissioner
- on-the-ground enforcement

District Court Decree vs. Water Court Decree

- Includes all water rights dated before Decree Issued
- Does not reflect newer water rights, permits, or changes

- Includes all water rights, permits, changes in appropriation, and is updated annually.



2014 Priority Date Index - Shields River Enforcement Area

Enforceable Priority Date	Water Right #	Owner	Type	Use	Acres	Pod ID	Means	Qtr Sec	Section	Twp Rge	Source	Enf #	Diversion Name	From - To	Cfs	Total Flow
18800601	43A W 11572 00	PORCUPINE CREEK RANCH INC	USE	ST		1	LS	N2SW	34	5N9E	SHIELDS RIVER	LS010	LS010	01 01 12 31		0.00
18830415	43A W 137659 00	MONTANA, STATE OF BOARD OF LAND COMMISSIONERS	USE	ST		1	DT	NWSENE	25	5N9E	SHIELDS RIVER	018	BECKER DITCH	01 01 12 31		0.00
18830425	43A W 193075 00	BRIGHT, GORDON L	DECR	IR	30.8	1	HG	SENWSW	9	4N9E	SHIELDS RIVER	012	BIG CANAL	05 01 10 04	0.43	0.43
18830425		BRIGHT, JACQUELINE J	DECR	IR	30.8	1	HG	SENWSW	9	4N9E	SHIELDS RIVER	012	BIG CANAL	05 01 10 04		0.43
18830425	43A W 31162 00	ADAMS, DIRK S	DECR	IR	104	1*	HG		4	4N9E	SHIELDS RIVER	012	BIG CANAL	05 15 10 19	3.33	3.76
18830425		ADAMS, DIRK S	DECR	IR	104	2*	HG	NWNWNW	3	4N9E	SHIELDS RIVER	014P	ADAMS PUMP SITE	05 15 10 19		3.76
18830425	43A W 33140 00	ADAMS, DIRK S	DECR	ST		1	LS	SESW	16	4N9E	SHIELDS RIVER	LS006	LS006	01 01 12 31		3.76
18830610	43A W 113381 00	ADAMS, ANITA L	DECR	IR	212	1*	HG	SWSWSE	4	4N9E	SHIELDS RIVER	011	UPPER SWANDAL DITCH	04 15 10 31	1.69	5.45
18830610		ADAMS, ANITA L	DECR	IR	212	2*	HG	SESENW	9	4N9E	SHIELDS RIVER	010	MIDDLE SWANDAL DITCH	04 15 10 31		5.45
18830610		ADAMS, ANITA L	DECR	IR	212	3*	HG	SENWSE	9	4N9E	SHIELDS RIVER	009	LOWER SWANDAL DITCH	04 15 10 31		5.45
18830610		ADAMS, DIRK S	DECR	IR	212	1*	HG	SWSWSE	4	4N9E	SHIELDS RIVER	011	UPPER SWANDAL DITCH	04 15 10 31		5.45
18830610		ADAMS, DIRK S	DECR	IR	212	2*	HG	SESENW	9	4N9E	SHIELDS RIVER	010	MIDDLE SWANDAL DITCH	04 15 10 31		5.45
18830610		ADAMS, DIRK S	DECR	IR	212	3*	HG	SENWSE	9	4N9E	SHIELDS RIVER	009	LOWER SWANDAL DITCH	04 15 10 31		5.45
18830610	43A W 11582 00	PORCUPINE CREEK RANCH INC	DECR	IR	425	1	HG	NWSENE	25	5N9E	SHIELDS RIVER	018	BECKER DITCH	05 15 09 19	0.56	6.01
18830610	43A W 191857 00	ADAMS, ANITA L	USE	ST		1*	DT	SWSWSE	4	4N9E	SHIELDS RIVER	011	UPPER SWANDAL DITCH	01 01 12 31		6.01
18830610		ADAMS, ANITA L	USE	ST		2*	DT	SESENW	9	4N9E	SHIELDS RIVER	010	MIDDLE SWANDAL DITCH	01 01 12 31		6.01
18830610		ADAMS, ANITA L	USE	ST		3*	DT	SENWSE	9	4N9E	SHIELDS RIVER	009	LOWER SWANDAL DITCH	01 01 12 31		6.01

Tuesday, March 11, 2014 Page 1 of 29

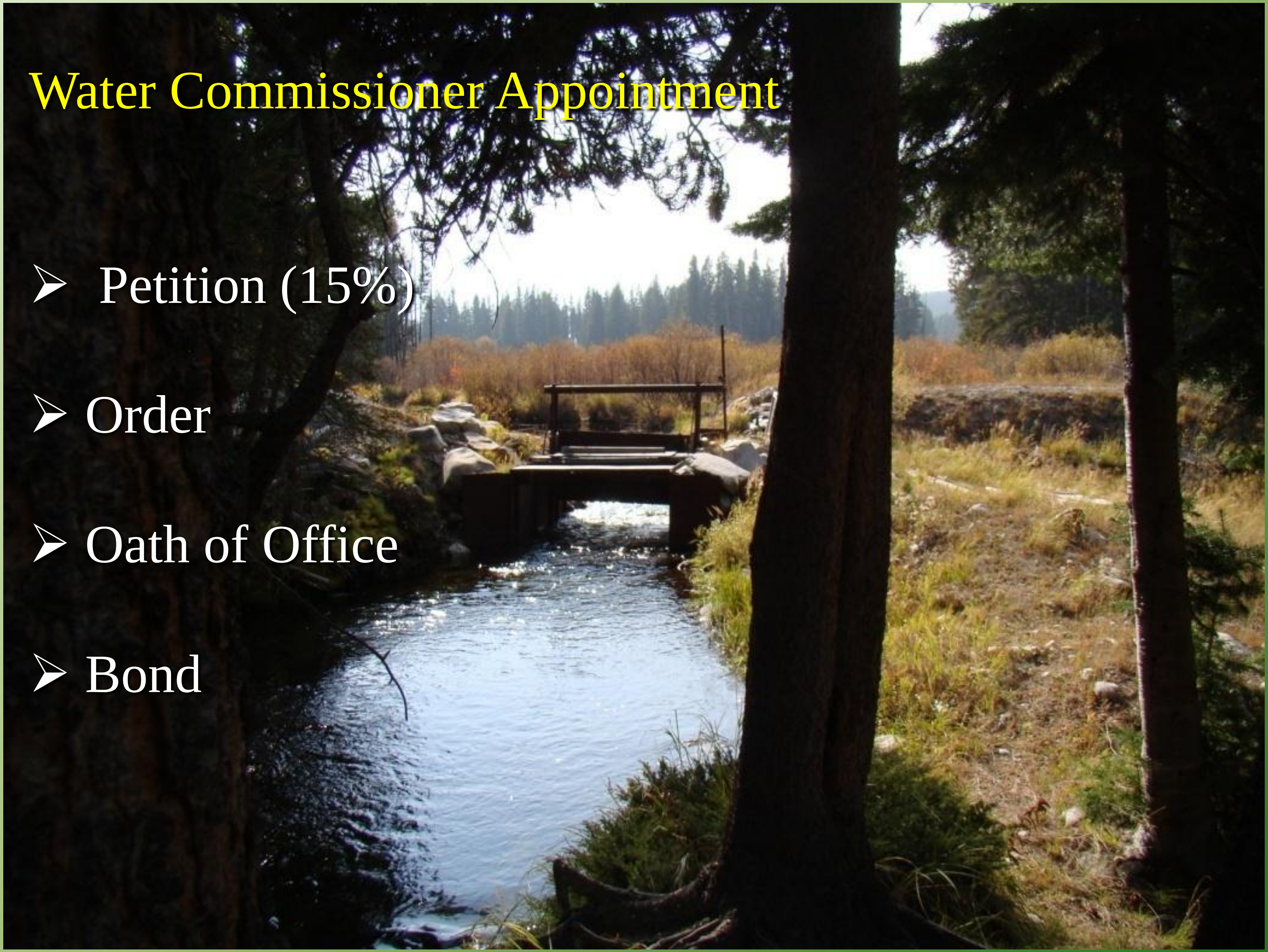
How is a decree enforced?

Through the appointment of a water commissioner who:

- Enforces priority date limits for water use.
- Monitors headgates and measuring devices to ensure compliance with decree.
- Keeps records of water use and submits reports to District Court.

Water Commissioner Appointment

- Petition (15%)
- Order
- Oath of Office
- Bond



Once Appointed, now what??

- duties
- list of water users, map, DNRC Tabulation
- notification
- payment system
- worker’s compensation

Water Commissioner Duties

- Measure and distribute waters based on Prior Appropriations Doctrine

"first in time, first in right.."

- Deliver water based on District Court or Water Court Decree

- Inspect headgates and measuring devices to ensure proper functioning condition.

- Record (daily) water distribution and expenses.

- Not apportion or distribute water if the water user fails to have a proper measuring device or fails to pay.

Water Commissioners Do Not Have the Following Responsibilities

- Approval of changes in points of diversion, flow rate, place of use, priority date, or period of use.

- Exemption from 310 permit for headgate and diversion dam repair.
  (Natural Streambed and Land Preservation Act)

More Things Water Commissioners Can/Should and Can't/Shouldn't Do:

Yes

- Access any headgate related to the POD of a water right in the decree.
  Establish with water user best way to access headgate and measuring device.
- Establish clear understanding/communication with water users pertaining to turn on/shut off. For example, there may be a lag when delivering stored water, etc.
- Work with water user if headgate or measuring device requires repair/replacement.
- Clearly name or number headgates on your stream.
- Provide clear contact info for water users (and vise-versa)

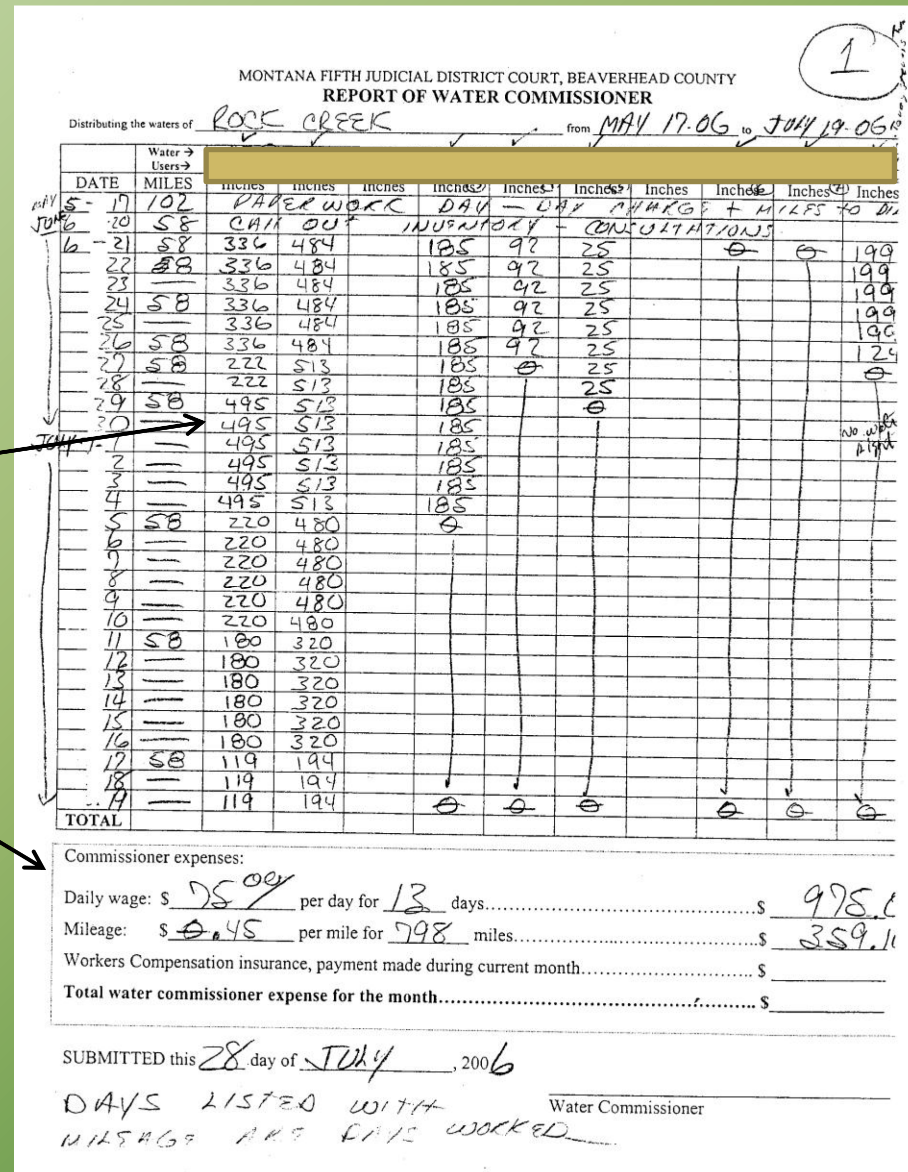
No

- Trade water outside of flow rate, period of use, place of use
- Distribute water to a non-water right holder
- Distribute by purpose of use. All beneficial uses have equal standing (irrigation, stock , municipal, instream flow for fisheries, storage, etc.)

Daily Record of Water Distribution

Daily allotment (inches)

Payment (wage and mileage)



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MONTANA FIFTH JUDICIAL DISTRICT COURT, BEAVERHEAD COUNTY

REPORT OF WATER COMMISSIONER

Distributing the waters of ROCK CREEK from MAY 17. 06 to JULY 19. 06

[redacted]

DATE	Water → Users → MILES	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
MAY 5-17	102	PAPER WORK									
JUNE 6-20	58	CALL OUT		INVENTORY	DAY - DAY CHARGE + MILES TO DI…		CONSULTATIONS				
6-21	58	336	484		185	92	25		⊖	⊖	199
22	58	336	484		185	92	25				199
23	—	336	484		185	92	25				199
24	58	336	484		185	92	25				199
25	—	336	484		185	92	25				196
26	58	336	484		185	92	25				124
27	58	222	513		185	⊖	25				⊖
28	—	222	513		185		25				
29	58	495	513		185		⊖				
30	—	495	513		185						No water right
JULY 7-1	—	495	513		185						
2	—	495	513		185						
3	—	495	513		185						
4	—	495	513		185						
5	58	220	480		⊖						
6	—	220	480								
7	—	220	480								
8	—	220	480								
9	—	220	480								
10	—	220	480								
11	58	180	320								
12	—	180	320								
13	—	180	320								
14	—	180	320								
15	—	180	320								
16	—	180	320								
17	58	119	194								
18	—	119	194								
19	—	119	194		⊖	⊖	⊖		⊖	⊖	⊖
TOTAL											

Commissioner expenses:

Daily wage: $ 75.00 per day for 13 days...$ 975.0

Mileage: $ 0.45 per mile for 798 miles...$ 359.1

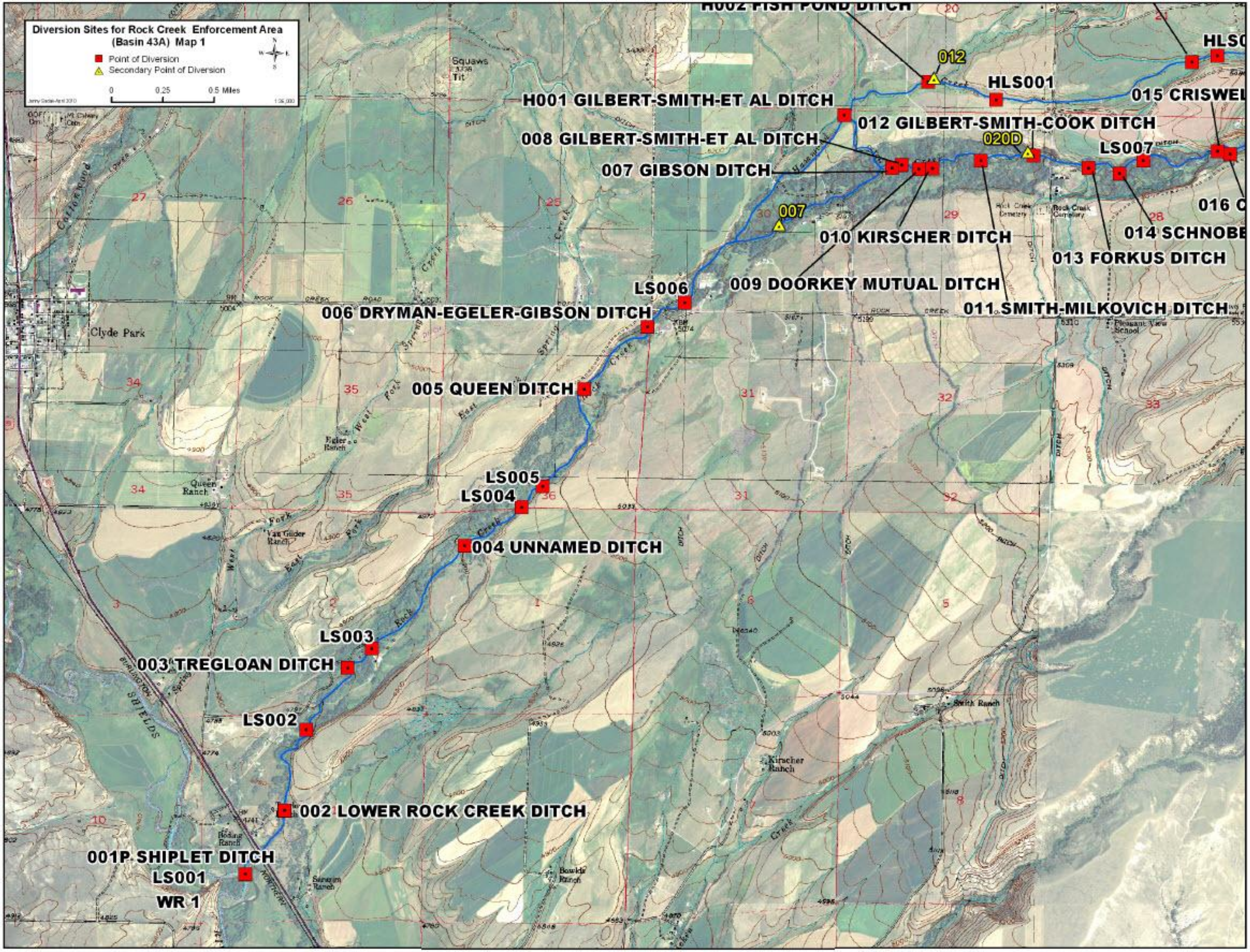
Workers Compensation insurance, payment made during current month..........................$

Total water commissioner expense for the month..$

SUBMITTED this 28 day of JULY, 2006

Water Commissioner

DAYS LISTED WITH MILEAGE ARE DAYS WORKED


Diversion Sites for Rock Creek Enforcement Area (Basin 43A) Map 1
Point of Diversion
Secondary Point of Diversion
0 0.25 0.5 Miles
H002 FISH POND DITCH
012
HLS001
H001 GILBERT-SMITH-ET AL DITCH
012 GILBERT-SMITH-COOK DITCH
015 CRISWEL
HLS0
008 GILBERT-SMITH-ET AL DITCH
020D
LS007
007 GIBSON DITCH
007
016 C
010 KIRSCHER DITCH
014 SCHNOBE
013 FORKUS DITCH
009 DOORKEY MUTUAL DITCH
011 SMITH-MILKOVICH DITCH
LS006
006 DRYMAN-EGELER-GIBSON DITCH
Clyde Park
005 QUEEN DITCH
LS005
LS004
004 UNNAMED DITCH
LS003
003 TREGLOAN DITCH
LS002
002 LOWER ROCK CREEK DITCH
001P SHIPLET DITCH
LS001
WR 1

$$$ Payment

- Each water user pays for water they received (proportionately).
- Payment system (MCA 85-5-204, 2007) Can receive money up front.
- Water Commissioner is paid directly through Clerk of Courts office
- If user does not pay, water can be shut off and/or court can summon to “show cause” hearing.

Expenses billed to water users include:

- set fee billed proportionately based on water used
- mileage
- telephone
- repairs to headgates, ditches, measuring devices
- Commissioner Training (?)
- Worker's Compensation

(document everything)

MONTANA STATEFUND

5 South Last Chance Gulch · P.O. Box 4759 · Helena, MT 59604-4759
Customer Service: 1-800-332-6102 or 406-444-6500
Fraud Hotline: 1-888-682-7463 (888-MT-CRIME)

Laurence Hubbard, President/CEO

WORKERS COM ARRANGEMENT FOR WATER COMMISSIONERS
04/1/2014 *

1. Term: Two options:
   a. Short term: Policy will only run for the period requested for coverage for the water commissioner. Policy will cancel and not renew & if commissioner is appointed for another period, a new application will have to be completed & submitted.
   b. Regular 12 month term: Policy will run for 12 months with coverage for the water commissioner being only for the months given. The application needs to be specific on the time frame required for coverage on the owner of the policy. The policy will automatically renew in 12 months as long as payrolls & payments are kept up to date.
2. Binding Effective date: This will be the day following the date when 3 items have been received in MSF office:
   a. Any prior policy reconciled (payroll reports received & payment received) if applicable.
   b. Completed application.
   c. Deposit & expense constant or 1st installment.
3. Coverage for water commissioner: The covered period will be from no sooner than the effective date of the policy (can use a later date) to the last date the commissioner thinks he/she will need coverage. Ex: policy starts 06/01/2014 & coverage is needed from 06/01/2014 to the end of Oct. So the last day of coverage would be 10/31/2014. ***If the commissioner stops earlier, it is his/her responsibility to contact MSF to request the coverage stop sooner. If the coverage is needed longer again it is the responsibility of the commissioner to notify MSF PRIOR to ending coverage date for an extension.***
4. The 2 options of policies:
   a. Installment method:
      i. This will require a payment of at least $**400.12** down (includes the expense constant) & 2 more monthly payments to pay off the premium in advance. Usually has an annual payroll reporting frequency.

MONTANA STATEFUND

5 South Last Chance Gulch · P.O. Box 4759 · Helena, MT 59604-4759
Customer Service: 1-800-332-6102 or 406-444-6500
Fraud Hotline: 1-888-682-7463 (888-MT-CRIME)

Laurence Hubbard, President/CEO

   b. Deposit method:
      i. This will require the payment of the expense constant plus a 20% of the estimated premium.
      ii. The payroll reporting will be semi-annually, meaning a payroll report will be sent July & Jan. They have to be filled out & returned by due date & premium due will need to be paid by due date. These payrolls will be due the end of July & the end of Jan with the premium due the following months.

The rates for the water commissioners this year will be:
$**9.72**/PER $100.

The lowest wage that commissioners can elect is $900/month for sole proprietors. The approximate premium cost would be $**400.12** to bind coverage and 2 monthly installments of $**358.62**. Which would ***be prorated when coverage is removed or cancelled as stated above.*** Other options may be considered.

Your contacts are **Rabecca Lindal** for Team 2 at 1-800-332-6102 ext **5260** and **Karen Beddow 5112** for Team 1 at 1-800-332-6102. Both of these customer service specialists will be able to assist you with any questions.

**note: 2014 adjustments are bolded. Changes made on 4/1/14 by DNRC per email contact with Rabecca Lindal from Montana State Fund.*

note: **07/01/2014 Rates change any application received after 07/01/2014 will be subject to new rates & binding amount.*

Montana's insurance carrier of choice and industry leader in service.

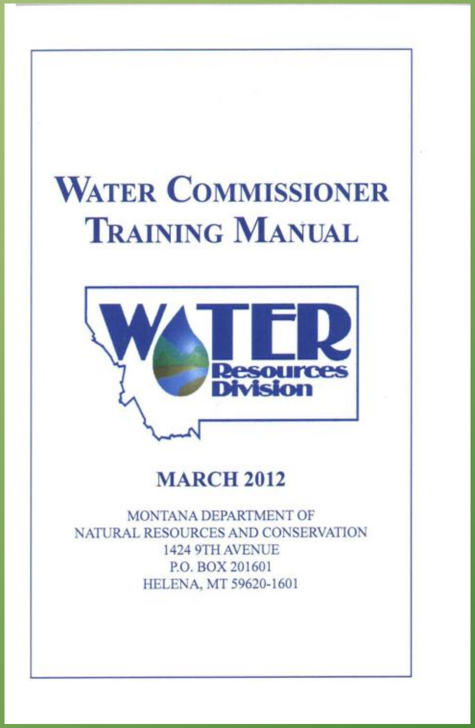
Through July 1, 2015 (MCA 85-5-101(7))

Rights and Duties of Water Users:

- ➢ May file dissatisfied user complaint with judge.
- ➢ Failure of Water Commissioner to perform duty is Contempt of Court.
- ➢ Required to have suitable and functioning headgate and measuring device.

Special Circumstances

- water rights not in decree
- contract water
- carriage water
- temporary changes
- road construction
- instream flow/lease enforcement
- return flow
- seepage rights
- futile call



Stored Water Distribution

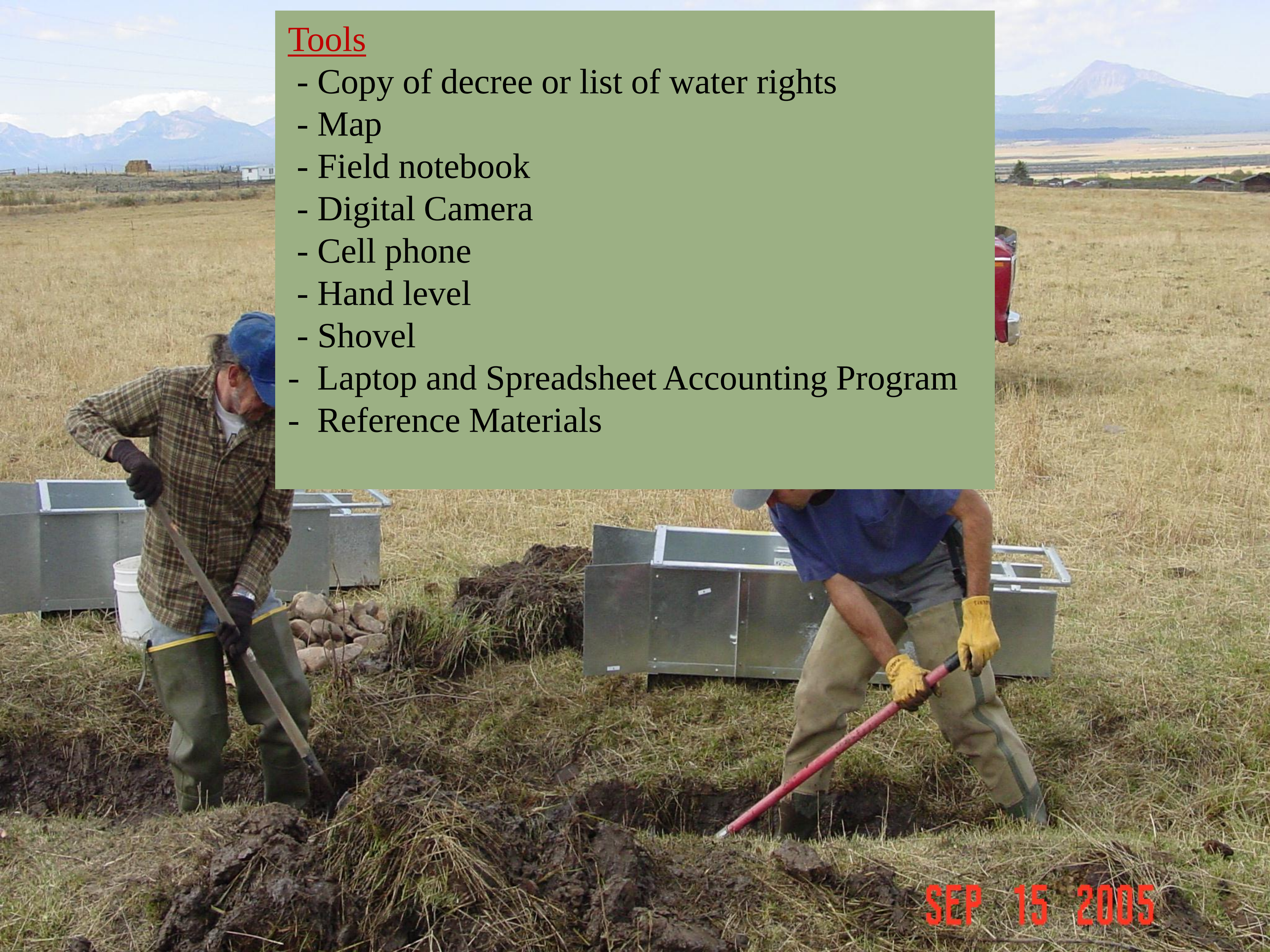
- Contract water
- Administered separate from natural flows
- May use stream channel as conveyance but must be measured at reservoir outlet (in most cases)

Document

- date and time of anything you do
- daily record of water distribution
- mileage
- telephone
- any repairs (photo document, date)
- repair costs
- correspondence with users, Judge, DNRC, Water Court
- worker's compensation insurance

Tools

- Copy of decree or list of water rights
- Map
- Field notebook
- Digital Camera
- Cell phone
- Hand level
- Shovel
- Laptop and Spreadsheet Accounting Program
- Reference Materials



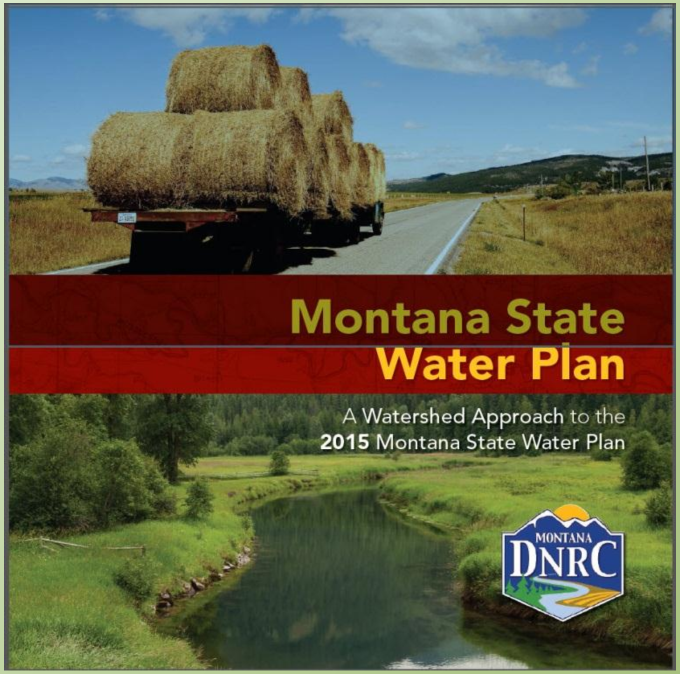
http://lmcd.mt.nacdnet.org/MREP/

Communication

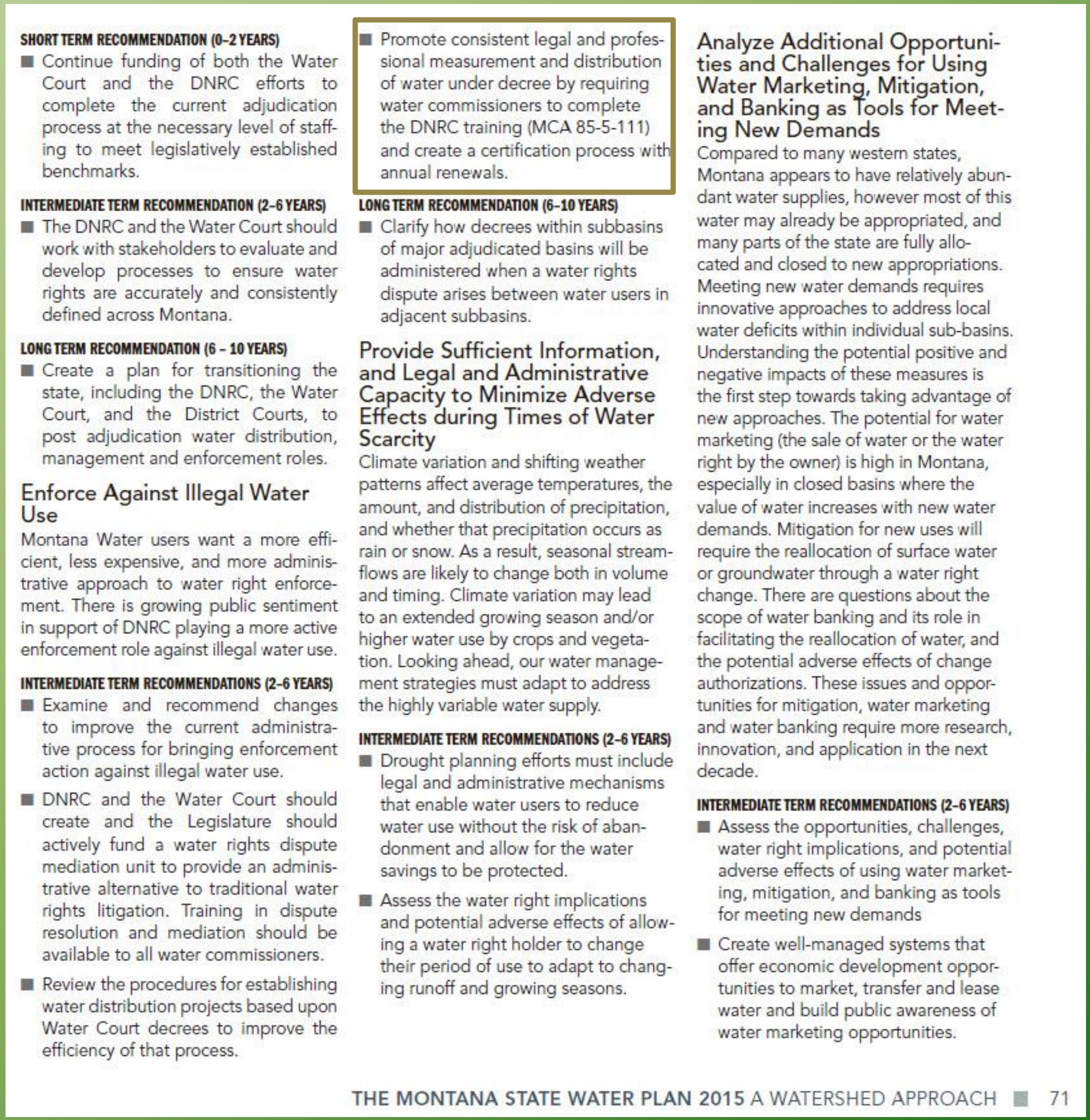
Water Commissioner and Water User　　Water Commissioner and District Court

Issues that require Communication include:

- Turning on/off
- Headgate Adjustment
- Access
- Repair/Replacement
- Payment Issues



Water Commissioner Training Requirement and Certification??



SHORT TERM RECOMMENDATION (0–2 YEARS)

- Continue funding of both the Water Court and the DNRC efforts to complete the current adjudication process at the necessary level of staffing to meet legislatively established benchmarks.

INTERMEDIATE TERM RECOMMENDATION (2–6 YEARS)

- The DNRC and the Water Court should work with stakeholders to evaluate and develop processes to ensure water rights are accurately and consistently defined across Montana.

LONG TERM RECOMMENDATION (6 – 10 YEARS)

- Create a plan for transitioning the state, including the DNRC, the Water Court, and the District Courts, to post adjudication water distribution, management and enforcement roles.

Enforce Against Illegal Water Use

Montana Water users want a more efficient, less expensive, and more administrative approach to water right enforcement. There is growing public sentiment in support of DNRC playing a more active enforcement role against illegal water use.

INTERMEDIATE TERM RECOMMENDATIONS (2–6 YEARS)

- Examine and recommend changes to improve the current administrative process for bringing enforcement action against illegal water use.
- DNRC and the Water Court should create and the Legislature should actively fund a water rights dispute mediation unit to provide an administrative alternative to traditional water rights litigation. Training in dispute resolution and mediation should be available to all water commissioners.
- Review the procedures for establishing water distribution projects based upon Water Court decrees to improve the efficiency of that process.
- Promote consistent legal and professional measurement and distribution of water under decree by requiring water commissioners to complete the DNRC training (MCA 85-5-111) and create a certification process with annual renewals.

LONG TERM RECOMMENDATION (6–10 YEARS)

- Clarify how decrees within subbasins of major adjudicated basins will be administered when a water rights dispute arises between water users in adjacent subbasins.

Provide Sufficient Information, and Legal and Administrative Capacity to Minimize Adverse Effects during Times of Water Scarcity

Climate variation and shifting weather patterns affect average temperatures, the amount, and distribution of precipitation, and whether that precipitation occurs as rain or snow. As a result, seasonal streamflows are likely to change both in volume and timing. Climate variation may lead to an extended growing season and/or higher water use by crops and vegetation. Looking ahead, our water management strategies must adapt to address the highly variable water supply.

INTERMEDIATE TERM RECOMMENDATIONS (2–6 YEARS)

- Drought planning efforts must include legal and administrative mechanisms that enable water users to reduce water use without the risk of abandonment and allow for the water savings to be protected.
- Assess the water right implications and potential adverse effects of allowing a water right holder to change their period of use to adapt to changing runoff and growing seasons.

Analyze Additional Opportunities and Challenges for Using Water Marketing, Mitigation, and Banking as Tools for Meeting New Demands

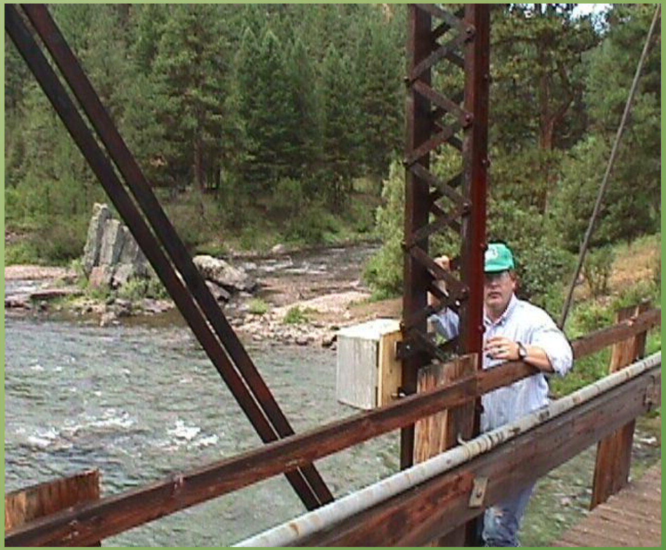
Compared to many western states, Montana appears to have relatively abundant water supplies, however most of this water may already be appropriated, and many parts of the state are fully allocated and closed to new appropriations. Meeting new water demands requires innovative approaches to address local water deficits within individual sub-basins. Understanding the potential positive and negative impacts of these measures is the first step towards taking advantage of new approaches. The potential for water marketing (the sale of water or the water right by the owner) is high in Montana, especially in closed basins where the value of water increases with new water demands. Mitigation for new uses will require the reallocation of surface water or groundwater through a water right change. There are questions about the scope of water banking and its role in facilitating the reallocation of water, and the potential adverse effects of change authorizations. These issues and opportunities for mitigation, water marketing and water banking require more research, innovation, and application in the next decade.

INTERMEDIATE TERM RECOMMENDATIONS (2–6 YEARS)

- Assess the opportunities, challenges, water right implications, and potential adverse effects of using water marketing, mitigation, and banking as tools for meeting new demands
- Create well-managed systems that offer economic development opportunities to market, transfer and lease water and build public awareness of water marketing opportunities.


Safety First


Boil
Backwash
Low-Head
Dam
Escape Route



Take Precautions

Basin Snowpack

2015

MONTANA SNOTEL Snow Water Equivalent Update Graph

As of MONDAY: APRIL 6 , 2015

Basin	Snow Water Equivalent Percent of Median
KOOTENAI RIVER BASIN	54%
FLATHEAD RIVER BASIN	82%
UPPER CLARK FORK RIVER BASIN	87%
BITTERROOT RIVER BASIN	80%
LOWER CLARK FORK RIVER BASIN	56%
JEFFERSON RIVER BASIN	75%
MADISON RIVER BASIN	69%
GALLATIN RIVER BASIN	85%
MISSOURI HEADWATERS	75%
HEADWATERS MISSOURI MAINSTEM	78%
SMITH, JUDITH, AND MUSSELSHELL RIVER BASINS	82%
SUN, TETON AND MARIAS RIVER BASINS	64%
MISSOURI MAINSTEM RIVER BASIN	74%
ST MARY AND MILK RIVER BASINS	62%
UPPER YELLOWSTONE RIVER BASIN	83%
WIND RIVER BASIN (WYOMING)	69%
SHOSHONE RIVER BASIN (WYOMING)	75%
BIGHORN RIVER BASIN (WYOMING)	78%
TONGUE RIVER BASIN (WYOMING)	73%
POWDER RIVER BASIN (WYOMING)	77%
LOWER YELLOWSTONE RIVER BASIN	73%

Legend: <70% | 70-90% | 91-110% | 111-130% | >130%

* = Data are not available or data may not provide a valid measure of conditions for over half of the sites within the basin.

2014

MONTANA SNOTEL Snow Water Equivalent Update Graph

As of WEDNESDAY: APRIL 2 , 2014

Basin	Snow Water Equivalent Percent of Median
KOOTENAI RIVER BASIN	119%
FLATHEAD RIVER BASIN	132%
UPPER CLARK FORK RIVER BASIN	147%
BITTERROOT RIVER BASIN	159%
LOWER CLARK FORK RIVER BASIN	132%
JEFFERSON RIVER BASIN	141%
MADISON RIVER BASIN	126%
GALLATIN RIVER BASIN	140%
MISSOURI HEADWATERS	135%
HEADWATERS MISSOURI MAINSTEM	156%
SMITH, JUDITH, AND MUSSELSHELL RIVER BASINS	150%
SUN, TETON AND MARIAS RIVER BASINS	145%
MISSOURI MAINSTEM RIVER BASIN	152%
ST MARY AND MILK RIVER BASINS	134%
UPPER YELLOWSTONE RIVER BASIN	153%
WIND RIVER BASIN (WYOMING)	133%
SHOSHONE RIVER BASIN (WYOMING)	146%
BIGHORN RIVER BASIN (WYOMING)	149%
TONGUE RIVER BASIN (WYOMING)	144%
POWDER RIVER BASIN (WYOMING)	160%
LOWER YELLOWSTONE RIVER BASIN	143%

Legend: <70% | 70-90% | 91-110% | 111-130% | >130%

Montana DNRC State Water Projects Bureau Reservoirs

MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
WATER RESOURCES DIVISION - STATE WATER PROJECTS BUREAU

March 31, 2015
All Contents in Acre-Feet

RESERVOIR	TOTAL CAPACITY (includes dead storage)*	CONTENTS							
	Full Pool	AVERAGE	Last Year	Last Month	PRESENT	% CAPACITY	%AVERAGE	READING DATE	COMMENTS
	Contents	1960 - 2014	3/31/2014	2/28/2015	3/31/2015	3/31/2015	3/31/2015		
ACKLEY	6,722	3,231	4,153	3,851	3,997	59	124	3/31/2015	elev.= 4306.25
BAIR	7,300	4,373	3,773	5,200	5,609	77	128	3/31/2015	elev.=5318.28
COONEY	28,230	20,912	21,461	20,311	22,280	79	107	4/3/2015	elev.=4243.8 (22,190 AF)
COTTONWOOD	1,900	1,014	1,596	1,284	1,940	102	191	3/16/2015	elev.= 5102.64
DEADMAN'S BASIN	75,968	49,256	56,444	65,930	70,577	93	143	3/30/2015	elev.=3918.3 (66,827 AF)
E.F. ROCK CREEK	16,040	9,591	9,720	10,589	11,045	69	115	3/30/2015	elev.=6041.7
FRENCHMAN	2,777	2,156	2,777	2,777	2,777	100	129	3/31/2015	spilling
MARTINSDALE	23,348	9,135	7,344	17,937	19,337	83	212	3/30/2015	elev.=4775.0
MIDDLE CREEK	10,184	6,163	4,499	5,418	5,818	57	94	3/30/2015	elev.=6699.3
NEVADA CREEK	11,207	7,819	6,521	9,574	10,861	97	139	3/29/2015	elev.=4615.05
NILAN	10,992	6,707	6,391	8,532	10,020	91	149	3/31/2015	elev.=4440.67
N.FK. SMITH RIVER	11,406	7,082	8,148	9,000	10,330	91	146	3/31/2015	elev.= 5484.8
RUBY RIVER	37,612	31,222	34,501	34,212	37,137	99	119	3/30/2015	elev.=5392.5
TONGUE RIVER	79,071	50,139	60,558	52,106	56,093	71	112	3/30/2015	elev.=3421.5
W.F. BITTERROOT	32,362	9,221	14,125	13,528	20,019	62	217	3/27/2015	elev.=4703.71
WILLOW CREEK	18,000	16,386	16,183	14,300	16,127	90	98	3/25/2015	elev.= 4733.6
YELLOWATER	3,842	1,250	3,496	3,106	3,236	84	259	3/31/2015	elev.=3116.9

* Note: Reservoir contents include dead storage at the following:

Ackley	1001 AF	**
Cooney	90 AF	**
Deadman's	3750 AF	**
Nilan	900 AF	**

** O&M slope storage table does not include dead storage (so dead storage has to be added into the storage from the table)

Tongue River	711 AF	(O&M storage table includes dead storage)
W. F. Bitterroot	656 AF	(O&M storage table includes dead storage)
Willow Creek	269 AF	(O&M storage table includes dead storage)

* Note: Cooney capacity reflects capacity after 1982 dam rehabilitation; prior capacity was 24,195 A.F.. Average storage shown is for post rehabilitation data.

* Note: Middle Creek capacity reflects capacity after 1993 dam rehabilitation; prior capacity was 8,027 A.F.. Average storage shown is for post rehabilitation data.

* Note: Nevada Creek Reservoir Capacity reflects live storage capacity survey conducted in year 2000. Prior live storage capacity documented as 12,723 AF.

* Note: Tongue River capacity reflects capacity after 1999 dam rehabilitation; prior capacity was 68,040 A.F.. Average storage is post rehabilitation data.

* Note: Frenchman Reservoir capacity tables updated based on aerial survey; prior capacity was 3752 A.F. Average shown is pre aerial survey

DNRC-SWP

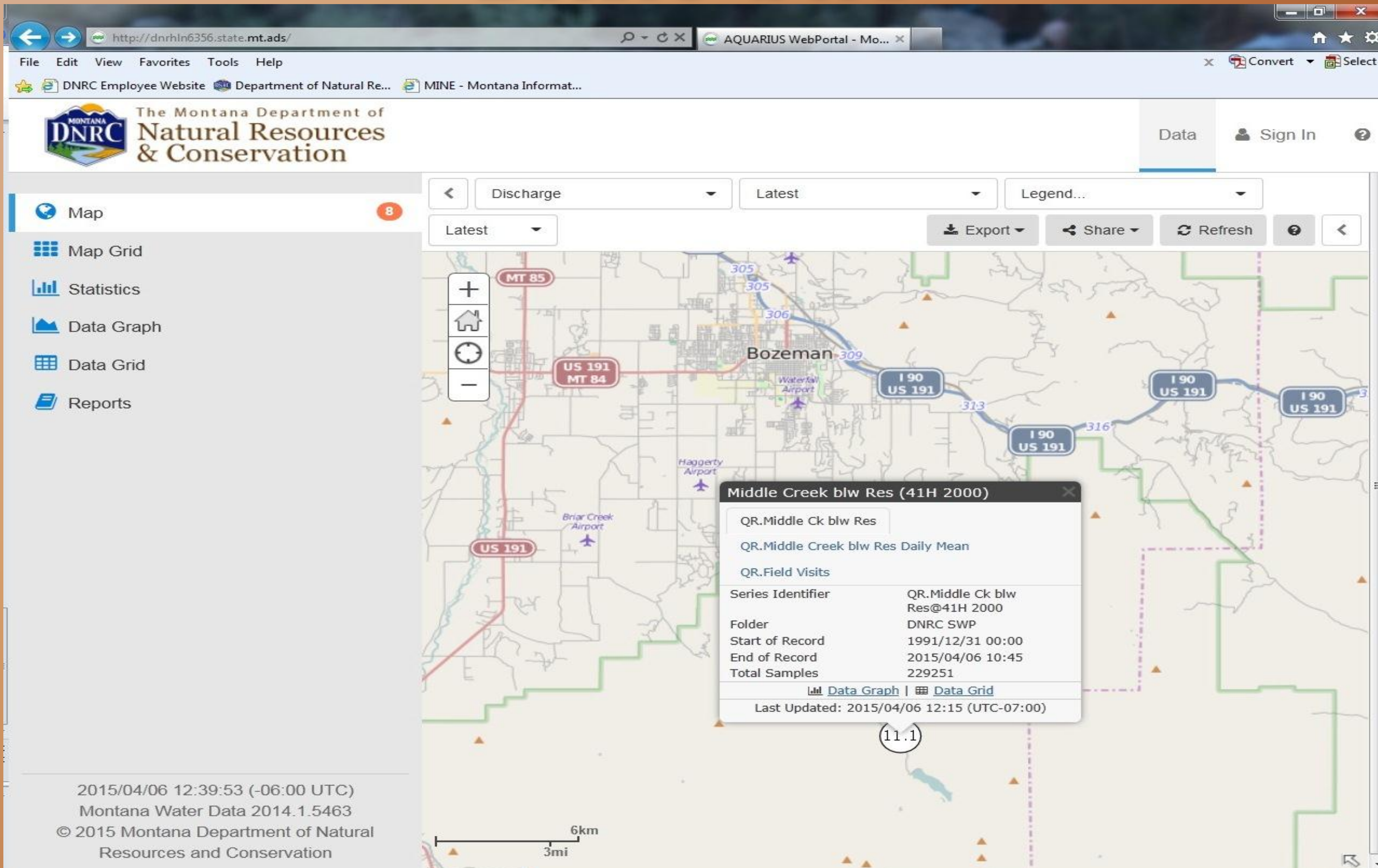
- Administers the Operation and Maintenance of State-Owned Water Storage Projects.
- 20 Active Storage Projects. Consists of 22 Dams, and over 250 miles of Canals.
- One Hydroelectric project-Toston-Broadwater on the Missouri. 10 MW, single turbine facility.
- Water is marketed to 18 Water Users Associations for a total of 310,000 Acre-feet.
- Coordinates with local water commissioners and ditch riders for water deliveries

DNRC-SWP

- Benefits of Water Storage Projects:
  - Agricultural – irrigation
  - Municipal and industrial
  - In-Stream Flow regulation (MT-FWP)
  - Flood control
  - Environmental – Extends river flows, creates wetland habitat, increases riparian space.
  - Recreational – Boating, fishing, camping, float trips, etc.

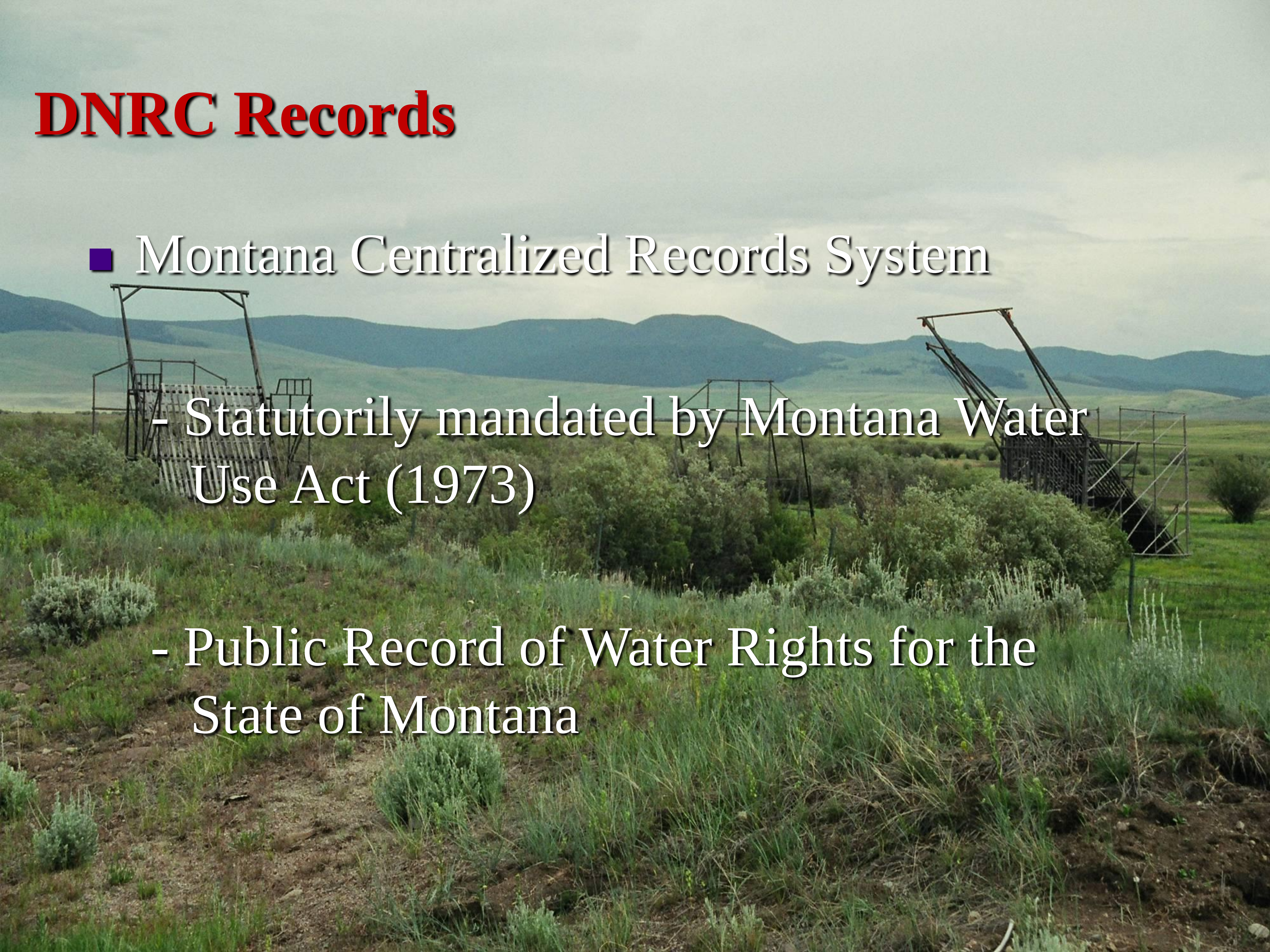
DNRC-SWP

DNRC-SWP



http://dnrhln6356.state.mt.ads/
AQUARIUS WebPortal - Mo...
File Edit View Favorites Tools Help
Convert Select
DNRC Employee Website
Department of Natural Re...
MINE - Montana Informat...
The Montana Department of Natural Resources & Conservation
Data
Sign In
Map 8
Map Grid
Statistics
Data Graph
Data Grid
Reports
Discharge
Latest
Legend...
Latest
Export
Share
Refresh
MT 85
US 191 MT 84
Bozeman
I 90 US 191
Haggerty Airport
Waterfall Airport
Briar Creek Airport
US 191
Middle Creek blw Res (41H 2000)
QR.Middle Ck blw Res
QR.Middle Creek blw Res Daily Mean
QR.Field Visits
Series Identifier QR.Middle Ck blw Res@41H 2000
Folder DNRC SWP
Start of Record 1991/12/31 00:00
End of Record 2015/04/06 10:45
Total Samples 229251
Data Graph | Data Grid
Last Updated: 2015/04/06 12:15 (UTC-07:00)
11.1
6km
3mi
2015/04/06 12:39:53 (-06:00 UTC)
Montana Water Data 2014.1.5463
© 2015 Montana Department of Natural Resources and Conservation

Discussion?



DNRC Records

- Montana Centralized Records System

  - Statutorily mandated by Montana Water Use Act (1973)

  - Public Record of Water Rights for the State of Montana

Useful Websites and Contacts

Montana Department of Natural Resources and Conservation (DNRC)
http://dnrc.mt.gov/divisions/water

- Water Right Forms and Records,
  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/watershed-planning

DNRC Water Resources Regional Offices

Billings: (406) 247-4415
Bozeman: (406) 586-3136
Glasgow: (406) 228-2561
Havre: (406) 265-5516
Helena: (406) 444-6999
Kalispell: (406) 752-2288
Lewistown: (406) 538-7459
Missoula: (406) 721-4284

Current **Streamflow** Conditions - United States Geological Survey (USGS)

http://waterdata.usgs.gov/mt/nwis/current/?type=flow

Current **Snowpack** Conditions – Natural Resources and Conservation Services (NRCS)

http://www.nrcs.usda.gov/wps/portal/nrcs/detail/mt/snow/?cid=nrcs144p2_057794

Web **Soil** Survey – NRCS

http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

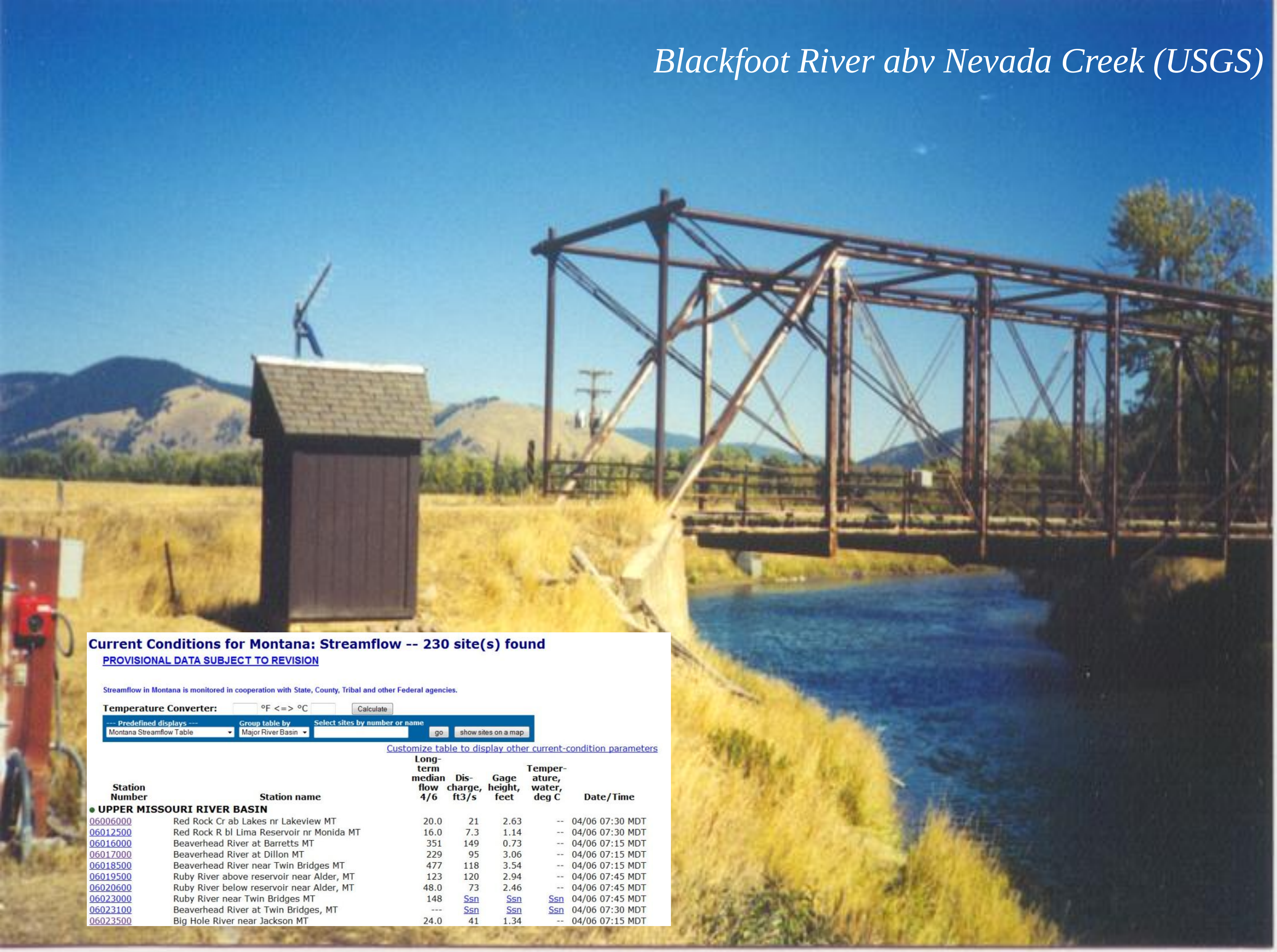
Current **Drought** and Water Supply Conditions – State of Montana

http://drought.mt.gov/default.aspx

Groundwater/**Well** Information Montana Bureau of Mines and Geology (MBMG)

http://www.mbmg.mtech.edu/grw/grw-main.asp

Blackfoot River abv Nevada Creek (USGS)



Current Conditions for Montana: Streamflow -- 230 site(s) found

PROVISIONAL DATA SUBJECT TO REVISION

Streamflow in Montana is monitored in cooperation with State, County, Tribal and other Federal agencies.

Temperature Converter: °F <=> °C Calculate

--- Predefined displays --- Montana Streamflow Table | Group table by Major River Basin | Select sites by number or name go | show sites on a map

Customize table to display other current-condition parameters

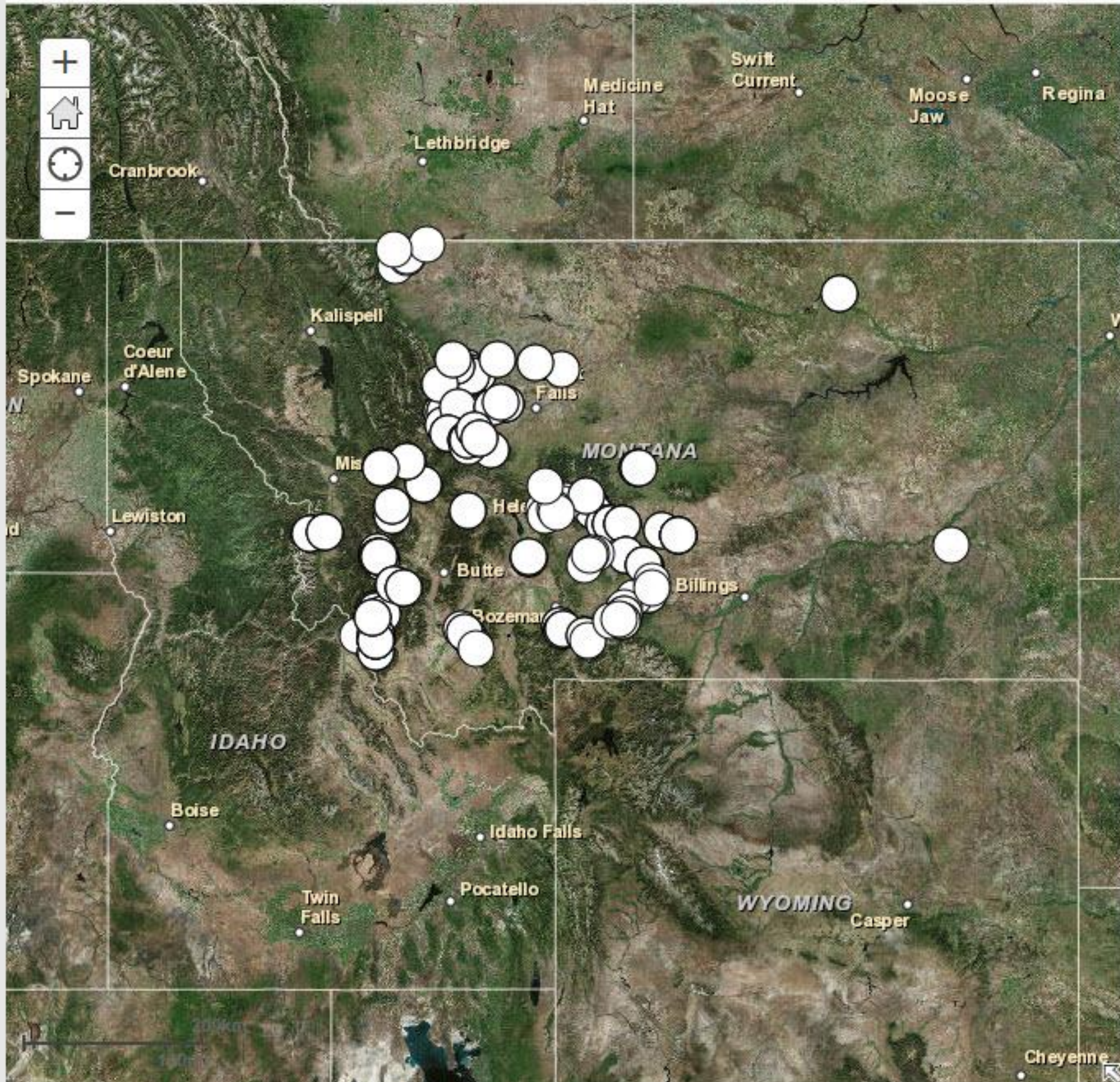
Station Number	Station name	Long-term median flow 4/6	Dis-charge, ft3/s	Gage height, feet	Temper-ature, water, deg C	Date/Time
UPPER MISSOURI RIVER BASIN						
06006000	Red Rock Cr ab Lakes nr Lakeview MT	20.0	21	2.63	--	04/06 07:30 MDT
06012500	Red Rock R bl Lima Reservoir nr Monida MT	16.0	7.3	1.14	--	04/06 07:30 MDT
06016000	Beaverhead River at Barretts MT	351	149	0.73	--	04/06 07:15 MDT
06017000	Beaverhead River at Dillon MT	229	95	3.06	--	04/06 07:15 MDT
06018500	Beaverhead River near Twin Bridges MT	477	118	3.54	--	04/06 07:15 MDT
06019500	Ruby River above reservoir near Alder, MT	123	120	2.94	--	04/06 07:45 MDT
06020600	Ruby River below reservoir near Alder, MT	48.0	73	2.46	--	04/06 07:45 MDT
06023000	Ruby River near Twin Bridges MT	148	Ssn	Ssn	Ssn	04/06 07:45 MDT
06023100	Beaverhead River at Twin Bridges, MT	---	Ssn	Ssn	Ssn	04/06 07:30 MDT
06023500	Big Hole River near Jackson MT	24.0	41	1.34	--	04/06 07:15 MDT

The Montana Department of
Natural Resources
& Conservation

Map 118
Map Grid
Statistics
Data Graph
Data Grid
Reports

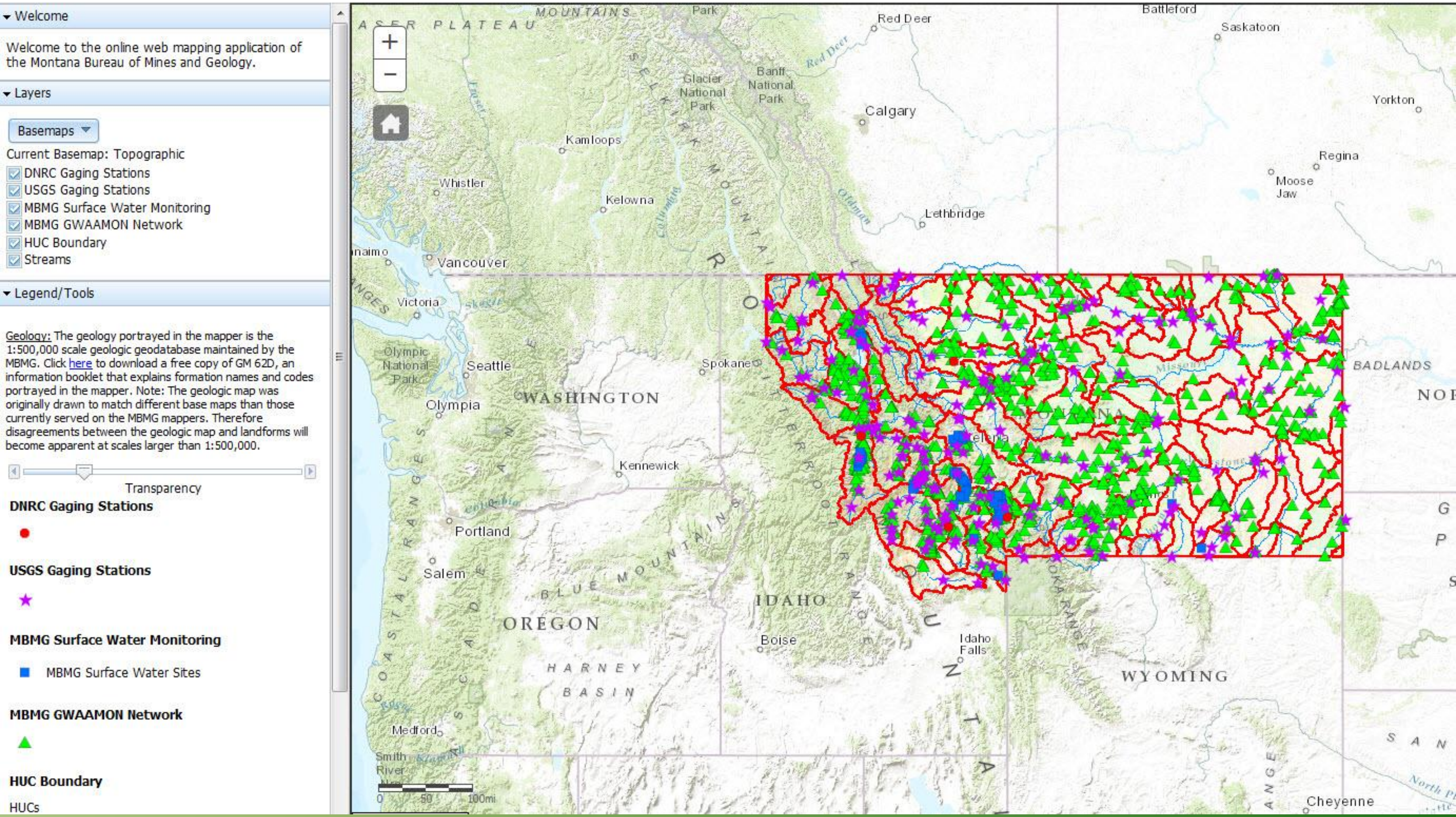
Discharge | Statistic... | Legend...

Yearly | 2015 | Export | Share | Refresh

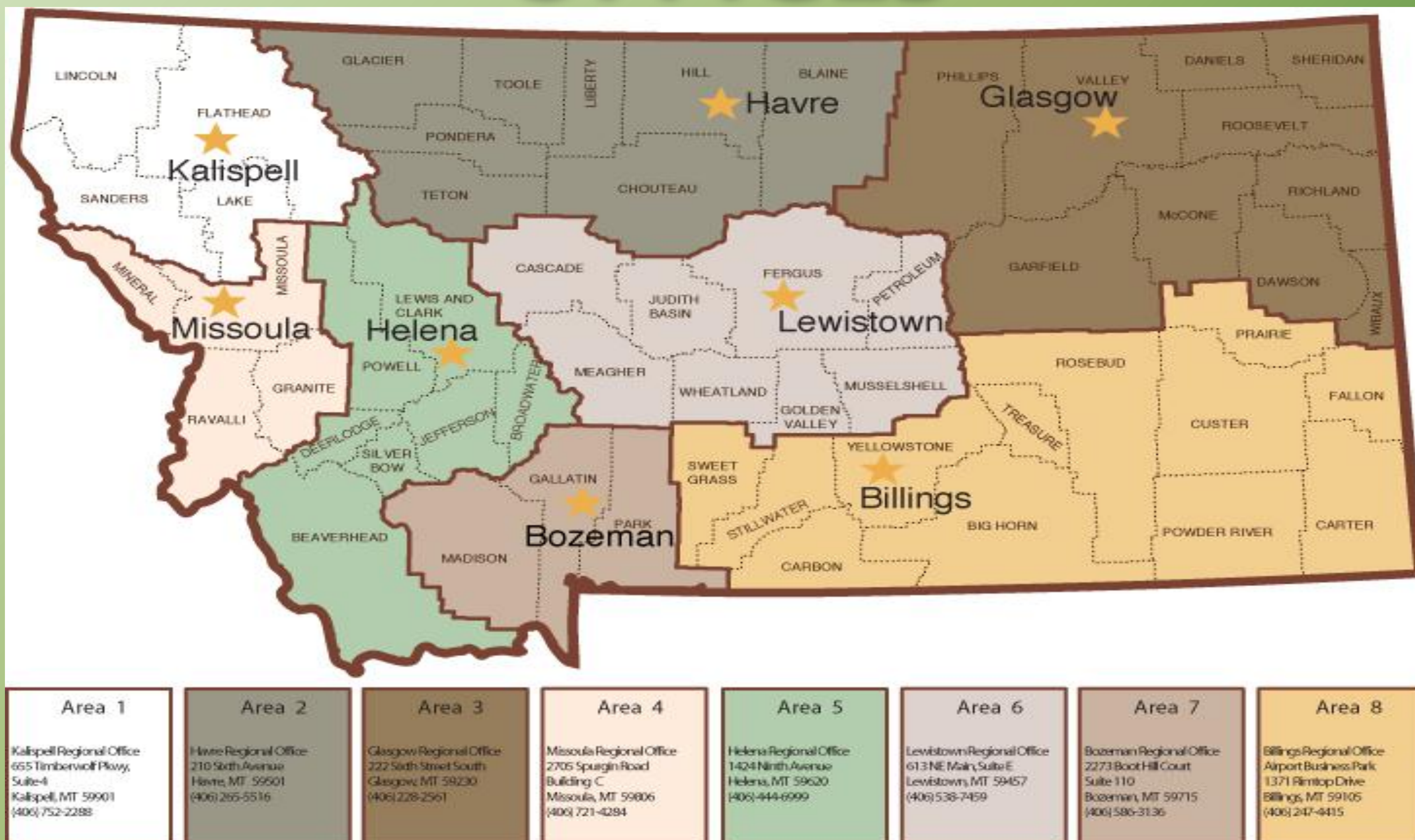


2015/04/06 12:58:01 (-06:00 UTC)
Montana Water Data 2014.1.5463

MBMG
Montana Bureau of Mines and Geology



DNRC REGIONAL OFFICES



DNRC Helena Water Resources REGIONAL OFFICE

Water Resources Division

The Helena Regional offices service the following counties:

[Beaverhead]
[Broadwater]
[Deerlodge]
[Jefferson]
[Lewis and Clark]
[Powell]
[Silverbow]

Deputy Regional Manager – Bryan Gartland	444-5783
Regional Office Engineering Specialist – **John Connors**	444-9724
Hydrologist/Specialist – **Russell Gates**	444-6602
Compliance Technician – **Kristeen Wofford**	444-6999
Water Resource Specialist – **Jennifer Daly**	444-6862
Water Resource Specialist – **Terry Scow**	444-6753
Water Resource Specialist – **Myles VanHemelryck**	444-6810

Water Trivia Questions

1) What Montana county had the highest annual production of alfalfa (2013 Ag-Stats): Ravalli, Fergus, or Beaverhead?

2) Rank the following cities from highest annual precipitation to lowest: Bozeman, Whitefish, Helena, Billings?

3) What is the State Fish of Montana?

4) Name a well-known person or tractor from Big Sandy, Montana?

5) Which Missouri headwater stream is the largest contributor of flow: Madison, Jefferson, or Gallatin?

6) In 1999, residents of Saco, MT set a world record by cooking a 6000 pound hamburger. How many cows did that require?

Water Trivia Questions

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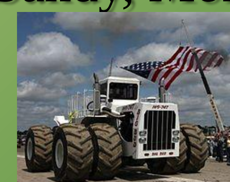
John Tester

Jeff Ament



Big Bud 747

Bobcat Great Doug Hashley

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also: Doug Hashley

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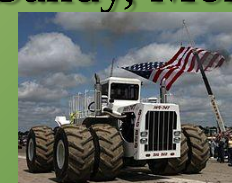

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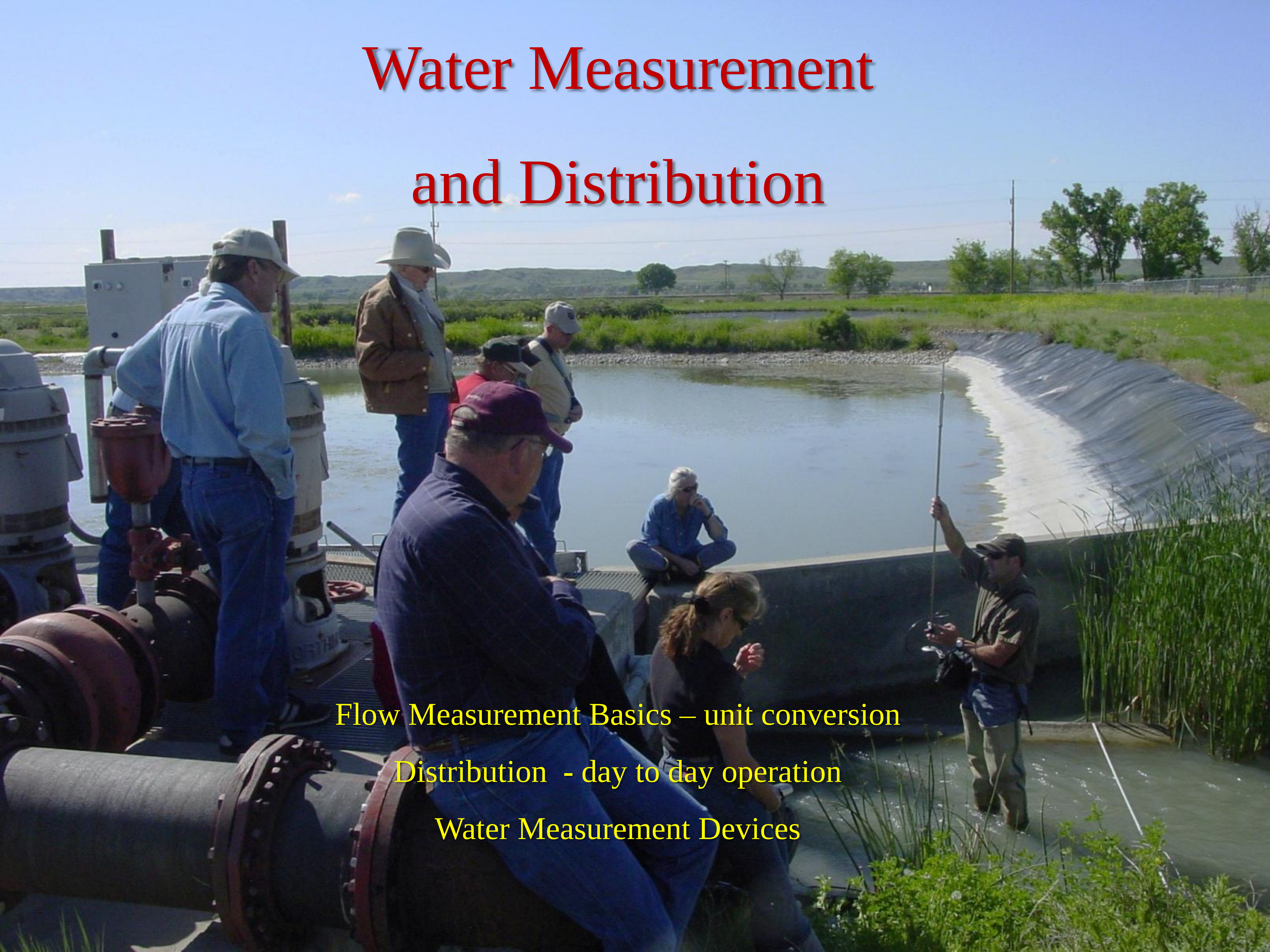
Water Measurement
and Distribution
Flow Measurement Basics – unit conversion
Distribution - day to day operation
Water Measurement Devices

Flow Measurement Basics

- Flow Rate or discharge is the volume of water passing a flow section per unit time

- Standard units of ***cubic feet per second*** (cfs)

Flow Measurement Basics

- Basic flow equation
  - Flow Rate (discharge) = Area · Velocity
  - Q = A · V

$$30\,ft^2 \bullet 3\,\frac{ft}{\sec} = ?$$

Flow Measurement Basics

- Basic flow equation
  - Flow Rate (discharge) = Area · Velocity
  - $Q = A \cdot V$

$$30\,ft^2 \bullet 3\frac{ft}{\sec} = ?$$

90 ft^3/sec
or
90 cfs

Flow Measurement Basics

- Flow rate (discharge) units
  - The standard unit for flow rate or discharge is cubic feet per second (cfs)

1 cfs is equivalent to:

Flow Measurement Basics

- Flow rate (discharge) units
  - The standard 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)

1.98 ac-ft per day

Flow Measurement Basics

- Flow rate (discharge) units continued
  - A commonly used unit for flow rate or discharge is miner's inches or "inches"

1 Miner's inch in Montana is equivalent to:

1/40 cfs

11.22 gpm

1/20 ac-ft per day

Flow Measurement Basics

- Volume Units
  - Standard unit of volume is acre-feet (ac-ft)
  - An ac-ft is equivalent to a foot of water on one acre.

1 ac-ft is equivalent to:	325,851 gallons
	43,560 cubic feet

Flow Measurement Basics

Example Problems

WCT Manual: inside cover
or page 55

An irrigator has a water right for 7.5 cubic feet per second (cfs).

1) Convert to miners inches (mi).

2) Convert to gallons per minute (gpm).

3) Convert to gallons per day (gpd).

4) How many acre-feet (af) is the irrigator entitled to in 6 days?

An irrigator is entitled to 360 acre-feet over a period of 20 days. Assuming irrigation is non-stop, what is their flow rate in cfs?

1 cfs = 40 m.i.
1 cfs = 448.8 gpm
1 cfs for 24 hrs = 1.983 acre-feet

An irrigator has a water right for 7.5 cubic feet per second (cfs).

1) Convert to miners inches (mi).

7.5 cfs x 40 mi/cfs = 300 mi

2) Convert to gallons per minute (gpm).

3) Convert to gallons per day (gpd).

4) How many acre-feet (af) is the irrigator entitled to in 6 days?

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7.5 cfs x 40 mi/cfs = 300 mi

2) Convert to gallons per minute (gpm).

7.5 cfs x 448.8 gpm/cfs = 3,366 gpm

3) Convert to gallons per day (gpd).

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3,366 gpm x 60 min x 24 hr = 4,847,040 gpd

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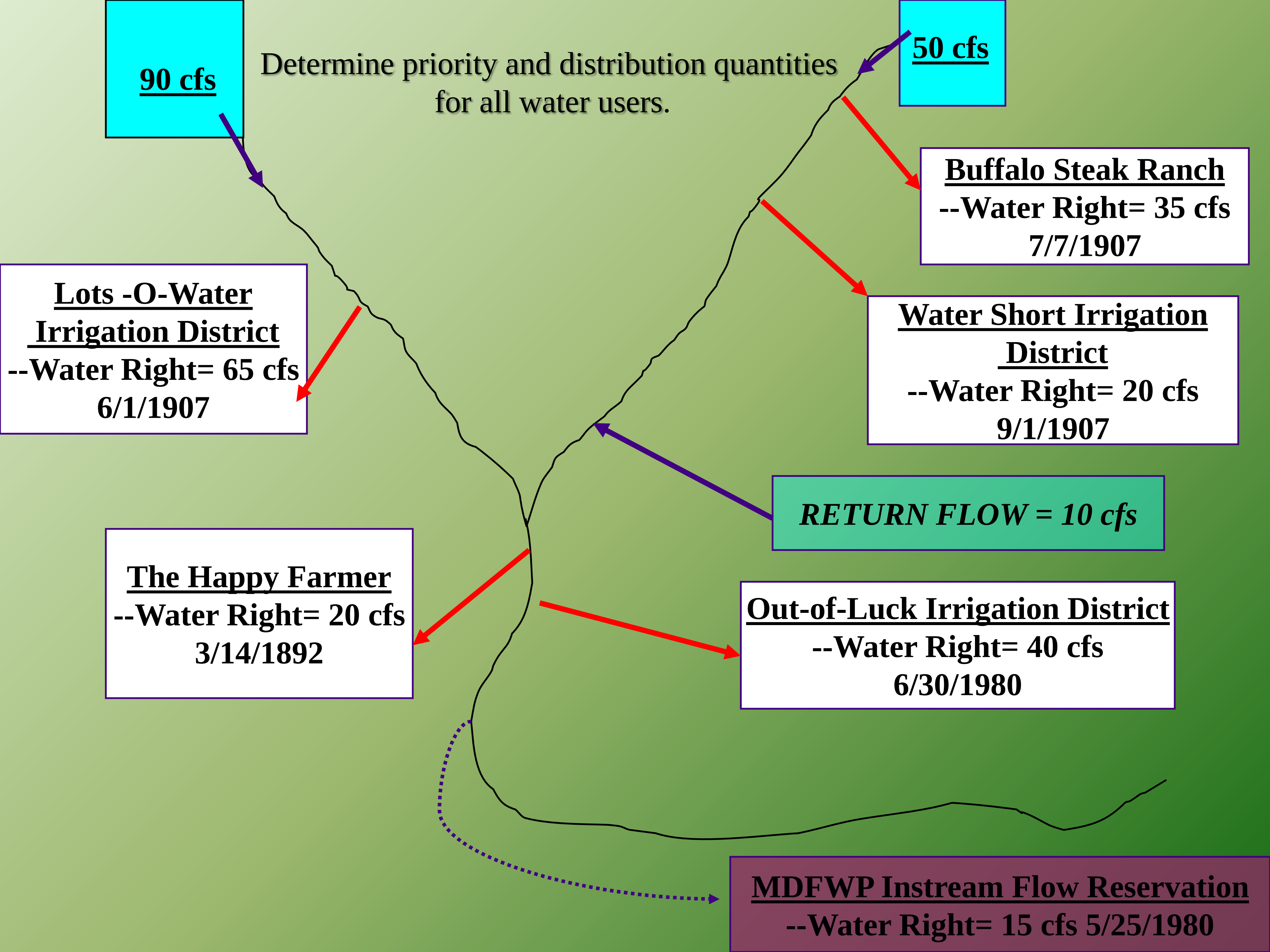
7.5 cfs x 1.983 af/cfs x 6 days = 89.2 af

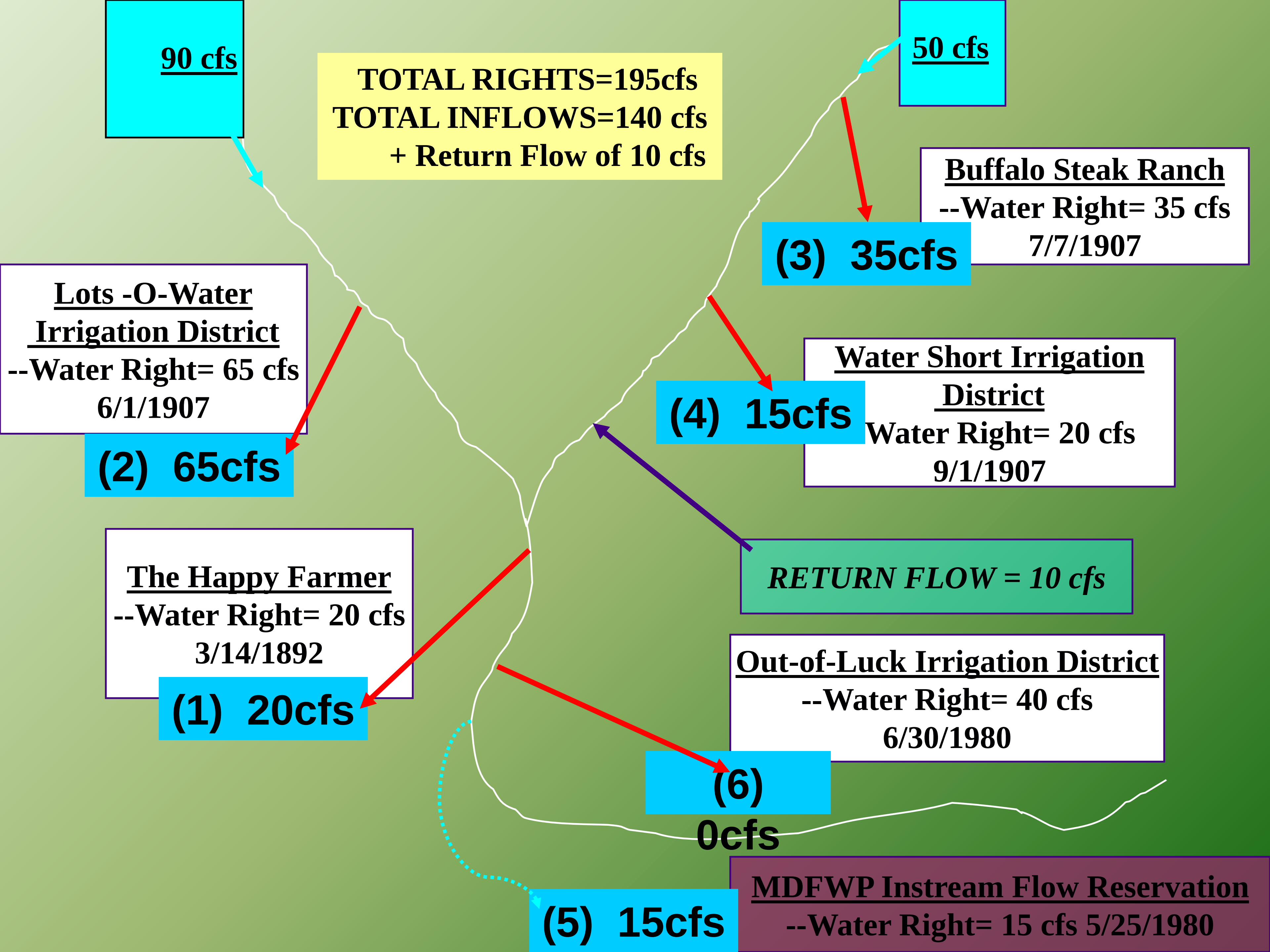
An irrigator is entitled to 360 acre-feet over a period 20 days. Assuming irrigation is non-stop, what is their flow rate in cfs?

360 af/20 days = 18 af/day → 18 af/day divided by 1.983 af/cfs = 9.08 cfs

Water Distribution

- Priority and Instream Flow
- Decreed vs. Stored Waters
- Understanding hydrology of system


Determine priority and distribution quantities for all water users.
90 cfs
50 cfs
Buffalo Steak Ranch
--Water Right= 35 cfs 7/7/1907
Lots -O-Water Irrigation District
--Water Right= 65 cfs 6/1/1907
Water Short Irrigation District
--Water Right= 20 cfs 9/1/1907
RETURN FLOW = 10 cfs
The Happy Farmer
--Water Right= 20 cfs 3/14/1892
Out-of-Luck Irrigation District
--Water Right= 40 cfs 6/30/1980
MDFWP Instream Flow Reservation
--Water Right= 15 cfs 5/25/1980


90 cfs
TOTAL RIGHTS=195cfs
TOTAL INFLOWS=140 cfs
+ Return Flow of 10 cfs
50 cfs
Buffalo Steak Ranch
--Water Right= 35 cfs
7/7/1907
(3) 35cfs
Lots -O-Water
Irrigation District
--Water Right= 65 cfs
6/1/1907
(2) 65cfs
Water Short Irrigation
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3/14/1892
(1) 20cfs
RETURN FLOW = 10 cfs
Out-of-Luck Irrigation District
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(6)
0cfs
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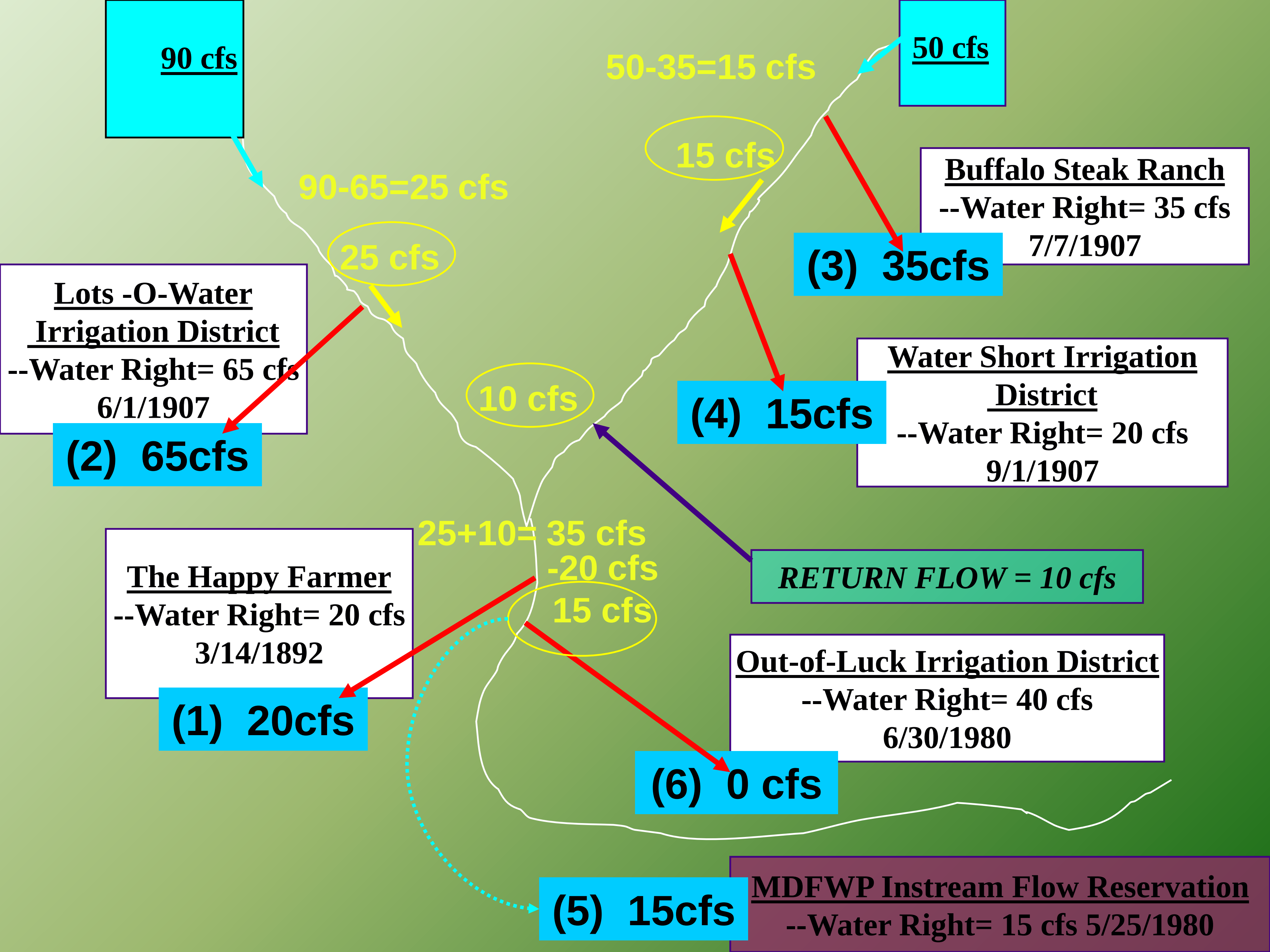
(5) 15cfs


90 cfs
50 cfs
50-35=15 cfs
15 cfs
Buffalo Steak Ranch
--Water Right= 35 cfs
7/7/1907
(3) 35cfs
90-65=25 cfs
25 cfs
Lots -O-Water
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6/1/1907
(2) 65cfs
10 cfs
Water Short Irrigation
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9/1/1907
(4) 15cfs
25+10= 35 cfs
-20 cfs
15 cfs
RETURN FLOW = 10 cfs
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3/14/1892
(1) 20cfs
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(6) 0 cfs
(5) 15cfs
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--Water Right= 15 cfs 5/25/1980

Stored and Decreed Water: Part I

Little Creek has three water right contracts from Fish Reservoir as well as three decreed water rights directly from the stream. The Fish Lake Irrigation District relies solely on the 20 cfs of stored water released from the dam. No seepage losses or gains occur during conveyance. If evaporation and seepage in the reservoir are negligible, determine the amount of water at each location.

A =

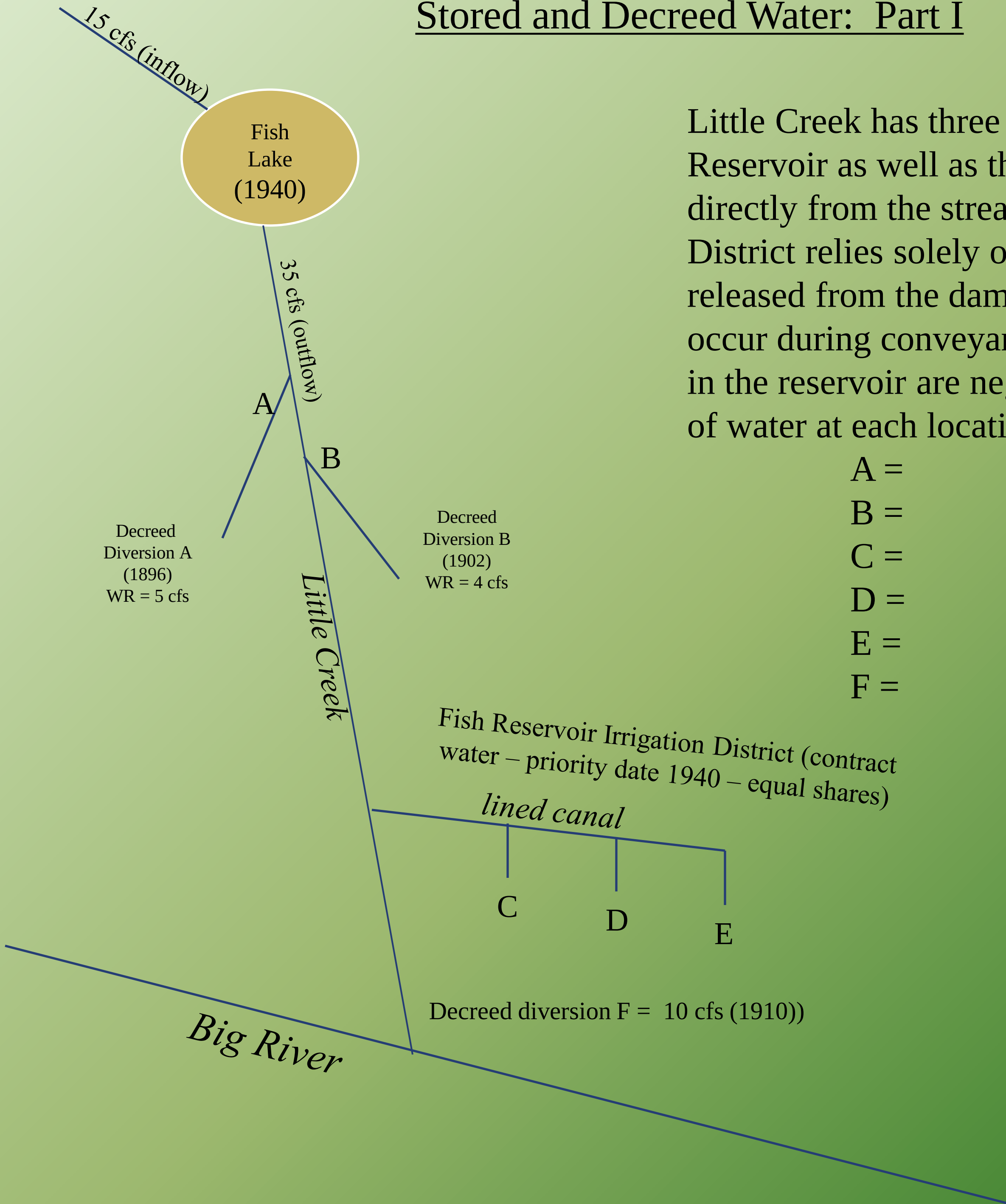
B =

C =

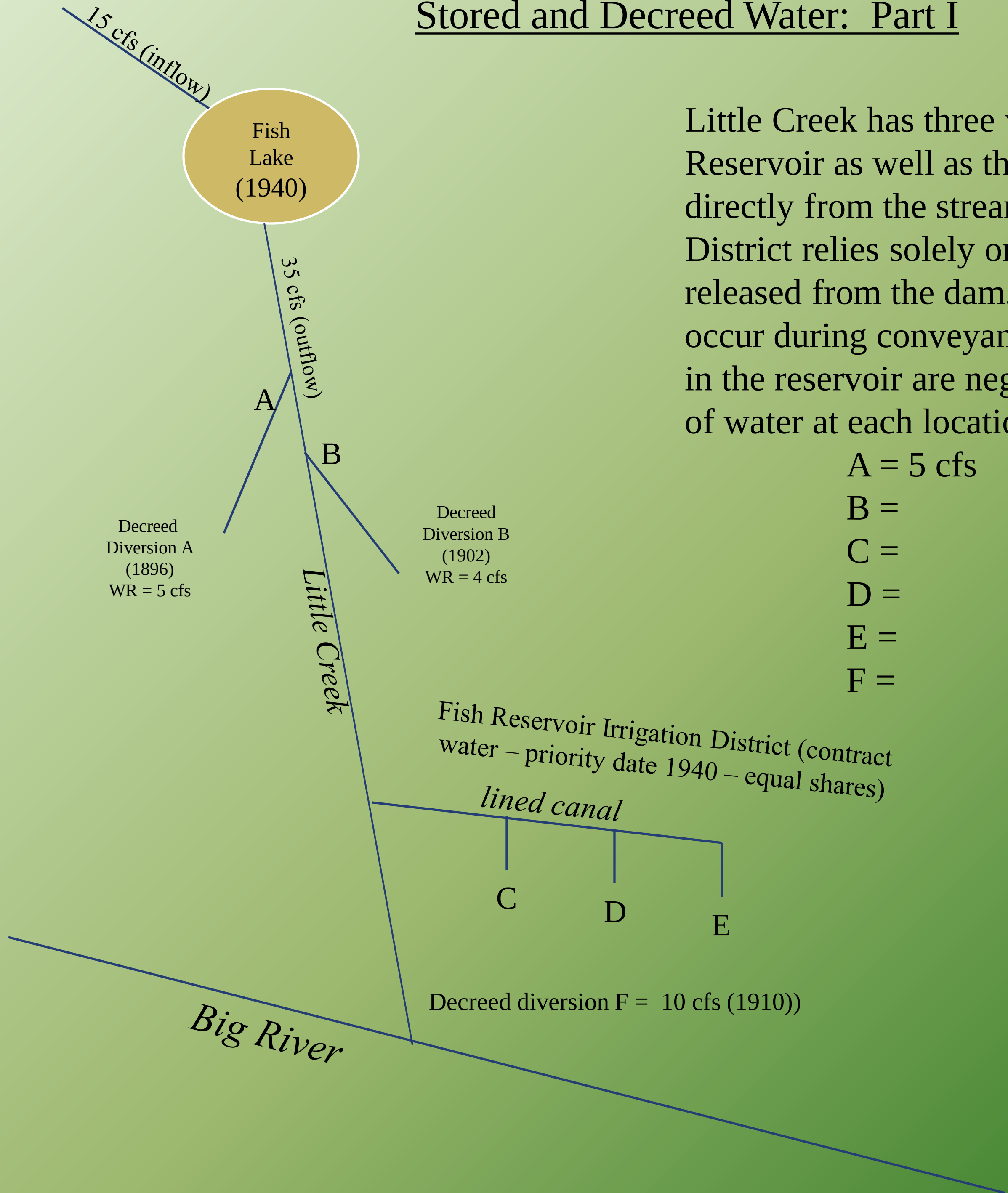
D =

E =

F =



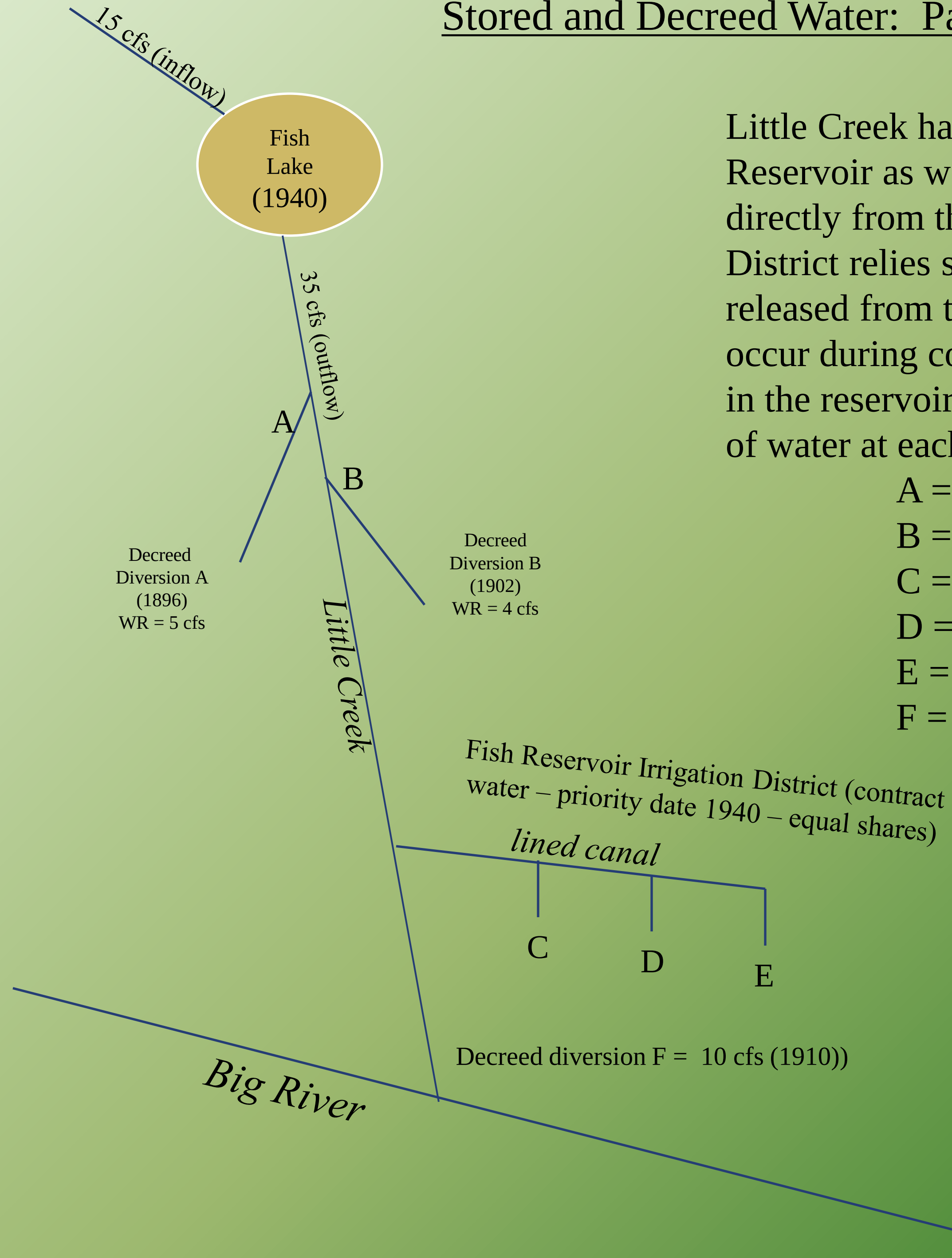
Stored and Decreed Water: Part I



Little Creek has three water right contracts from Fish Reservoir as well as three decreed water rights directly from the stream. The Fish Lake Irrigation District relies solely on the 20 cfs of stored water released from the dam. No seepage losses or gains occur during conveyance. If evaporation and seepage in the reservoir are negligible, determine the amount of water at each location.

A = 5 cfs
B =
C =
D =
E =
F =

Stored and Decreed Water: Part I



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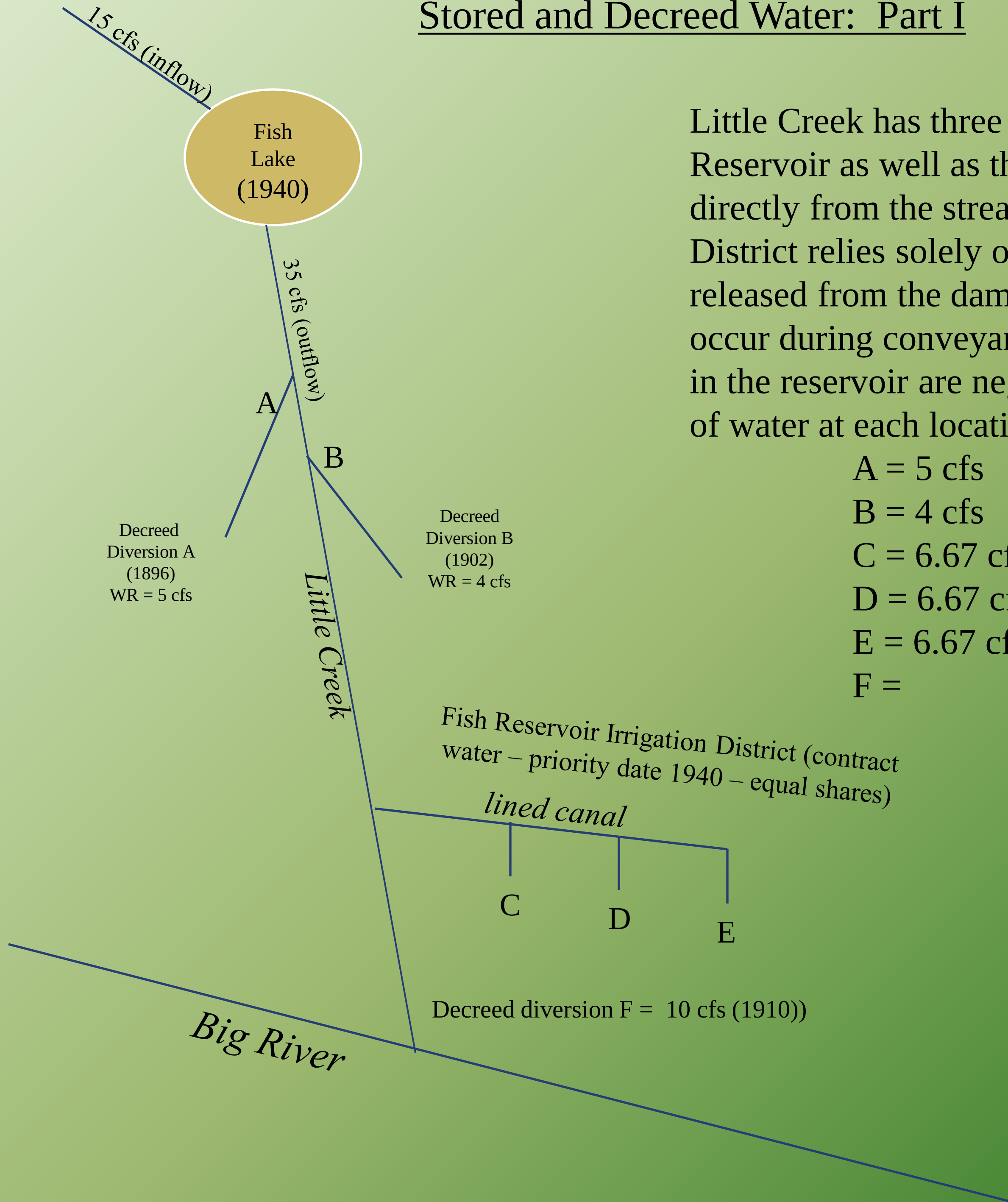
A = 5 cfs
B = 4 cfs
C =
D =
E =
F =

Stored and Decreed Water: Part I



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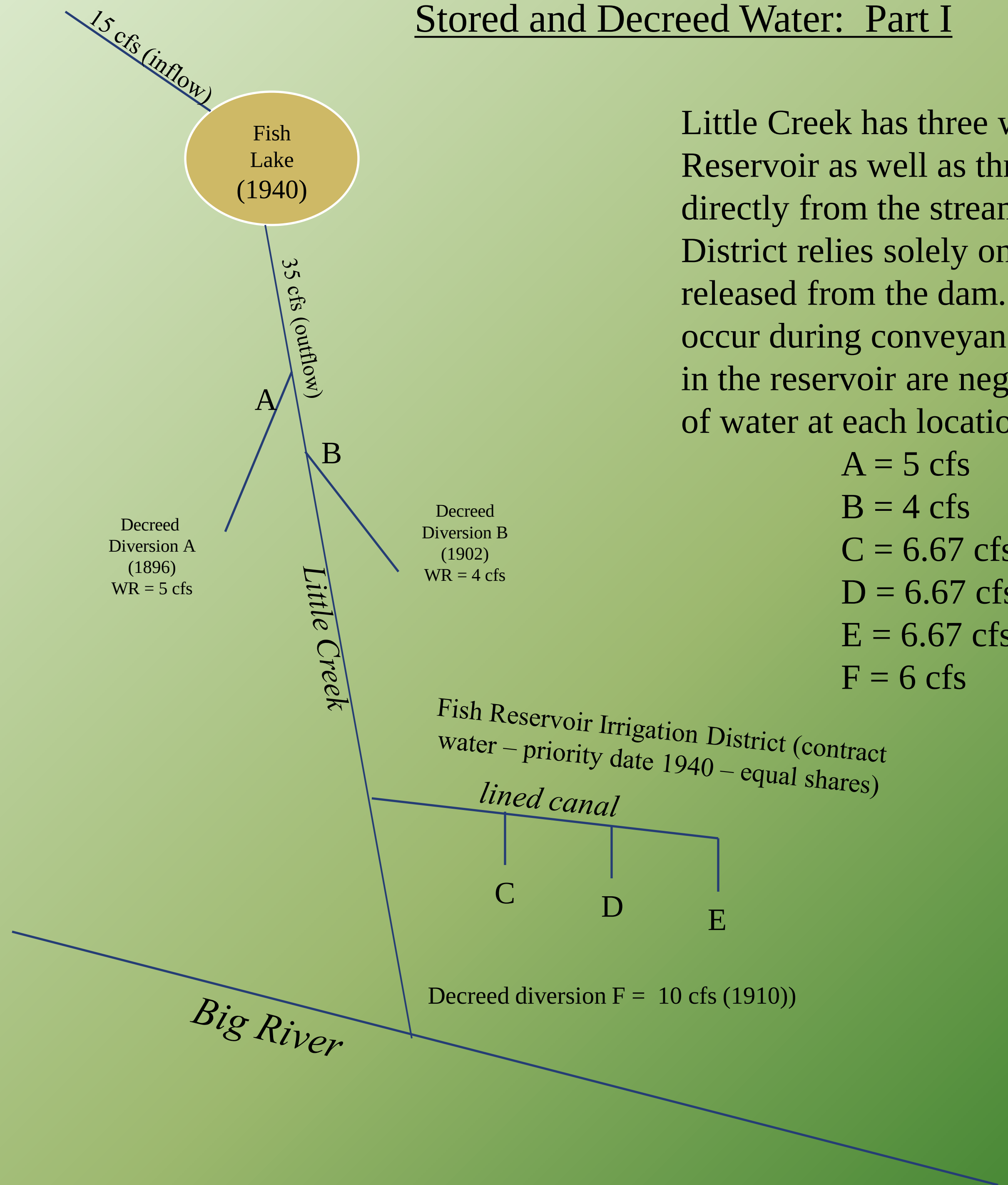
A = 5 cfs
B = 4 cfs
C = 6.67 cfs
D = 6.67 cfs
E = 6.67 cfs
F =

Stored and Decreed Water: Part I



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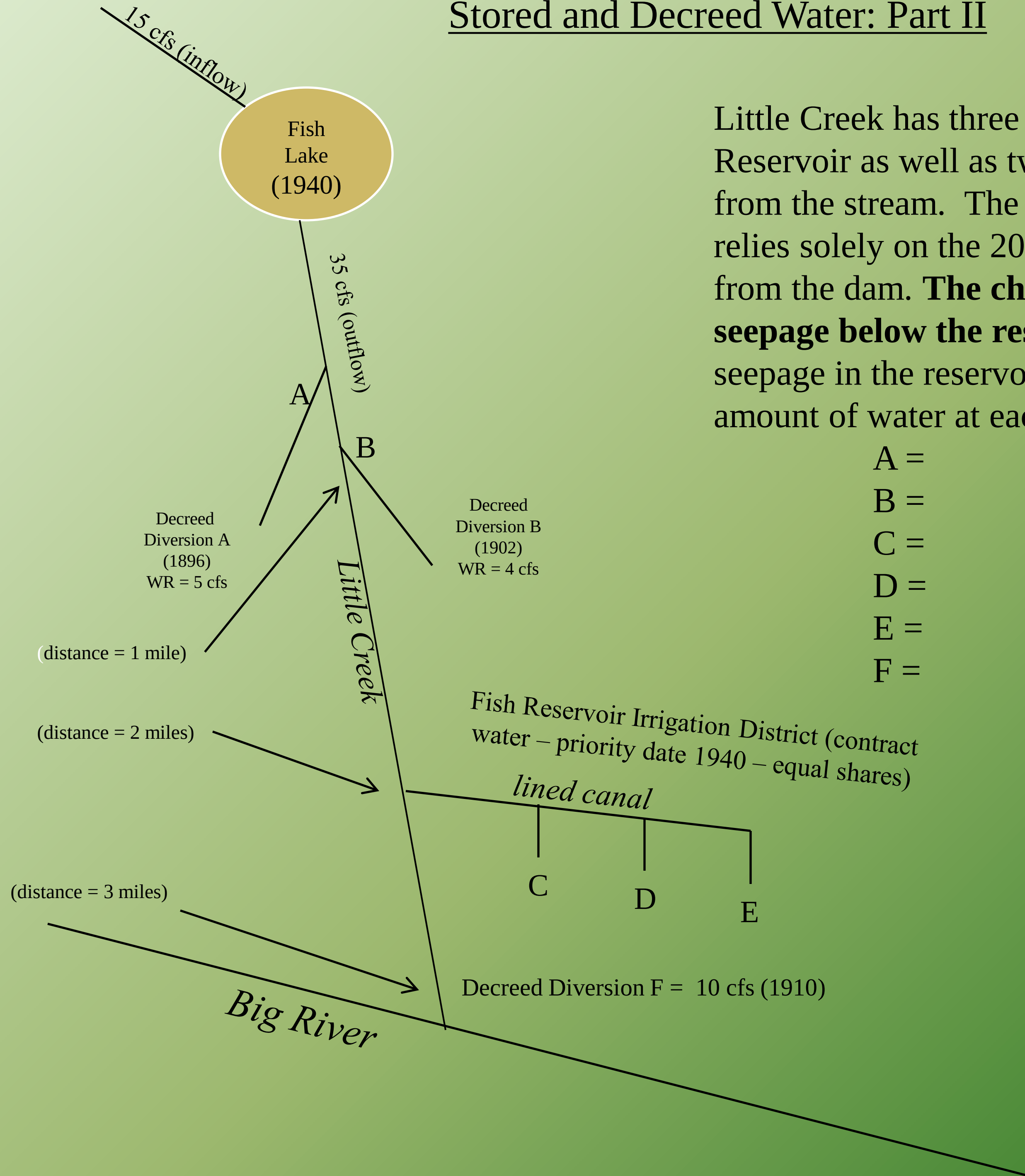
B = 4 cfs
C = 6.67 cfs
D = 6.67 cfs
E = 6.67 cfs
F = 6 cfs

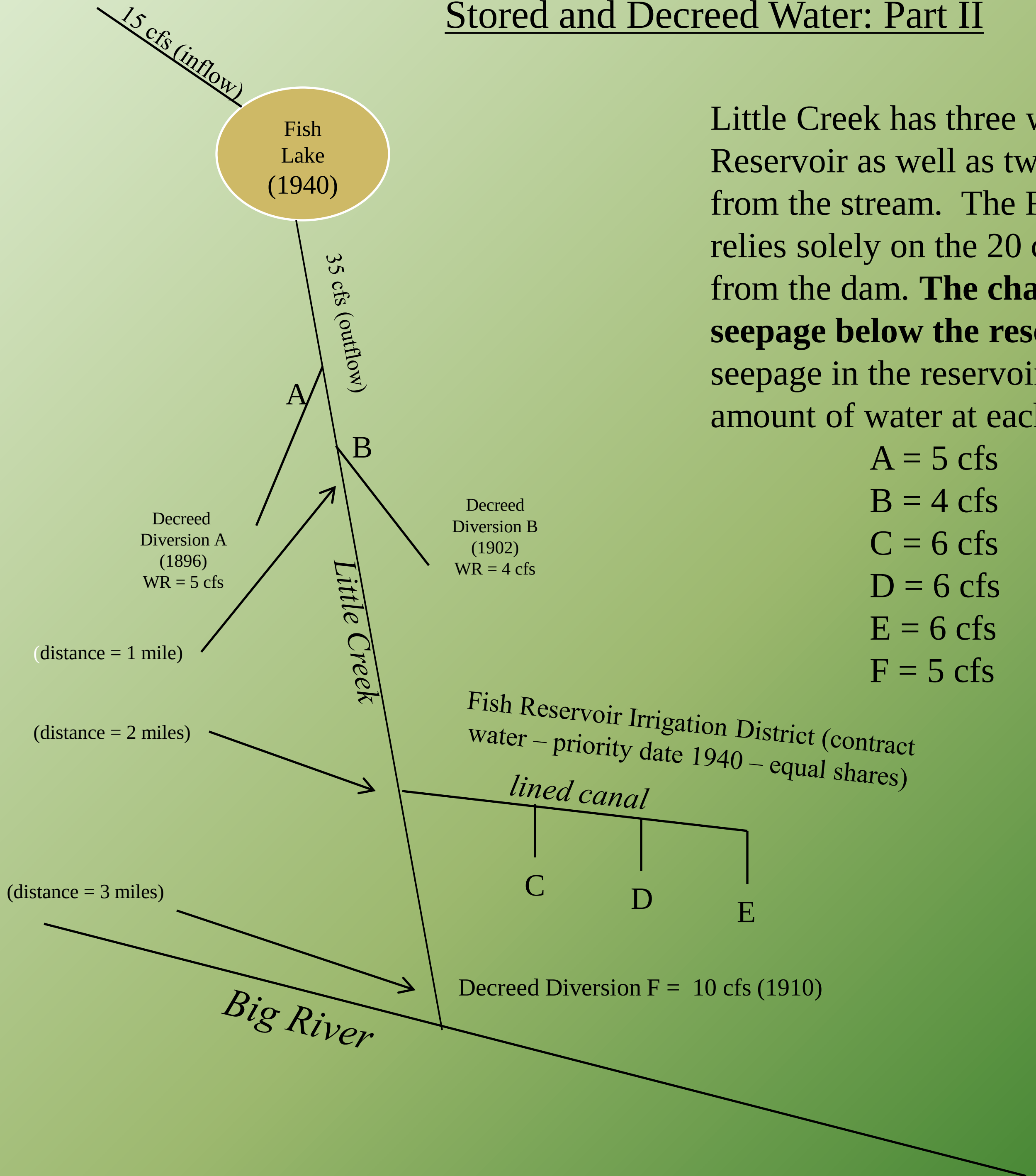
Stored and Decreed Water: Part II



Little Creek has three water right contracts from Fish Reservoir as well as two decreed water rights directly from the stream. The Fish Lake Irrigation District relies solely on the 20 cfs of stored water released from the dam. **The channel loses 1 cfs/mile to seepage below the reservoir**. If evaporation and seepage in the reservoir are negligible, determine the amount of water at each location.

A =
B =
C =
D =
E =
F =

Stored and Decreed Water: Part II



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A = 5 cfs
B = 4 cfs
C = 6 cfs
D = 6 cfs
E = 6 cfs
F = 5 cfs

A small reservoir has 25,000 acre-feet of water in storage on July 1. For the sake of this problem, assume no seepage or evaporation occurs. Between July 1 and August 31, average reservoir inflows equal 15 cfs. Irrigators require 3200 inches, 24 hours a day, from the reservoir. Lakeside residents constantly pump 2750 gpm from the reservoir for domestic water supply and water must be released from the dam at a rate of 7.5 cfs to satisfy FWP’s in-stream flow lease for west-slope cutthroat. **How many acre-feet of water are left in the reservoir on September 1?**

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September 1 storage = (July storage + Inflows) – (Outflows)

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September 1 storage = (July 1 storage + Inflows) – (Outflows)

Inflows: 15 cfs * 1.983 acre-feet/day/cfs * 62 days = **1844 acre-feet**

Outflows: Irrigators = 3200 in/40 in = 80 cfs * 1.983 af/d/cfs = 158.6 af/d * 62 days = **9836 acre-feet**

Residents = 2750 gpm/448.8 gpm/cfs = 6.13 cfs*1.983 af/d/cfs = 12.2 af/d * 62 days = **753 acre-feet**

West-Slope Cutthroat = 7.5 cfs * 1.983 af/d/cfs * 62 d = **922 acre-feet**

September 1 storage = (July storage + Inflows) – (Outflows)

(25,000 af + 1844 af) – (9836 af + 753 af + 922 af)

= 15,333 acre-feet

Water Measurement

- headgates
- flow measurement basics
- rated devices
- flumes and weirs
- automated devices
- manual measurements

- sample problems

MCA 85-5-302

….All persons using water from any stream or ditch whereon a water commissioner is appointed are required to have suitable headgates at the point where the ditch taps a stream and shall also, at some suitable place on the ditch and as near the headgate as practicable, place and maintain a proper measuring box, weir, or other appliance for the measurement of the waters flowing in the ditch.

What is a suitable headgate?

<u>“Suitable” Headgate</u>

- Can be shut-off
- Services the range of flows necessary to meet water rights
- Can be operated by one person


Suitable headgate?


Suitable Headgate??


MAR 30 2004

Rock Headgate – not properly functioning

functional

not so functional


Appx. $10,000 (installed)


JUN 21 2004

Suitable Location of Measuring Device

- depends on conveyance, logistics, ability to adjust flows, proximity to turbulent flow, etc.


measuring device
MAR 30 2004


Location of original measuring device
ditch
Pointof Diversion
scale 1 mile = 3.5 "


New Measuring Device
Point of Diversion


culvert to flume = 110'
undersized culvert
flume
headgate


pin and plank diversion dam
Waterman
screwgate
Parshall flume
measuring device
fish ladder

Flow Measurement Basics

Open Channel Flow

Closed Conduit Flow

Open Channel Flow

- Occurs whenever the flowing stream has a free or unconstrained surface that is open to the atmosphere
- The force that causes flow is the force of gravity on the fluid
- Canals and streams
- Half-full pipe

Closed Conduit Flow

- Occurs when the conveyance conduit carries water under pressure
- No free surface open to the atmosphere
- Rate of discharge is a function of pressure or head difference between the inlet and the outlet
- Pipelines

Water Measurement Devices

- Rated and standard devices - staff gages, flumes, weirs, orifices, weir sticks

- Manual measurement - current meters, estimation techniques (float-area method)

- Automated devices - gaging station, propeller meters, in-line meters, ultra-sonic meters, totalizers

Rated Devices

Stage vs. Discharge Rating
Staff Gages
Flumes
Weirs
Weir Sticks

definitions

Stage - height of water surface above an established datum
ex. staff gage reading

Discharge - volume of flow passing a point usually expressed in cubic feet per second (cfs) or inches.

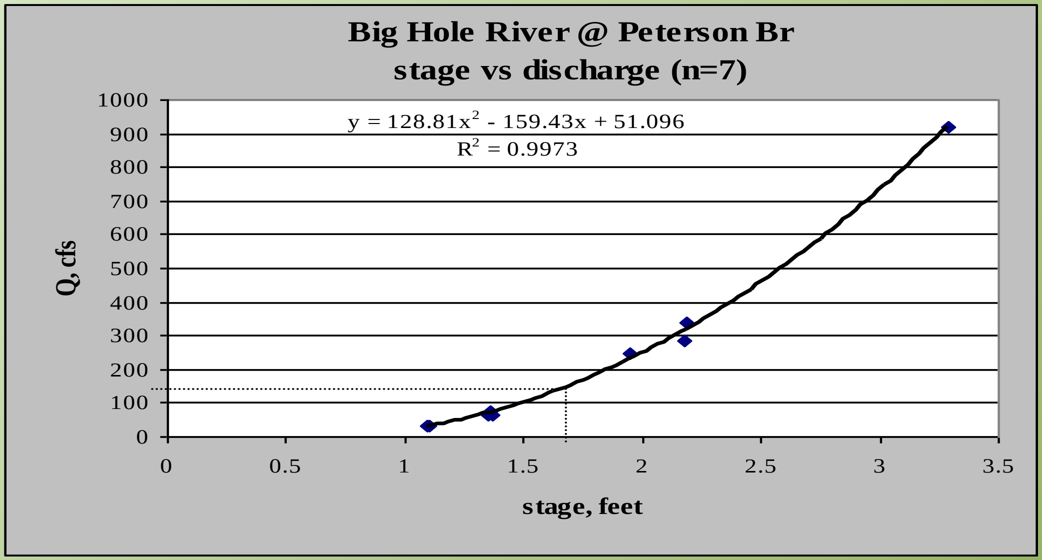
Rating – relationship between the stage of the stream/canal and the discharge.

Staff Gages

Stage = 1.16 feet

Stage = 0.67 feet

wire weight gage



stage	discharge	stage	discharge	stage	discharge
1.5	102	1.56	116	1.62	131
1.51	104	1.57	118	1.63	133
1.52	106	1.58	121	1.64	136
1.53	109	1.59	123	1.65	139
1.54	111	1.6	126	1.66	141
1.55	113	1.61	128	1.67	144

Table A8-12. Free-flow discharges in ft^3/sec through 1- to 8-foot Parshall flumes. Discharges for 2- to 8-ft flumes computed from the formula $Q = 4.00 W h_a^{1.522 (W^{0.026})}$. Discharges for 1-ft flume computed from the formula $Q = 3.95 h_a^{1.55}$.

Upper Head h_a, ft	Discharge for flumes of various throat widths, W							
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0
0.20	0.33	0.66	0.96	1.26	-----	-----	-----	-----
.21	.35	.71	1.04	1.36	-----	-----	-----	-----
.22	.38	.77	1.12	1.47	-----	-----	-----	-----
.23	.40	.82	1.20	1.57	-----	-----	-----	-----
.24	.43	.88	1.28	1.68	-----	-----	-----	-----
.25	.46	.93	1.37	1.80	2.22	2.63	-----	-----
.26	.49	.99	1.46	1.91	2.36	2.80	-----	-----
.27	.52	1.05	1.54	2.03	2.50	2.97	-----	-----
.28	.55	1.11	1.63	2.15	2.65	3.15	-----	-----
.29	.58	1.17	1.73	2.27	2.80	3.33	-----	-----
.30	.61	1.24	1.82	2.39	2.96	3.52	4.07	4.63
.31	.64	1.30	1.92	2.52	3.12	3.71	4.29	4.88
.32	.68	1.37	2.01	2.65	3.28	3.90	4.52	5.13
.33	.71	1.44	2.11	2.78	3.44	4.10	4.75	5.39
.34	.74	1.50	2.22	2.92	3.61	4.30	4.98	5.66
.35	.78	1.57	2.32	3.05	3.78	4.50	5.21	5.92
.36	.81	1.64	2.42	3.19	3.95	4.71	5.46	6.20
.37	.85	1.71	2.53	3.33	4.13	4.92	5.70	6.48
.38	.88	1.79	2.64	3.48	4.31	5.13	5.95	6.76
.39	.92	1.86	2.75	3.62	4.49	5.35	6.20	7.05
.40	.95	1.93	2.86	3.77	4.67	5.57	6.46	7.34
.41	.99	2.01	2.97	3.92	4.86	5.79	6.72	7.64
.42	1.03	2.09	3.08	4.07	5.05	6.02	6.98	7.94
.43	1.07	2.16	3.20	4.22	5.24	6.25	7.25	8.25
.44	1.11	2.24	3.32	4.38	5.43	6.48	7.52	8.56
.45	1.15	2.32	3.44	4.54	5.63	6.72	7.80	8.87
.46	1.19	2.40	3.56	4.70	5.83	6.96	8.08	9.19
.47	1.23	2.48	3.68	4.86	6.03	7.20	8.36	9.51
.48	1.27	2.57	3.80	5.03	6.24	7.45	8.65	9.84
.49	1.31	2.65	3.93	5.19	6.45	7.69	8.94	10.2
.50	1.35	2.73	4.05	5.36	6.66	7.95	9.23	10.5
.51	1.39	2.82	4.18	5.53	6.87	8.20	9.53	10.8
.52	1.43	2.90	4.31	5.70	7.08	8.46	9.83	11.2
.53	1.48	2.99	4.44	5.88	7.30	8.72	10.1	11.5
.54	1.52	3.08	4.57	6.05	7.52	8.98	10.4	11.9
.55	1.56	3.17	4.71	6.23	7.74	9.25	10.8	12.2
.56	1.61	3.26	4.84	6.41	7.97	9.52	11.1	12.6
.57	1.65	3.35	4.98	6.59	8.20	9.79	11.4	13.0
.58	1.70	3.44	5.11	6.77	8.43	10.1	11.7	13.3
.59	1.74	3.53	5.25	6.96	8.66	10.3	12.0	13.7

A-17

staff gage rating

Parshall flume


06/17/2008
Photo: Ethan Mace

Accurate Water Measurement is dependent on:

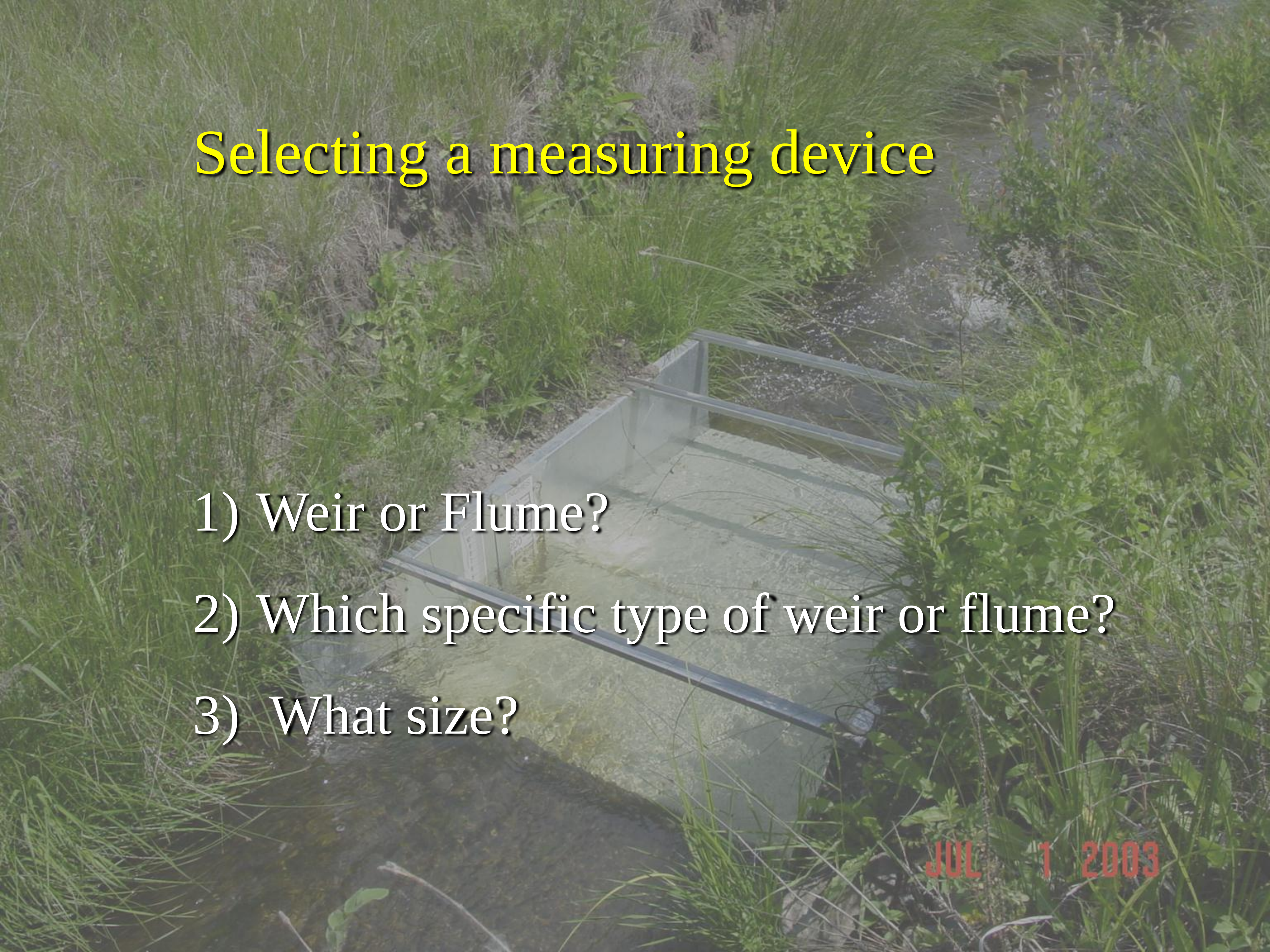
- Measuring device selection
- Installation
- Correct use of measuring device
- Maintenance and quality control

Selection Criteria

- Accuracy
- Cost
- Range of flows
- Head loss
- Adaptability to site conditions
- Ability to pass sediment
- Maintenance requirements
- Longevity of device for given environment
- User acceptance
- Vandalism potential
- Impact on environment

Selecting a measuring device

1) Weir or Flume?
2) Which specific type of weir or flume?
3) What size?



Flumes and Weirs

Flume – shaped, open-channel flow sections that force flow to accelerate.

Weir – an overflow structure built perpendicular to an open channel axis to measure the rate of flow.

Slope > 0.5%

Flumes

- Parshall
- Montana
- Cutthroat
- Ramp

Flume Classes

Long-Throated

Control discharge rate in a throat that is long enough to cause nearly parallel flow lines in the region of flow control. Ex. Ramp Flume

Short-Throated

Control discharge in a region that produces curvilinear flow. Ex. Parshall Flume

Parshall Flume

- low head loss requirement
- facilitates sand and silt
- tranquil flow (sub-critical)
  can be > 1 ft/s for approach
- wide range of sizes and flows
- can be measured under some
  submerged conditions
- difficult to build
- installation accuracy critical
- minimum head of 0.2 feet
- expensive (2.5' throat =
  $1500 to $2500)

Parshall Flumes

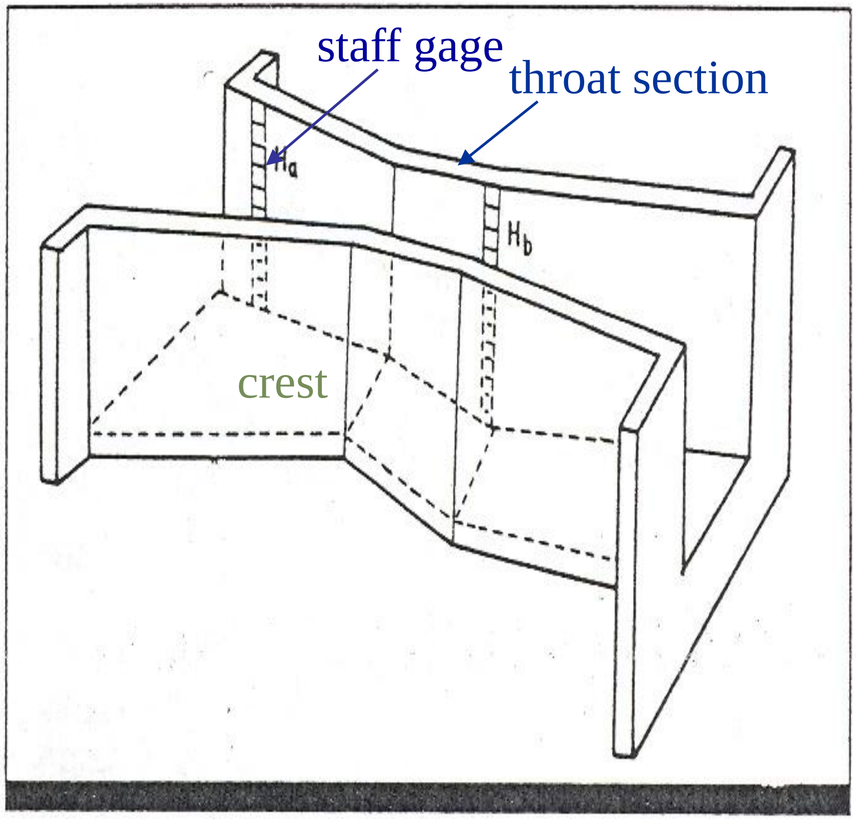


Figure 1. A Parshall measuring flume.

1 in. to 50 ft. (0.03 to > 3000 cfs)

2' Parshall 1 to 33 cfs

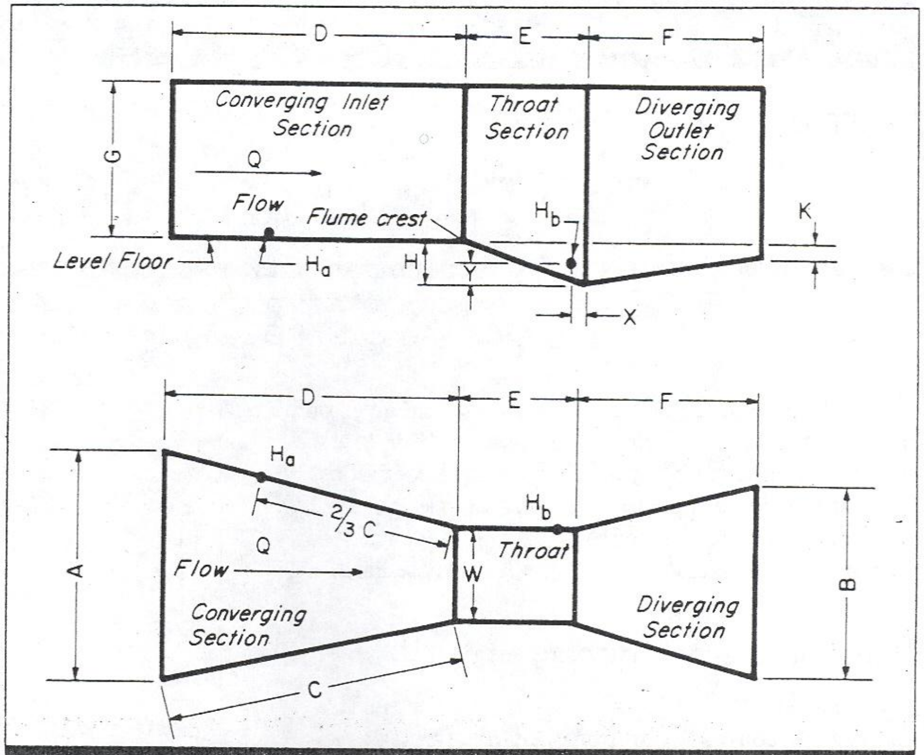


Figure 2. Section and plan views of a Parshall flume.

Specifications:

- straight section of ditch
- clear of obstructions that may disrupt even flow of approach
- floor of converging section must be level lengthwise and cross wise
- set flume floor above elevation of ditch to avoid submergence
- staff gage set at floor of converging section (crest)
- staff gage set 2/3 from crest


checking level


2/3
1/3

Throat width = 4 feet Q = ?

Stage = 0.49 feet

Water Measurement Manual

A Water Resources Technical Publication

U.S. Department of the Interior
Bureau of Reclamation
Third edition

Table A8-12. Free-flow discharges in ft^3/sec through 1- to 8-foot Parshall flumes. Discharges for 2- to 8-ft flumes computed from the formula $Q = 4.00 W h_a^{1.522(W \wedge 0.026)}$. Discharges for 1-ft flume computed from the formula $Q = 3.95 h_a^{1.55}$.

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.36	.81	1.64	2.42	3.19	3.95	4.71	5.46	6.20
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.56	1.61	3.26	4.84	6.41	7.97	9.52	11.1	12.6
.57	1.65	3.35	4.98	6.59	8.20	9.79	11.4	13.0
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.36	.81	1.64	2.42	3.19	3.95	4.71	5.46	6.20
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.43	1.07	2.16	3.20	4.22	5.24	6.25	7.25	8.25
.44	1.11	2.24	3.32	4.38	5.43	6.48	7.52	8.56
.45	1.15	2.32	3.44	4.54	5.63	6.72	7.80	8.87
.46	1.19	2.40	3.56	4.70	5.83	6.96	8.08	9.19
.47	1.23	2.48	3.68	4.86	6.03	7.20	8.36	9.51
.48	1.27	2.57	3.80	5.03	6.24	7.45	8.65	9.84
.49	1.31	2.65	3.93	5.19	6.45	7.69	8.94	10.2
.50	1.35	2.73	4.05	5.36	6.66	7.95	9.23	10.5
.51	1.39	2.82	4.18	5.53	6.87	8.20	9.53	10.8
.52	1.43	2.90	4.31	5.70	7.08	8.46	9.83	11.2
.53	1.48	2.99	4.44	5.88	7.30	8.72	10.1	11.5
.54	1.52	3.08	4.57	6.05	7.52	8.98	10.4	11.9
.55	1.56	3.17	4.71	6.23	7.74	9.25	10.8	12.2
.56	1.61	3.26	4.84	6.41	7.97	9.52	11.1	12.6
.57	1.65	3.35	4.98	6.59	8.20	9.79	11.4	13.0
.58	1.70	3.44	5.11	6.77	8.43	10.1	11.7	13.3
.59	1.74	3.53	5.25	6.96	8.66	10.3	12.0	13.7

Q = 5.19 cfs

Rating Table = 5.19 cfs
Measured flow (below) = 6.4 cfs
?

- out of level
- water flowing around or underneath
- staff gage improperly set
- submerged condition


05/04/2014


05/04/2014


Typical Max Flow Determination


1.5' Parshall Flume
Typical Maximum Flow = 5.1 cfs
high water mark

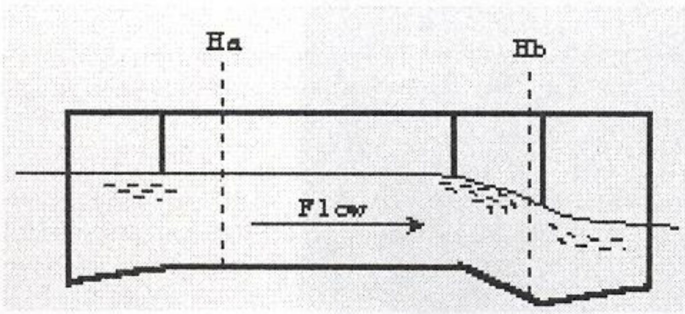


Figure 1

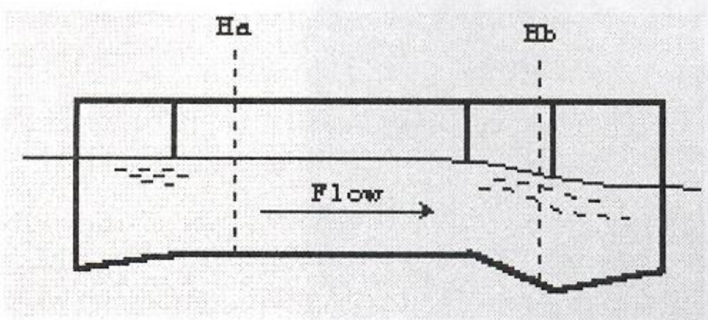


Figure 2

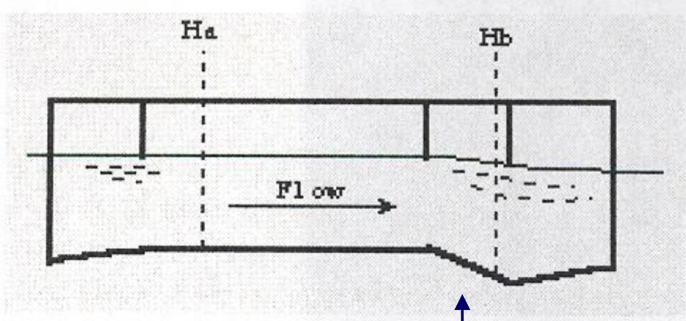


Figure 3

Free Flow

Defn. When the downstream water elevation does not influence flow through the measuring device.

Submerged Flow

Determined by Ratio: H_b/H_a

Defn. Occurs when the downstream elevation of the water surface of the flume or weir is high enough to retard flow.

Free Flow


sub-critical flow
critical flow
super-critical flow
hydraulic jump


Submerged Flow
JUN 2 2004

Submerged Parshall Flume Flow Calculation

University of Wyoming and US Bureau of Reclamation Methods

GIVEN

- 4-foot throat width Parshall Flume
- Flume is level in both directions
- The upstream gage (Ha) reads 0.70 feet
- The flow through the flume appears to be submerged so a downstream gage (Hb) is installed
- The downstream gage (Hb) reads 0.59 feet

SUBMERGENCE DETERMINATION

Submergence is checked by finding the ratio of the downstream head to the upstream head, as shown below.

% submergence = (Hb / Ha) X 100

For our flume, the submergence is:

% submergence = (0.59 / 0.70) X 100
% submergence = **84%**

Since the submergence is greater than 70%, this flow through this flume will have to be calculated as submerged flow. Please note that the % submergence requiring submergence calculations varies with the throat width of the flume. Check Page 13 in the Wyoming manual or Page 8-46 in the *Water Measurement Manual* for the maximum submergence allowed for free flow measurements.

WYOMING METHOD

Go to Figure 23 on Page 65. To use the figure it will be necessary to calculate the difference in the upstream (Ha) and downstream (Hb) heads.

Ha – Hb = 0.70 – 0.59 = **0.11 feet**

As shown in Illustration 1, start at 0.11 feet on the Ha – Hb axis (bottom). Move straight up until the 84% submergence line is met. From the intersection point on the 84% submergence line, move horizontally to the left until the discharge axis (left side) is crossed. Read the flume discharge of 7.95 cfs from the axis. Please note that this chart is valid for only a 4 foot throat Parshall Flume. Other charts, found in the manual, are required for other flume sizes.

Short-Throated Flumes

Parshall-Submergence

If Hb/Ha is less than percentage in table, then free flow exist and no submergence exists.

- 50% for 1,2, & 3 inch throats
- 60% for 6 & 9 inch throats
- 70% for 1 to 8 foot throats
- 80 % for 8 to 50 foot throats

Montana Flume (short parshall)

- low head loss requirement
- facilitates sediment
- no approach velocity requirement
- wide range of flows
- easy to build

- cannot measure submergence, must have free flow

Cutthroat Flume

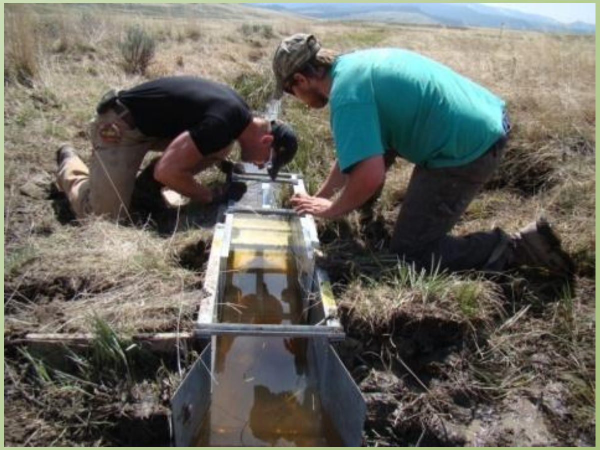
- easy installation
- less expensive than parshalls
- easy to construct
- variable hydraulic conditions
- difficult to tell submergence


Submerged Flow

Long Throated Flumes

Ramp Flume
Replogle Flume
Broad-Crested Weir
(very similar)

Long-Throated Flumes



•The required head loss over the long-throated flume to obtain a unique relationship between the upstream sill-referenced head and discharge is small.

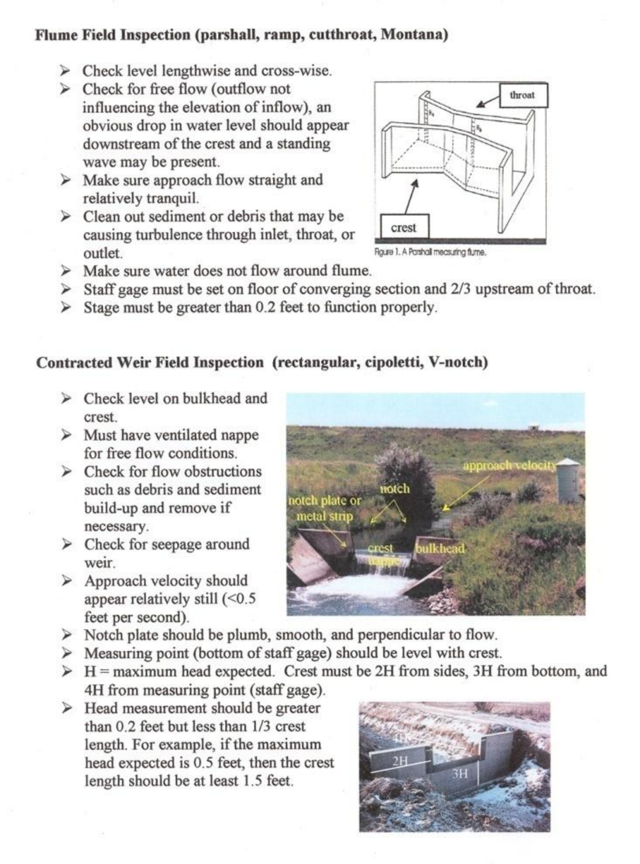
•Long-throated flumes can be made into portable devices that fit conveniently into open channels with considerably less complicated construction forming.

Pre-Fabricated Flumes

> example: 4 cfs capacity = $650

Flume Inspection

- Correct flume size
- Check for free flow (no submergence)
- Floor of converging section (crest) is level crosswise and lengthwise
- Staff gage is placed properly
- Check for seepage
- Clear of debris



Flume Field Inspection (parshall, ramp, cutthroat, Montana)

- Check level lengthwise and cross-wise.
- Check for free flow (outflow not influencing the elevation of inflow), an obvious drop in water level should appear downstream of the crest and a standing wave may be present.
- Make sure approach flow straight and relatively tranquil.
- Clean out sediment or debris that may be causing turbulence through inlet, throat, or outlet.
- Make sure water does not flow around flume.
- Staff gage must be set on floor of converging section and 2/3 upstream of throat.
- Stage must be greater than 0.2 feet to function properly.

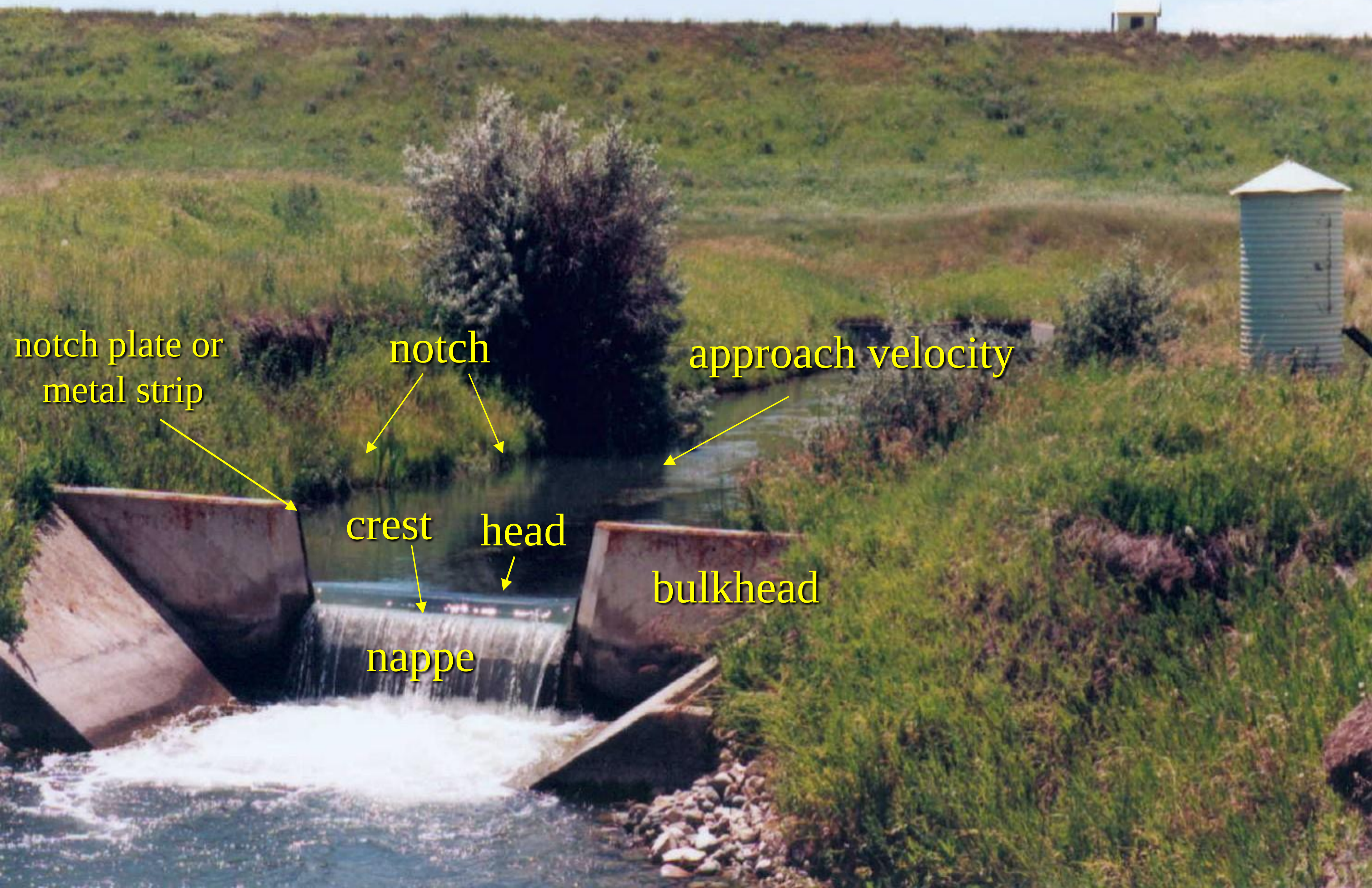
Figure 1. A Parshall measuring flume.

Contracted Weir Field Inspection (rectangular, cipoletti, V-notch)

- Check level on bulkhead and crest.
- Must have ventilated nappe for free flow conditions.
- Check for flow obstructions such as debris and sediment build-up and remove if necessary.
- Check for seepage around weir.
- Approach velocity should appear relatively still (<0.5 feet per second).
- Notch plate should be plumb, smooth, and perpendicular to flow.
- Measuring point (bottom of staff gage) should be level with crest.
- H = maximum head expected. Crest must be 2H from sides, 3H from bottom, and 4H from measuring point (staff gage).
- Head measurement should be greater than 0.2 feet but less than 1/3 crest length. For example, if the maximum head expected is 0.5 feet, then the crest length should be at least 1.5 feet.

Weirs

Overflow structure installed perpendicular to flow



Weir vs. Flume

- head loss requirement (need more slope for weirs)
- weirs have approach velocity requirement
- weirs can be easier to build
- weirs can collect sediment and debris

(require more maintenance)

Sharp-Crested Weir

3 Standard Types

Contracted Rectangular

Cipolletti Contracted

Contracted Triangular or V-Notch

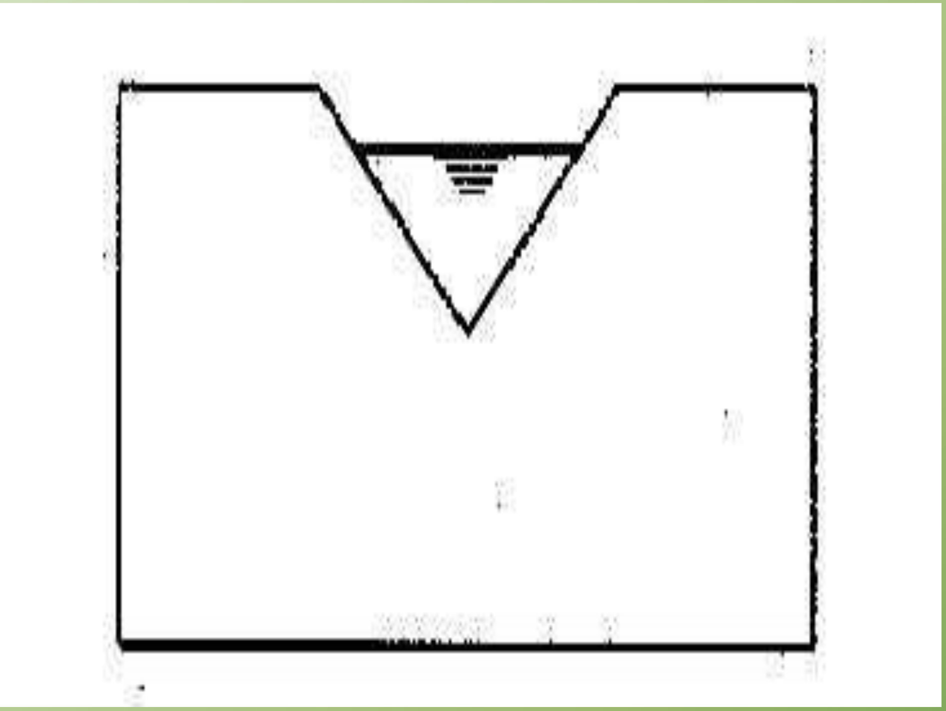
Sharp-Crested Weir

Contracted Rectangular

Sharp Crested Weir

Cipolletti Contracted - Trapezoidal in shape with sides that incline outwardly at a slope of 1 horizontal to 4 vertical. May be more accurate at lower stages than rectangular weir.

Sharp Crested Weir



Contracted Triangular or V-Notch

Measures flows up to 4.3 cfs or 1.25 feet of head

Conditions needed for all types of Sharp-Crested Weirs

- Weir should be installed in straight section of ditch/canal.
- Upstream face of the weir plates and bulkhead should be plumb, smooth, and normal to the axis of the channel.
- Approach velocity <= 0.5 feet/second (appear still).

Weir Measurement

The measurement of head on the weir is the difference between the crest and the water surface at a point located upstream from the weir a distance of at least 4 times the maximum head on the crest (4H).

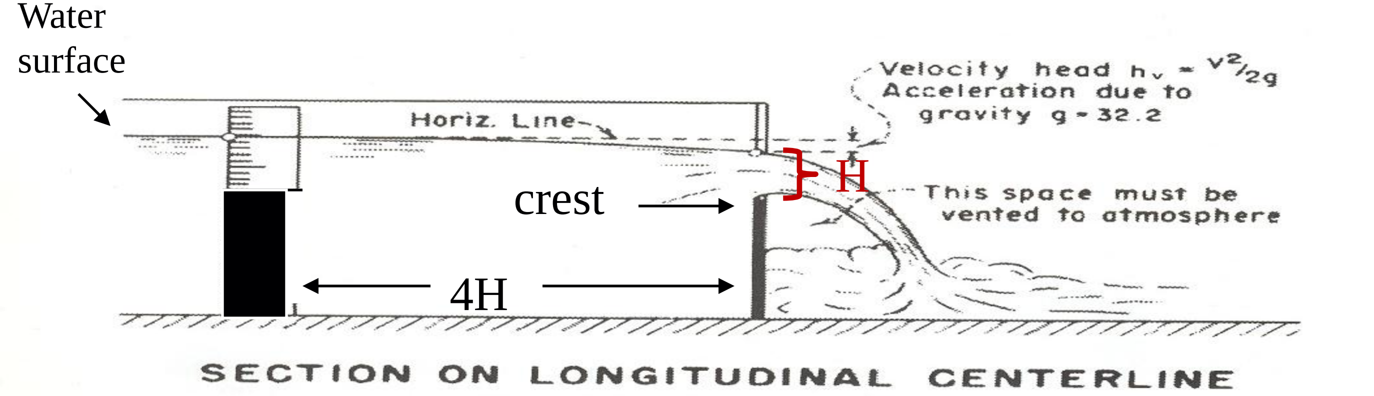


Figure 5-6.—Weir approach flow.


APR 7 2004

Free Flow Condition for Weirs

- The overflow sheet or nappe should touch only the upstream face of the crest and side plates (free flow).

- Maximum downstream water surface should be 3H from canal bottom.

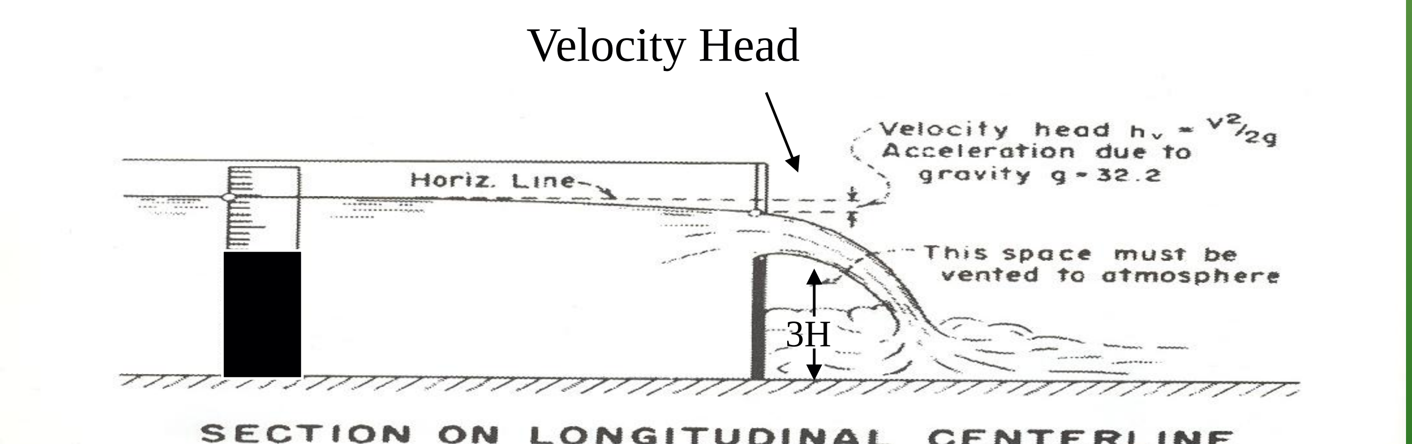
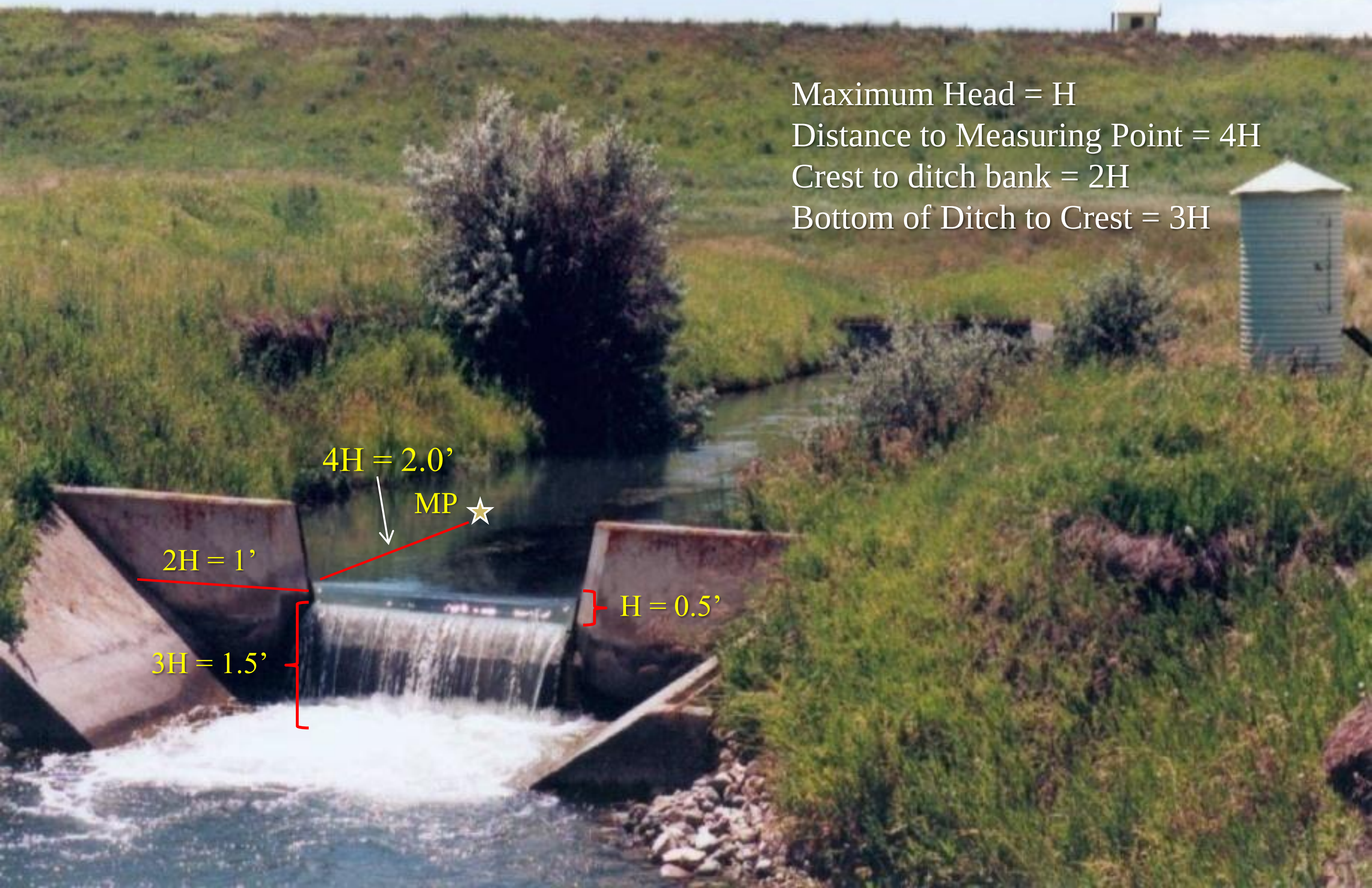


Figure 5-6.—Weir approach flow.


ventilated nappe
APR 7 2004

Weir Installation Specifications



Weir Inspection and Maintenance

- Approaching flow: low velocity (<0.5 f/s), even
- Check for flow obstructions, sediment, and/or debris build-up, remove if necessary
- Check crest level
- Check condition of crest
- Weir installation specifications (for contracted)
  - crest = 2H from sides
    3H from canal bottom
    4H from measuring point
- Measuring point elevation = crest elevation
- Adequate sizing (0.2 feet < H < 1/3 crest length)
- Check for free flow conditions (nappe ventilation)
- Check for seepage

Using your favorite Irrigation Water Measurement Guide, determine flow in cfs for the following measuring devices.

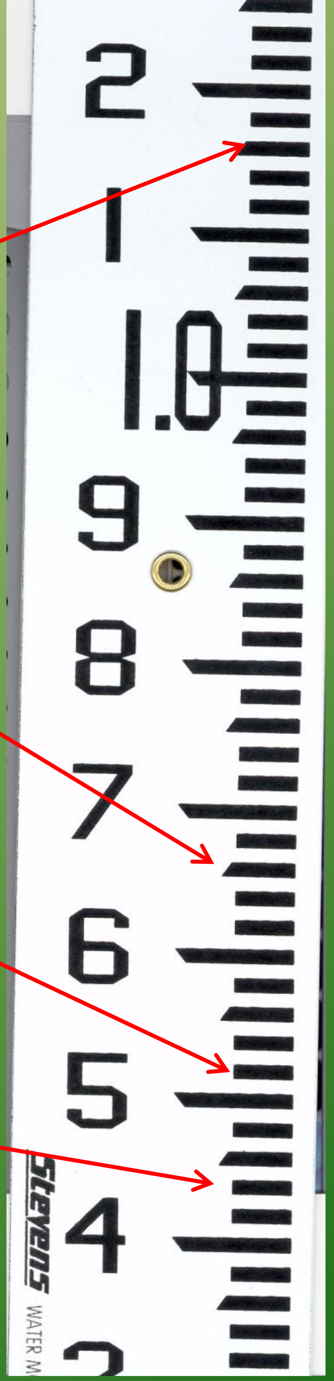
1) Parshall flume, throat width = 5 feet, gage reading

2) Montana Flume, throat width = 2.5 feet, gage reading

3) Cipoletti weir, crest length = 5 feet, gage reading

4) V-notch weir, gage reading

5) Parshall flume, throat size = 12 feet, gage reading = 0.05 feet



Using your favorite Irrigation Water Measurement Guide, determine flow in cfs for the following measuring devices.

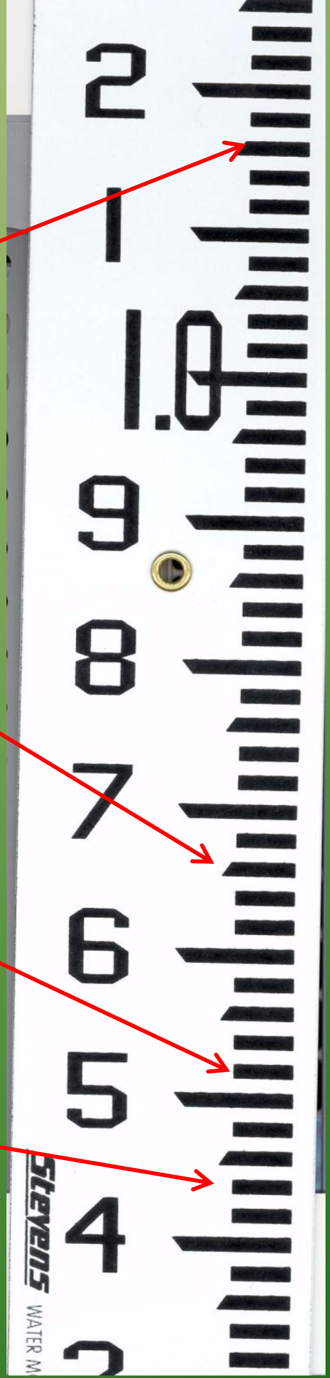
1) Parshall flume, throat width = 5 feet, gage reading gh = 1.16, Q = 25.3 cfs

2) Montana Flume, throat width = 2.5 feet, gage reading

3) Cipoletti weir, crest length = 5 feet, gage reading

4) V-notch weir, gage reading

5) Parshall flume, throat size = 12 feet, gage reading = 0.05 feet



Using your favorite Irrigation Water Measurement Guide, determine flow in cfs for the following measuring devices.

1) Parshall flume, throat width = 5 feet, gage reading
gh = 1.16’ Q = 25.3 cfs

2) Montana Flume, throat width = 2.5 feet, gage reading
gh = 0.65’ Q = 5.11 cfs

3) Cipoletti weir, crest length = 5 feet, gage reading

4) V-notch weir, gage reading

5) Parshall flume, throat size = 12 feet, gage reading = 0.05 feet

Using your favorite Irrigation Water Measurement Guide, determine flow in cfs for the following measuring devices.

1) Parshall flume, throat width = 5 feet, gage reading

gh = 1.16’   Q = 25.3 cfs

2) Montana Flume, throat width = 2.5 feet, gage reading

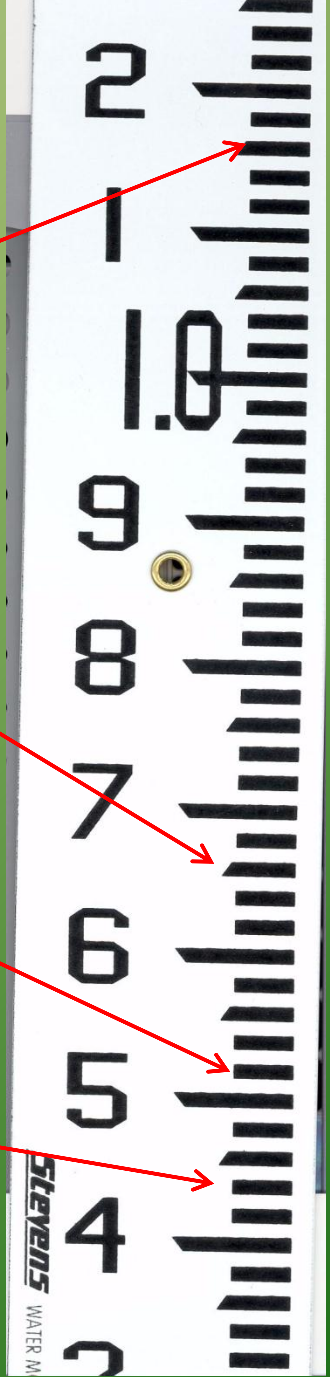
gh = 0.65’   Q = 5.11 cfs

3) Cipoletti weir, crest length = 5 feet, gage reading

gh = 0.51’   Q = 6.13 cfs

4) V-notch weir, gage reading

5) Parshall flume, throat size = 12 feet, gage reading = 0.05 feet



Using your favorite Irrigation Water Measurement Guide, determine flow in cfs for the following measuring devices.

1) Parshall flume, throat width = 5 feet, gage reading

gh = 1.16’ Q = 25.3 cfs

2) Montana Flume, throat width = 2.5 feet, gage reading

gh = 0.65’ Q = 5.11 cfs

3) Cipoletti weir, crest length = 5 feet, gage reading

gh = 0.51’ Q = 6.13 cfs

4) V-notch weir, gage reading

gh = 0.43’ Q = 0.31 cfs

5) Parshall flume, throat size = 12 feet, gage reading = 0.05 feet

Using your favorite Irrigation Water Measurement Guide, determine flow in cfs for the following measuring devices.

1) Parshall flume, throat width = 5 feet, gage reading

gh = 1.16’ Q = 25.3 cfs

2) Montana Flume, throat width = 2.5 feet, gage reading

gh = 0.65’ Q = 5.11 cfs

3) Cipoletti weir, crest length = 5 feet, gage reading

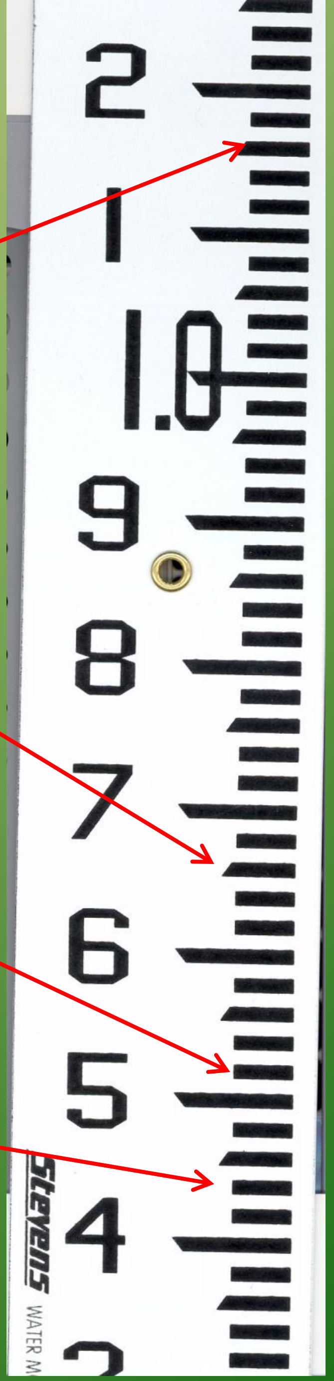
gh = 0.51’ Q = 6.13 cfs

4) V-notch weir, gage reading

gh = 0.43’ Q = 0.31 cfs

5) Parshall flume, throat size = 12 feet, gage reading = 0.05 feet

flow too low to accurately measure



Most Common Ditch/Canal Measuring Devices in Montana

If properly installed, maintained and operated, the following are acceptable measuring devices for Water Commissioners:

Flumes

- Parshall
- Montana
- Ramp
- Cutthroat

Weirs

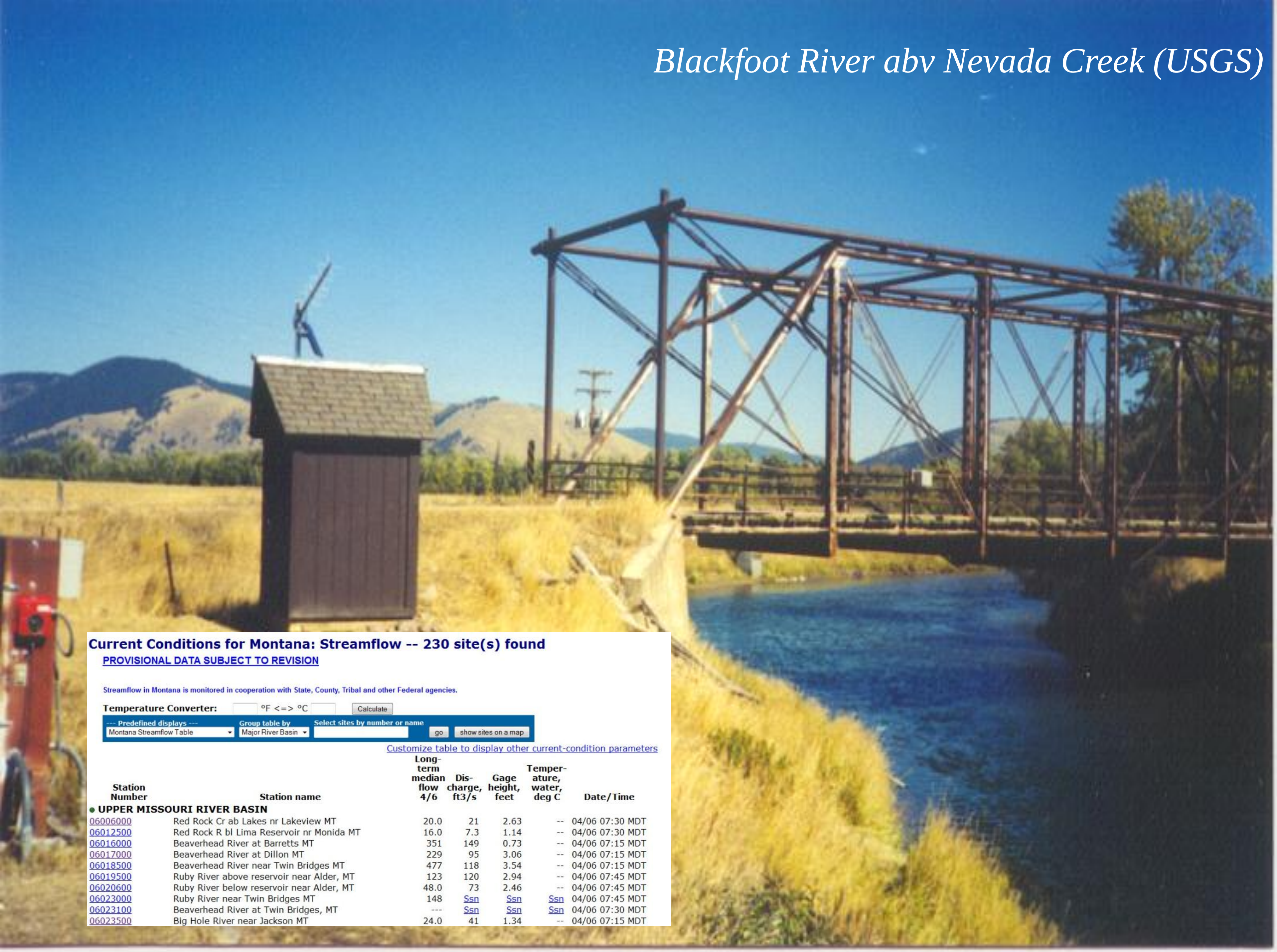
- Contracted rectangular
- Cipolleti
- V-Notch

Automated Devices

Streamflow Gaging Stations

Deadmans Supply Canal

Blackfoot River abv Nevada Creek (USGS)



Current Conditions for Montana: Streamflow -- 230 site(s) found

PROVISIONAL DATA SUBJECT TO REVISION

Streamflow in Montana is monitored in cooperation with State, County, Tribal and other Federal agencies.

Temperature Converter: °F <=> °C Calculate

--- Predefined displays --- Montana Streamflow Table | Group table by Major River Basin | Select sites by number or name go | show sites on a map

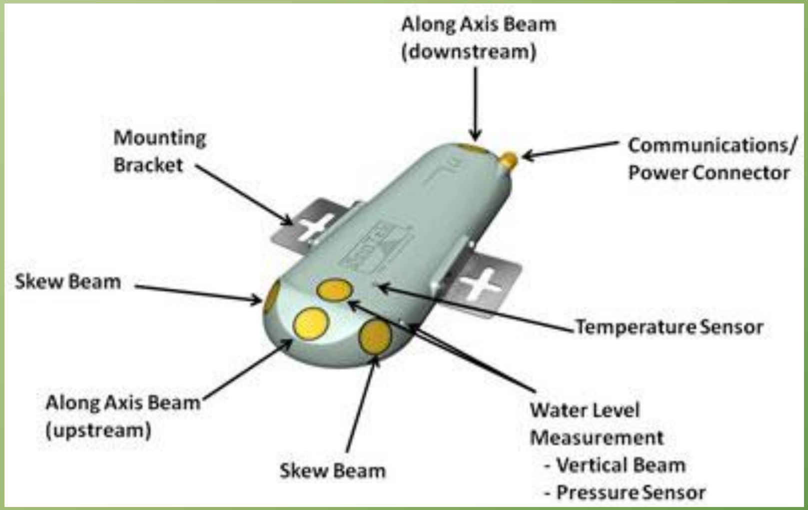
Customize table to display other current-condition parameters

Station Number	Station name	Long-term median flow 4/6	Dis-charge, ft3/s	Gage height, feet	Temper-ature, water, deg C	Date/Time
● UPPER MISSOURI RIVER BASIN						
06006000	Red Rock Cr ab Lakes nr Lakeview MT	20.0	21	2.63	--	04/06 07:30 MDT
06012500	Red Rock R bl Lima Reservoir nr Monida MT	16.0	7.3	1.14	--	04/06 07:30 MDT
06016000	Beaverhead River at Barretts MT	351	149	0.73	--	04/06 07:15 MDT
06017000	Beaverhead River at Dillon MT	229	95	3.06	--	04/06 07:15 MDT
06018500	Beaverhead River near Twin Bridges MT	477	118	3.54	--	04/06 07:15 MDT
06019500	Ruby River above reservoir near Alder, MT	123	120	2.94	--	04/06 07:45 MDT
06020600	Ruby River below reservoir near Alder, MT	48.0	73	2.46	--	04/06 07:45 MDT
06023000	Ruby River near Twin Bridges MT	148	Ssn	Ssn	Ssn	04/06 07:45 MDT
06023100	Beaverhead River at Twin Bridges, MT	---	Ssn	Ssn	Ssn	04/06 07:30 MDT
06023500	Big Hole River near Jackson MT	24.0	41	1.34	--	04/06 07:15 MDT

Continuous Water Level Sensors

- TruTracks
- Pressure Transducers

Bottom Mounted Doppler Meters



In-Line Meters and Flow Totalizers

Ultra-Sonic Meters

Weir Sticks

- Commercially calibrated stick that shows depth of flow plus velocity head when placed on weir crest. In this case velocity head would be equal to the run up of water on the stick (Clausen Rule)

- May be calibrated to be read at an angle.

Measuring Device Selection Guideline

Relative Qualitative Scale*: 1 - most favorable, 2 - average, 3 - least favorable							
Device	accuracy	low maintenance	range of flows	facilitates sediment/debris	head loss requirement	ease of construction	cost
Parshall Flume	1	2	1	1	1	3	2-3
Cutthroat Flume	2	2	1	1	1	2	2
Ramp Flume	1	1	2	1	1	2	2
Contracted Rectangular Weir	1-2	3	2	3	2	1-2	2
Cipoletti Weir	1-2	3	2	3	2	1-2	2
V-Notch Weir	1-2	3	3	3	2	1	2

**Relative scale based on DNRC qualitative assessment.*

<u>Open channel measuring device selection:</u> Choose the type of measuring device you the water commissioner would most likely recommend under the following conditions.

1) Moderate to high head loss, low sediment load.

2) High sediment load, trapezoidal ditch, potential for submerged conditions.

3) Need to measure seepage below a dam. Expected flows 0.5-2 cfs.

4) Low head loss, moderate to high sediment load, wide range of flows.

5) Point of diversion is small discharge (<25 gpm) from a pipe that is easily accessible.

6) Water right is contract water that is administered based on volume.

7) A ditch has a number of standard outlets through pipe conduits.

8) DNRC hydrologist is on-site and you want to check accuracy of your weir.

Open channel measuring Device Selection: Choose the type of measuring device you the water commissioner would most likely recommend under the following conditions.

1) Moderate to high head loss, low sediment load. **weir**

2) High sediment load, trapezoidal ditch, potential for submerged conditions.

3) Need to measure seepage below a dam. Expected flows 0.5-2 cfs.

4) Low head loss, moderate to high sediment load, wide range of flows.

5) Point of diversion is small discharge (<25 gpm) from a pipe that is easily accessible.

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Open channel measuring Device Selection: Choose the type of measuring device you the water commissioner would most likely recommend under the following conditions.

1) Moderate to high head loss, low sediment load. weir

2) High sediment load, trapezoidal ditch, potential for submerged conditions. **broad-crested weir or ramp flume**

3) Need to measure seepage below a dam. Expected flows 0.5-2 cfs.

4) Low head loss, moderate to high sediment load, wide range of flows.

5) Point of diversion is small discharge (<25 gpm) from a pipe that is easily accessible.

6) Water right is contract water that is administered based on volume.

7) A ditch has a number of standard outlets through pipe conduits.

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Open channel measuring Device Selection: Choose the type of measuring device you the water commissioner would most likely recommend under the following conditions.

1) Moderate to high head loss, low sediment load. weir

2) High sediment load, trapezoidal ditch, potential for submerged conditions. broad-crested weir or ramp flume

3) Need to measure seepage below a dam. Expected flows 0.5-2 cfs. **V-notch or small rectangular weir**

4) Low head loss, moderate to high sediment load, wide range of flows.

5) Point of diversion is small discharge (<25 gpm) from a pipe that is easily accessible.

6) Water right is contract water that is administered based on volume.

7) A ditch has a number of standard outlets through pipe conduits.

8) DNRC hydrologist is on-site and you want to check accuracy of your weir.

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2) High sediment load, trapezoidal ditch, potential for submerged conditions. broad-crested weir or ramp flume

3) Need to measure seepage below a dam. Expected flows 0.5-2 cfs. V-notch or small rectangular weir

4) Low head loss, moderate to high sediment load, wide range of flows. **flume**

5) Point of diversion is small discharge (<25 gpm) from a pipe that is easily accessible.

6) Water right is contract water that is administered based on volume.

7) A ditch has a number of standard outlets through pipe conduits

8) DNRC hydrologist is on-site and you want to check accuracy of your weir.

Open channel measuring Device Selection: Choose the type of measuring device you the water commissioner would most likely recommend under the following conditions.

1) Moderate to high head loss, low sediment load. weir

2) High sediment load, trapezoidal ditch, potential for submerged conditions. broad-crested weir or ramp flume

3) Need to measure seepage below a dam. Expected flows 0.5-2 cfs. V-notch or small rectangular weir

4) Low head loss, moderate to high sediment load, wide range of flows. flume

5) Point of diversion is small discharge (<25 gpm) from a pipe that is easily accessible. **bucket, stop watch**

6) Water right is contract water that is administered based on volume.

7) A ditch has a number of standard outlets through pipe conduits.

8) DNRC hydrologist is on-site and you want to check accuracy of your weir.

Open channel measuring Device Selection: Choose the type of measuring device you the water commissioner would most likely recommend under the following conditions.

1) Moderate to high head loss, low sediment load. weir

2) High sediment load, trapezoidal ditch, potential for submerged conditions. broad-crested weir or ramp flume

3) Need to measure seepage below a dam. Expected flows 0.5-2 cfs. V-notch or small rectangular weir

4) Low head loss, moderate to high sediment load, wide range of flows. flume

5) Point of diversion is small discharge (<25 gpm) from a pipe that is easily accessible. bucket, stop watch

6) Water right is contract water that is administered based on volume. **flume with totalizer**

7) A ditch has a number of standard outlets through pipe conduits.

8) DNRC hydrologist is on-site and you want to check accuracy of your weir.

Open channel measuring Device Selection: Choose the type of measuring device you the water commissioner would most likely recommend under the following conditions.

1) Moderate to high head loss, low sediment load. weir

2) High sediment load, trapezoidal ditch, potential for submerged conditions. broad-crested weir or ramp flume

3) Need to measure seepage below a dam. Expected flows 0.5-2 cfs. V-notch or small rectangular weir

4) Low head loss, moderate to high sediment load, wide range of flows. flume

5) Point of diversion is small discharge (<25 gpm) from a pipe that is easily accessible. bucket, stop watch

6) Water right is contract water that is administered based on volume. flume, totalizer

7) A ditch has a number of standard outlets through pipe conduits. **portable propeller, ultra sonic meter**

8) DNRC hydrologist is on-site and you want to check accuracy of your weir.

<u>Open channel measuring Device Selection:</u> Choose the type of measuring device you the water commissioner would most likely recommend under the following conditions.

1) Moderate to high head loss, low sediment load. weir

2) High sediment load, trapezoidal ditch, potential for submerged conditions. broad-crested weir or ramp flume

3) Need to measure seepage below a dam. Expected flows 0.5-2 cfs. V-notch or small rectangular weir

4) Low head loss, moderate to high sediment load, wide range of flows. flume

5) Point of diversion is small discharge (<25 gpm) from a pipe that is easily accessible. bucket, stop watch

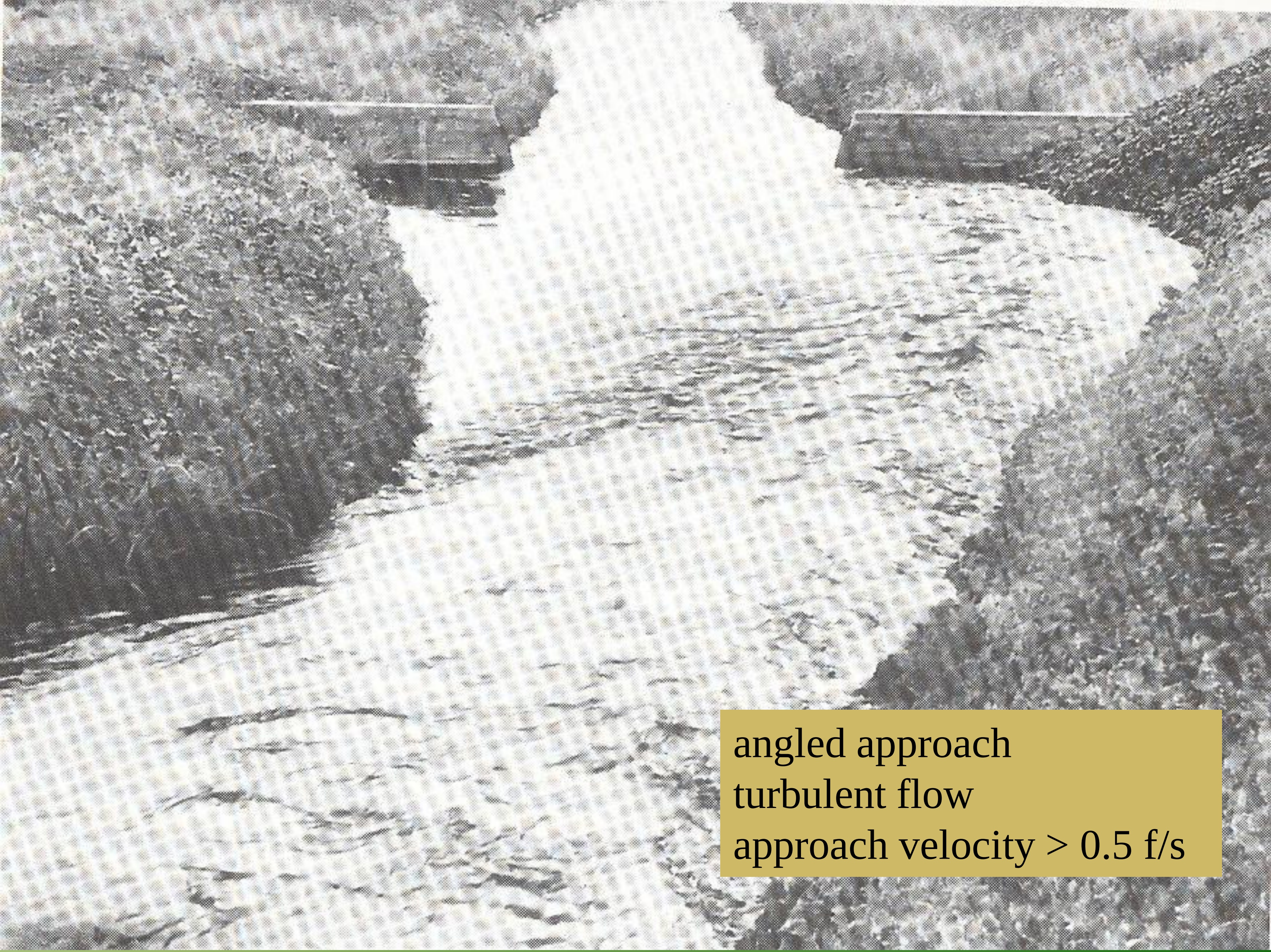
6) Water right is contract water that is administered based on volume. flume, rated section, totalizer

7) A ditch has a number of standard outlets through pipe conduits. portable propeller, ultra sonic meter

8) DNRC hydrologist is on-site and you want to check accuracy of your weir. **current meter**

Visual Examples


Problem?



angled approach
turbulent flow
approach velocity > 0.5 f/s

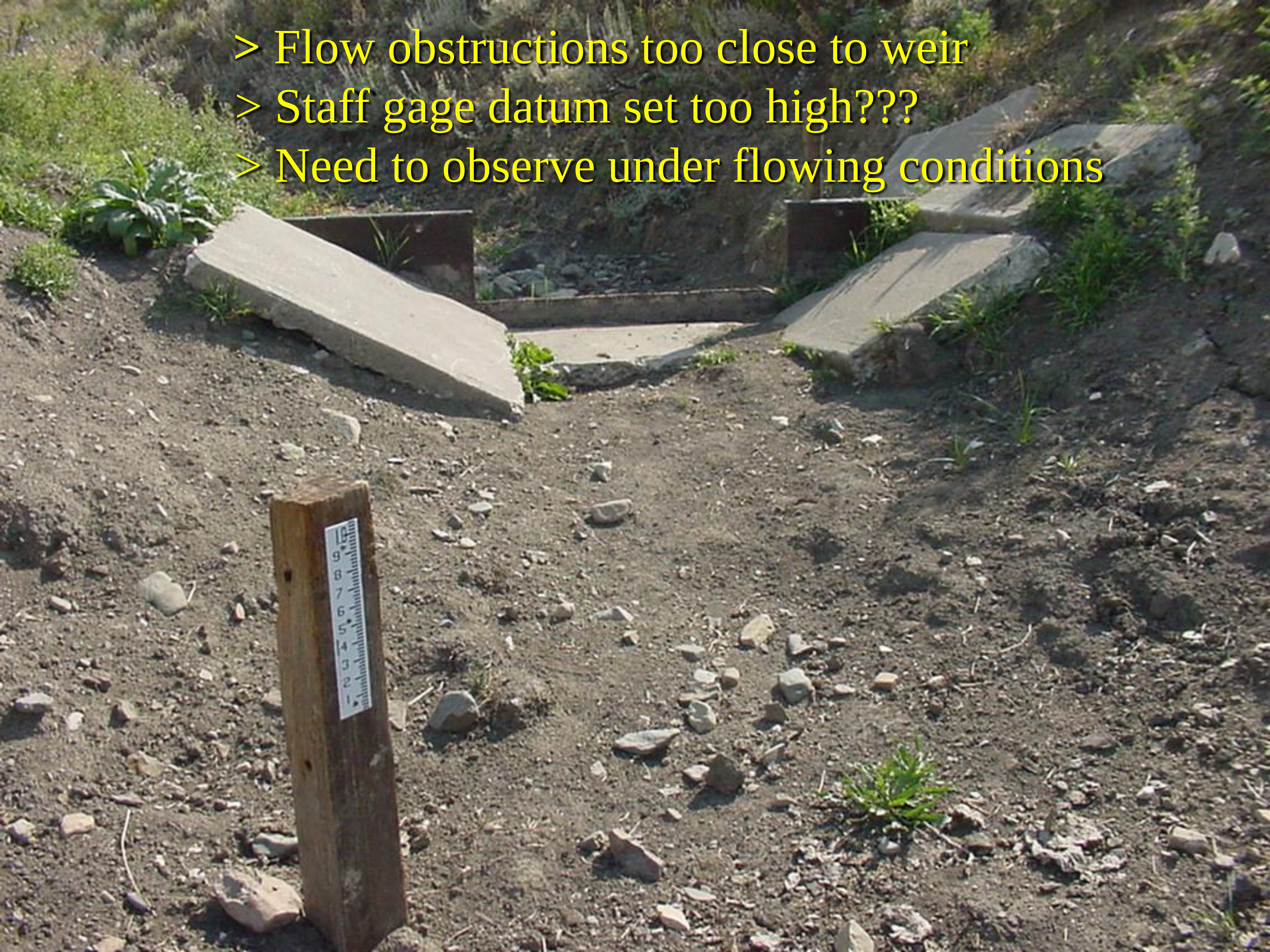

05/07/2014

Problem?

> Staff gage not level with weir crest

> Crest not level


proper location = 2/3 from throat


> Flow obstructions too close to weir
> Staff gage datum set too high???
> Need to observe under flowing conditions


MAR 30 2004


Needs:
• cleaning
• clearing of debris
MAR 30 2004


Good location
Proper sizing
JUN 2 2004


Submerged Flow
No hydraulic jump
Needs Re-setting
JUN 2 2004

3’ Parshall Flume


Flow direction?
Over- or underestimating flow?


Submerged Flow
Needs Re-setting


MUCK

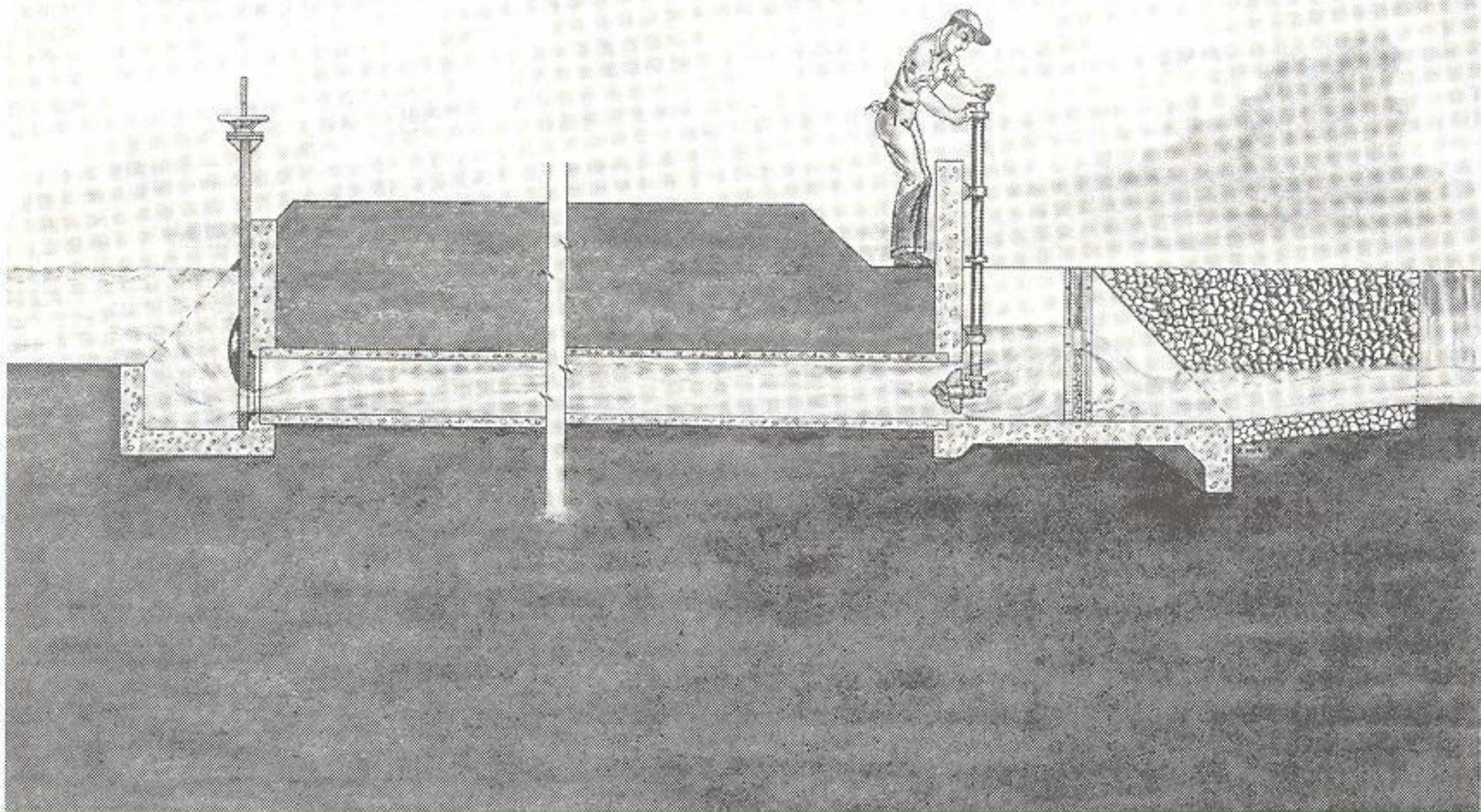

06/17/2008


Problem??
5 29 '03


Poor Sizing
Submerged Flow
Downstream checks?
5 29 '03

Closed Conduit Flow

Culvert Measurements and Closed Conduit Flow




CUBIC FEET PER SECOND


BLUE-WHITE® INDUSTRIES
MODE RESET
GALLONS PER MINUTE
Rate - Totalizer
F-1000-RT

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Estimating Water Flow Rates

W.L. Trimmer

Increasing competition for water resources has made water conservation a high priority. Measuring the flow rate of water is the first step to good water management. All water right holders in the State of Oregon must be able to measure the flow rate of the water being diverted.

If a flow meter, flume, or weir isn't available, there are several methods available to estimate flow rate that you can do with available tools like stopwatches, rulers, and buckets.

The usual unit measuring flow rate for irrigation water rights is a cubic foot per second (cfs). This is water flowing through a cross-sectional area of 1 ft^2 at a velocity of 1 foot per second, and it's sometimes called a second-foot.

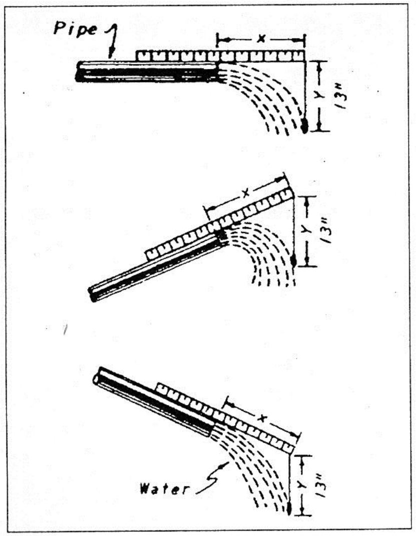


Figure 1.—Measuring horizontal distance (X) of a pipe flowing full with vertical drop Y=13".

A common diversion rate in eastern Oregon might be 1 cfs/40 acres. Here are some handy conversions (see page 4 for others): 1 cfs is about 450 gallons per minute; 1 cfs is about 1 acre-inch per hour; 1 cfs is about 2 acre-feet per day.

Propeller flow meters, weirs, and flumes provide the most accurate measures of flow rate, but in many instances you must make an estimate without them. Here are four methods to estimate irrigation diversions.

Method 1
Discharge from a pipe

If water can freely drop from a pipe, you can estimate the flow rate by measuring length with nothing more than a carpenter's rule. When the pipe is flowing full, place the rule as shown in Figure 1 and measure a horizontal distance when the vertical drop Y = 13 inches.

Find the proper pipe size in Table 1, and the discharge is in gallons per minute (gpm). If the pipe isn't level, use a plumb bob to measure the vertical drop Y.

Example 1. An 8-inch-diameter pipe is flowing full, and the horizontal distance X is measured to be 20 inches. From Table 1, the flow rate is 1,005 gpm.

If the pipe is flowing only partially full, find the ratio of the unfilled portion of pipe to the diameter of the pipe to estimate flow rate in gallons per minute, as shown in Table 2.

Example 2. A 10-inch-diameter pipe is flowing only partially full. The measured distance U is 2 inches. The ratio U ÷ D in Table 2 is 2 ÷ 10 = 0.2. The flow rate is 825 gpm.

Walter L. Trimmer, former Extension irrigation specialist, Oregon State University.

OREGON STATE UNIVERSITY EXTENSION SERVICE

Table 1.—Discharge (gallons per minute) from pipes flowing full, with vertical drop Y = 13" and variable horizontal distances X.

Pipe size		Horizontal distance X (in inches)												
Inside diam.	Area (sq in)	12	14	16	18	20	22	24	26	28	30	32	34	36
2.0	3.14	38	44	50	57	63	69	75	82	88	94	100	107	113
2.5	4.91	59	69	79	88	98	108	118	128	137	147	157	167	177
3.0	7.07	85	99	113	127	141	156	170	184	198	212	226	240	255
4.0	12.57	151	176	201	226	251	277	302	327	352	377	402	427	453
5.0	19.64	236	275	314	354	393	432	471	511	550	589	628	668	707
6.0	28.27	339	396	452	509	565	622	678	735	792	848	905	961	1013
7.0	38.48	462	539	616	693	770	847	924	1000	1077	1154	1231	1308	1385
8.0	50.27	603	704	804	905	1005	1106	1206	1307	1408	1508	1609	1709	1810
9.0	63.62	763	891	1018	1145	1272	1400	1527	1654	1781	1909	2036	2163	2290
10.0	78.54	942	1100	1257	1414	1471	1728	1885	2042	2199	2356	2513	2670	2827
11.0	95.03	1140	1330	1520	1711	1901	2091	2281	2471	2661	2851	3041	3231	3421
12.0	113.10	1357	1583	1809	2036	2262	2488	2714	2941	3167	3393	3619	3845	4072

$Q = \frac{3.61\,AX}{\sqrt{Y}}$, where:
A = Cross-sectional area of discharge pipe in square inches
X = Horizontal distance in inches
Y = Vertical distance in inches

Table 2.—An approximate method of estimating discharge from pipes flowing partially full.

	Inside diameter of pipe = D in inches				
$\frac{U}{D}$	4	6	8	10	12
0.1	142	334	379	912	1310
0.2	128	302	524	825	1185
0.3	112	264	457	720	1034
0.4	94	222	384	605	868
0.5	75	176	305	480	689
0.6	55	130	226	355	510
0.7	37	88	152	240	345
0.8	21	49	85	134	194
0.9	8	17	30	52	74
1.0	0	0	0	0	0


Looks level to me, what do you think?
Questions??

Manual Measurements

-Current meters

- Float-area method

Current Meters

Classes of current meters

- Mechanical: Anemometer and propeller velocity meters
  (not discussed)
- Electromagnetic velocity meters
- Doppler velocity meters

Current Meters

- Electromagnetic

Example: Marsh-McBirney Velocity Meter with digital read-out

Current meter probe produces a magnetic field, water moving through that field generates a voltage which is proportional to the velocity of the water

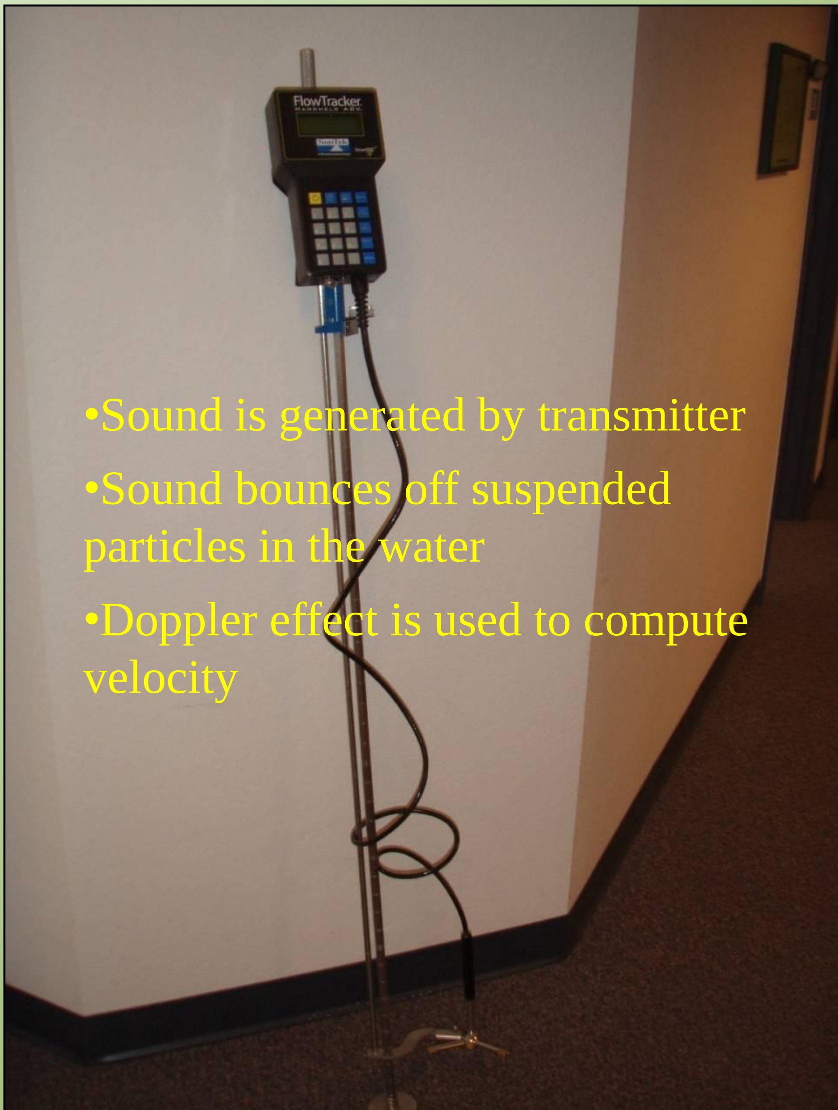
Current Meters

Maintenance (Marsh-McBirney)

- zero test every two weeks (depending on usage) or prior to going to field
- clean probe when necessary (400-600 grit sandpaper)
- May need laboratory calibration

Doppler-Style Current Meters

Example: Flow-Tracker Acoustic Doppler Meter



- Sound is generated by transmitter
- Sound bounces off suspended particles in the water
- Doppler effect is used to compute velocity

Meter Transmitter

Keypad and Discharge Computer

Doppler-Style Current Meters

Acoustic Doppler Current Profiler (ADCP)

Measuring Flow with Current Meters

- Current meters measure velocity at a point.

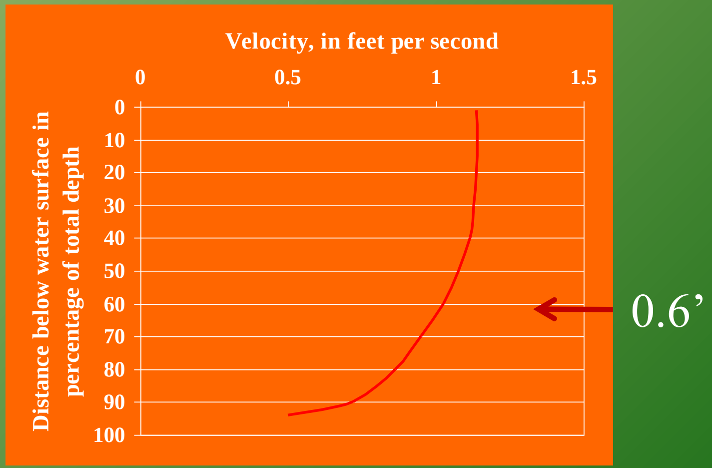
- USGS Methodology

  (Rantz, 1982 USGS WSP 2175
  Nolan and Shields WRI 00-4036)

- Typically 20 points across section
  Accuracy Goal per section = 5%
  Re-measure if > 10%

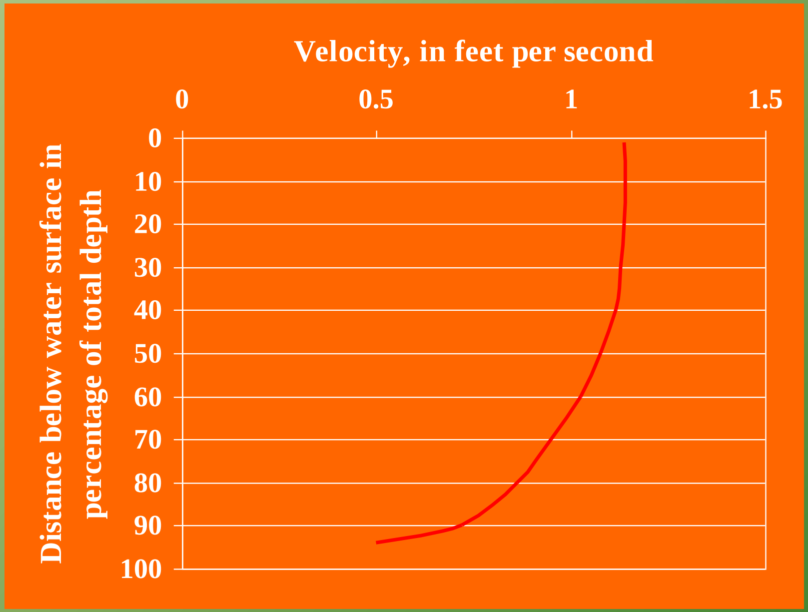
- Meter is placed six-tenths depth from the surface (mean V)

- 40 second intervals



Measuring Flow with Current Meters

- If depth greater than 2.5 feet, 2-point measurement
  - average 0.2 and 0.8 depths
- If velocity profile is “abnormal”, 3-point measurement
  - average 0.6 with average of 0.2 and 0.8



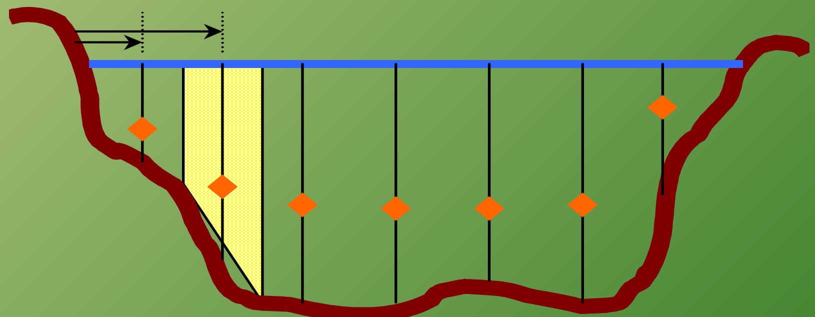
Current Meters

- Velocity-Area principle used to compute discharge

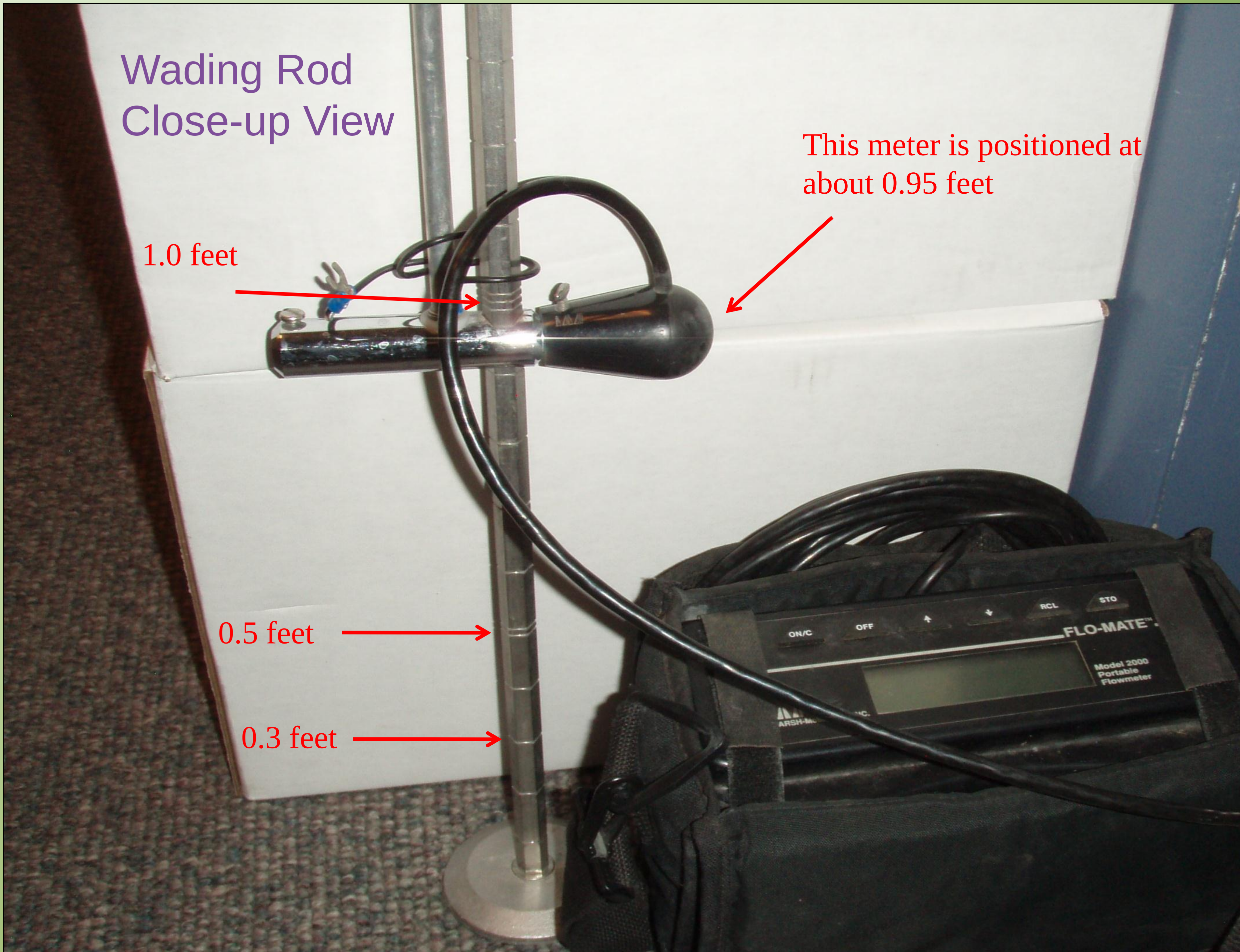
$$Q = A \cdot V$$

Total discharge is a summation of the partial discharges in measurement sections

$$Q_{Total} = A_1 \cdot V_1 + A_2 \cdot V_2 + \ldots + A_n \cdot V_n$$



Wading Rod Close-up View



Technique:

Hold rod perpendicular to channel bottom
Hold instrument parallel to current
Stand behind and to the side of probe
Wear a cool hat

Current Meters

Selection of cross section for conventional current metering

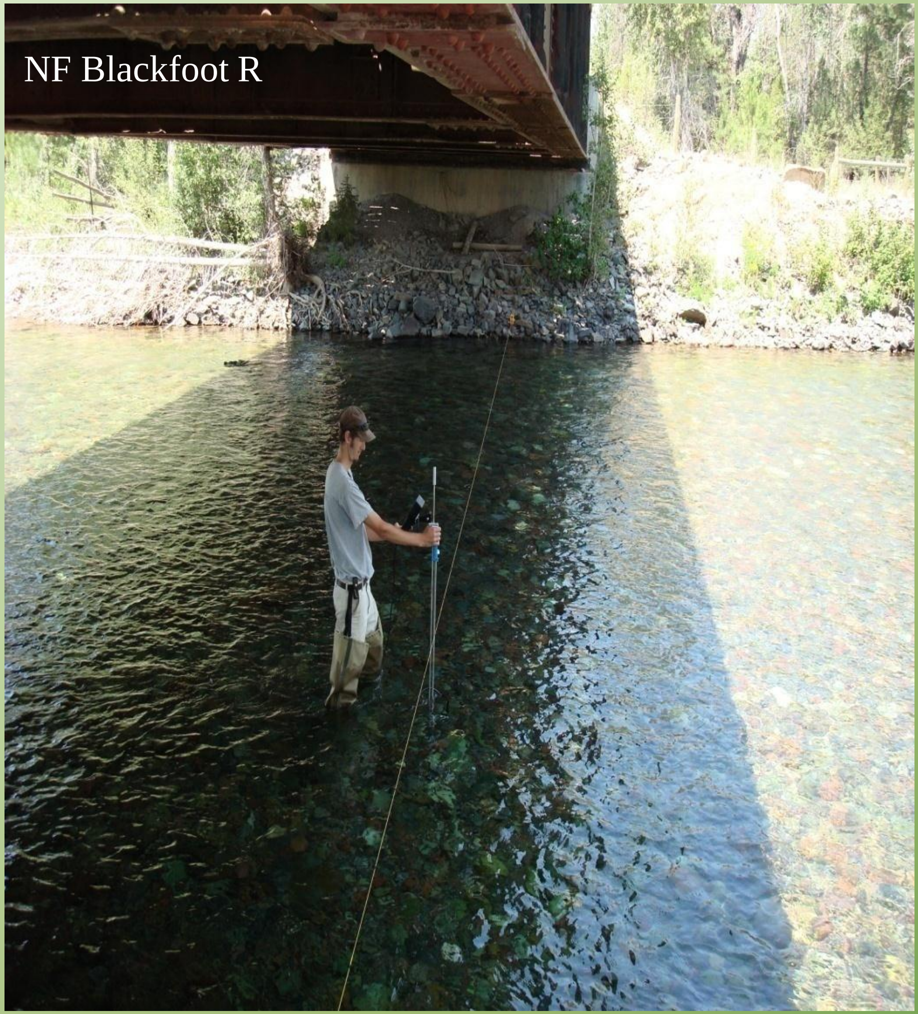
- Cross section should lie within a straight reach, where stream flow lines are parallel to each other
- Velocities should be greater than 0.25 ft/s and depths greater than 0.25 ft
- Streambed should be relatively uniform and free of numerous boulders and heavy aquatic growth

Current Meters

Selection of cross section for conventional current metering (cont)

- Flow in cross section should be relatively uniform and free of eddies, slack water, and excessive turbulence
- Measurement section should be relatively close to the gaging station; there should be no tributary inflows or water diversions between the measurement section and the gage

Site Selection - Q



Good cross-section

Bad cross-section

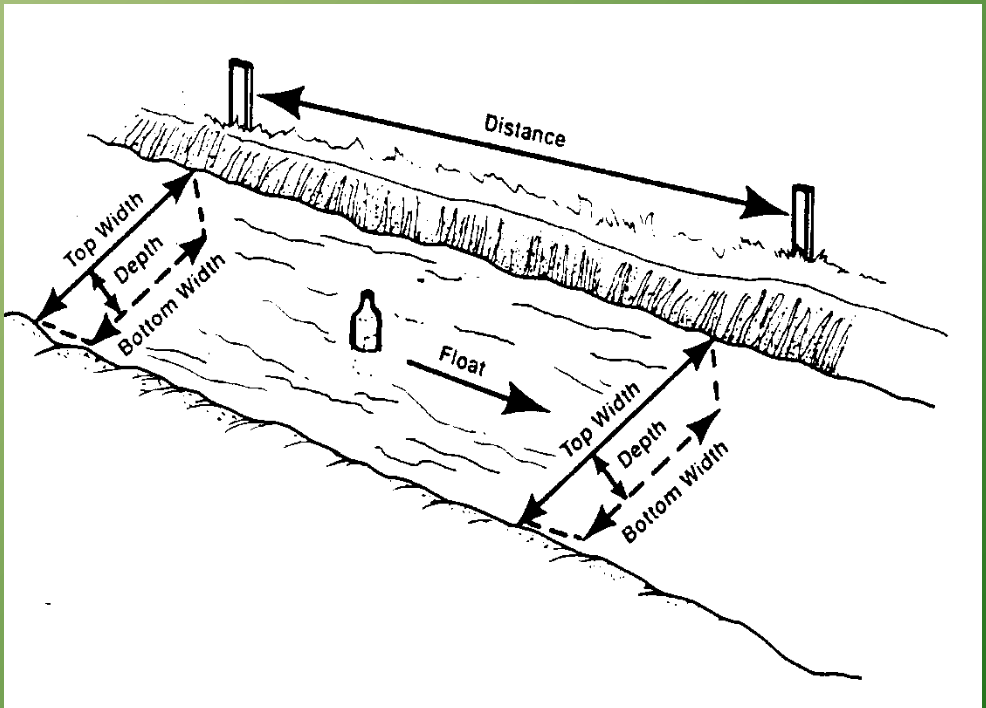

Sometimes you have no choice

Float-Area Method

- Advantages
  - useful when elaborate methods not warranted (ballpark assessment)
  - Useful for demonstrating flow-area concept
- Disadvantages
  - difficulty in determining average cross section
  - susceptible to wind currents, surface disturbances, and cross currents
  - least accurate of all other methods, not applicable for enforcement
  - Susceptible to criticism in a legal proceeding.

Float-Area Method

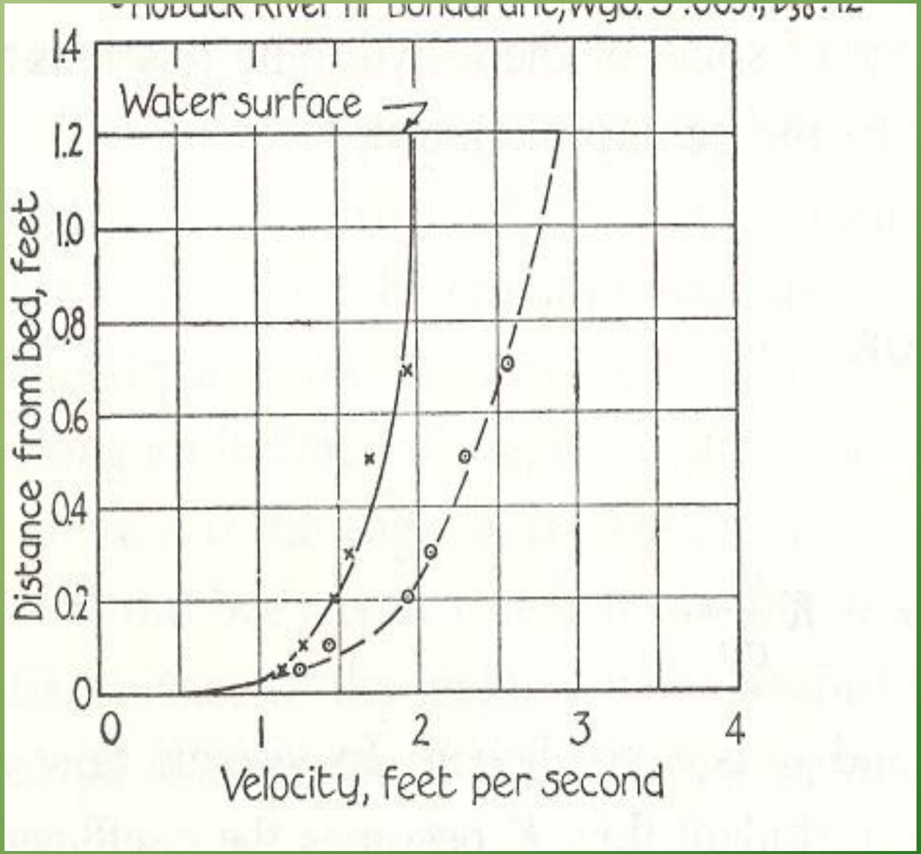
- Utilizes Basic Flow Equation to determine discharge
  - $Q = A_{average} \cdot V_{average}$



Float-Area Method

Coefficients for Converting Float Velocity to Water Velocity

Average Depth (ft)	Coefficient
1	0.66
2	0.68
3	0.70
4	0.72
5	0.74
6	0.76
9	0.77
12	0.78
15	0.79
20 and above	0.80




K-MART
I-15
CAPITOL