Bulletin No. 53 - Measurement of Water for Irrigation

University of Wyoming Agricultural Experiment Station

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The Measurement of Water for Irrigation.

By BURTON P. FLEMING.

Bulletins will be sent free upon request. Address: Director Experimentation Station, Laramie, Wyo.
Wyoming Agricultural Experiment Station.

UNIVERSITY OF WYOMING.

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Introduction.

Numerous inquiries have been received by this Station during the past year with regard to the construction of cheap and efficient measuring devices by which the amount of water flowing in streams and canals could with fair accuracy be determined. These inquiries have come from irrigators and water masters in different parts of the state and indicate an awakening at least in a subject which promises to become of increasing importance as water becomes more valuable. In some parts of the state scarcity of water is already being felt and the state law concerning the measurement of water is beginning to be enforced. The measurements are, however, in many cases extremely inaccurate, due unfortunately to the fact that some of the water commissioners themselves have very indefinite ideas as regards the units used and the means and methods employed in water measurement. A more general knowledge of this subject is necessary before any considerable system and accuracy can be obtained in the distribution of water.

Further, this Station has for some time been engaged in and proposes to continue a study of the duty of water and of the moisture requirements of different crops. In order to make such results of value it has been thought advisable to supplement and precede them by such information on the measurement of water as will make the results interesting to the average farmer and enable him if he so desires to make use of them in his own work.

Attempt has been made in the discussion of the subject to avoid formulas and technicalities as far as possible, but where impossible to avoid them they have been explained as well as may be in simpler terms. The principles of the measurement of water are dealt with in some detail, more perhaps than many to whom the subject is familiar may think necessary. It has been thought, however, that an explanation of the reasons for certain statements would greatly aid in a better understanding of the subject.
Measurement of Water for Irrigation.

COMPLIANCE WITH WATER LAWS IN WYOMING.

Before entering upon what bears particularly upon the subject in hand, it has been deemed advisable to state, so far as we have been able to learn by correspondence and observation, to what extent irrigators in Wyoming comply with those provisions of law regarding the measurement and division of water. The writer has corresponded with a number of Water Commissioners in each of the several divisions of the state and through their kindly interest has been able to gather some quite reliable and valuable information concerning the practical working of one portion, at least, of Wyoming's water laws.

Wyoming is one of the few states in the arid west which has instituted a rigid system of state control in the appropriation and distribution of water for irrigation. It is quite widely admitted that a strict compliance with that portion of the law governing the distribution of water would, in almost all cases, bring to an end the disputes which inevitably must and do arise between irrigators whose rights are vested in the same stream and each of whom firmly believes the other is diverting and using more water than he is rightfully entitled to.

In order, however, to carry out a system of distribution, whether the Wyoming system or any other more or less perfect, it is absolutely essential that some means be provided; first, for regulating the flow of water in the ditches and canals of the irrigators according to their vested rights; and second, for measuring the water flowing in order that a just and true apportionment may be made.

Although our Wyoming law is fairly explicit in its requirements as to headgates and measuring devices yet as a general
rule the provisions are either totally disregarded or most woefully carried out. In many cases a piece of turf or a clod of dirt does service as a headgate and the stream is measured by a process of "sizing up."

In response to the question, "What proportion of the ditches in your district have good, substantial headgates," two-thirds of the water commissioners to whom the inquiry was sent reported that none of the ditches had headgates answering to the description substantial, and, as to weirs or rating flumes, only one in four commissioners reported that they had any in their districts, while seven out of eight reported that complaints from irrigators over the distribution of water were numerous and grievous.

Many things conspire to cause irrigators to be as lax as they are in these matters. Undoubtedly a lack of definite knowledge of how to construct and use measuring devices has something to do with it and probably many can be accused of indifference. Many also, perhaps, are afraid that in the event of a measuring device being placed in their ditch, they themselves may be deprived of water which they unconsciously have been using in excess of their appropriation. Unfortunately there is also another class, "who," as a water commissioner in District No.2 aptly puts it, "do not want the water divided at all and who are only satisfied when they have all that their ditch will carry from the creek regardless of the fact that perhaps half is wasted in leaky flumes, sloughs, etc., before it reaches the point of distribution."

After the eleven years in which the present system of laws has been in force, it is, indeed, surprising to find how little progress has been made toward system and accuracy in the distribution of water. Wyoming is, it is true, as yet just beginning to assume importance as an agricultural state, and methods of measurement and division must, necessarily, be crude, owing to sparsity of population and consequent comparative abundance of water. This is true, however, only in a general way. In
some valleys of the state will be found a large population devoted to agricultural pursuits. It is in such districts that scarcity of water is soonest and most often felt. Here it is that we should expect to find people taking advantage of any state law which would enable them to live in harmony with their neighbors, avoiding those disputes which so frequently and necessarily arise between appropriators in states with less perfect systems of water laws. As a matter of fact, however, the people in few, if any, of the districts in the state attempt to measure the water which they use nor do many ranchmen, except when compelled to, even so much as put headgates in their ditches.

In traveling through one of the more thickly settled valleys in the southeastern part of the state, the writer does not remember of having seen a single headgate which could be called "substantial," nor does he remember of having seen in the whole district a weir or rating flume. Yet, he was informed by many of the people themselves, that each man took as much water as he pleased, and that there were frequent causes for dispute between neighbors.

One ranchman asserted that after a number of ranchmen, living farther up the stream than he and with later rights than his, had diverted what they cared to take, not enough water reached his ranch to provide for the watering of stock and culinary purposes.

Many are inclined to blame the Water Commissioner for such a state of affairs as that illustrated above. The Water Commissioner, however, is supposed to assert his authority only when called upon to do so. And, supposing he is called upon to adjust a difference, how can he make a fair division when no rating flume or weir is provided so that at any time he can accurately measure the water flowing in the stream; and further, what is to prevent a recurrence of the dispute when for a headgate which could be set by the Water Commissioner and locked, there is nothing but a pile of dirt and rocks
which it is possible for either of the disputants to remove or add to as occasion and his own interests may demand?

A very wise amendment has recently been made to the statutes giving to the Division Superintendent the authority to order the construction of headgates and measuring devices wherever and whenever the proper division of water may require. Necessarily, however, there must be some complaint raised by an aggrieved irrigator before the Division Superintendent would have his attention drawn to the grievance. It is not our purpose to attempt to stir up discord between irrigators on the question of priorities. A too strict observance of the system is nearly as baneful in its effects as no system at all. In other words, in times of scarcity an agreement between the appropriators along a stream by which each man uses the water in turn, instead of the man with the earlier right using as much as he pleases while the later comers get what is left, will often tend to promote harmony and perhaps save a great deal of money to all concerned. Likewise it would be a doubtful policy when there is sufficient water in the stream for the use of all, to insist upon a too strict observance of priorities. It is usually, if not always the case, however, that in every district there are some men who absolutely must have as much water as they can use, and more too, at any time they choose to open their headgates, regardless of the loss and inconvenience it may cause others. In such cases as this a more general employment of the right of appeal to the Water Commissioner or Division Superintendent regarding the illegal use of water would tend to promote the general welfare by increasing the amount of land which could be cultivated with the ordinary flow of the stream and by removing the cause of the dissatisfaction which usually results when persons are not sure but that their rights are being infringed upon.

It depends, to a great extent, upon the people of Wyoming themselves, whether they have the chaotic conditions which naturally arise when each man is a self-appointed water com-
missioner, diverting and using water in such amounts and at such times as best suits himself alone, or the order and system which is bound to prevail when the sole power to raise or lower headgates lies with one man appointed to act impartially and strictly according to the acknowledged rights of each appropriator in his district.

It is probably due, in large part, to ignorance of many of the provisions of the law, that it apparently is so lightly regarded. When irrigators, generally, learn of the penalties which it is possible to impose for disturbance of headgates after set by the Water Commissioner, and for refusal or neglect to install headgates and measuring weirs or rating flumes, we may expect an improvement over present conditions. After all, perhaps, the ready acceptance and compliance with regulations concerning the measurement of water will have to come with time, when the population has increased to such an extent that water becomes a commodity to be measured out with as much care as a pound of sugar is weighed, and when the duty of water has been determined for various crops so that farmers will find it to their interest to apply the water in amounts that will produce the largest crop or for a certain prescribed amount of water will economically produce the best results.

In the meantime, however, in the interest of justice and harmony, each man should be allowed the amount of water to which his water certificate entitles him and no more. Further, in times of scarcity, he should be required to do without water or use such an amount as will not injure the earlier rights of men farther down the stream. Likewise, men with early priorities should not be allowed to use the water in excess of the amounts to which their certificates entitle them, thereby preventing injury to later settlers. This can be accomplished by irrigators building, or being made to build, rating flumes or weirs in their ditches with headgates which can be set and locked.
PRINCIPLES OF WATER MEASUREMENT.

Before much can be said regarding the means by which a stream is measured some explanation seems necessary of the principles upon which the measurement depends. To a great many people who have not made a study of the subject the measurement of flowing water seems to be a mystery. They can readily enough conceive of the measurement of the volume of bodies of still water in terms of gallons or cubic feet, but the element of time entering into the measurement of volumes of running water introduces a factor to which they are not accustomed. Many people have seen the means employed in the measurement of flowing water but not knowing the principles underlying the operation, it only added to the mystery.

It is first necessary to understand why water runs down hill. It seems a very easy and complete explanation to say that water flows in a river because its mouth is lower than its source. In reality such an explanation is far from being complete. This is one of the things which though very simple and commonplace has puzzled the wisest heads and has never yet been explained with entire satisfaction. Probably an explanation based on the theory as to the composition of water, best explains the phenomena.

Water is supposed to be made up of small particles or definite units in much the same way that a quantity of sand is made up of individual grains. How large these water particles are is not known, as no microscope has as yet been invented of sufficient power to bring them to view. These small particles or molecules as they are called, naturally have some weight, and are supposed to move over and around each other with practically no friction or cohesion. The slightest impulse, therefore, causes them to move. If water is confined in a vessel and the vessel is tilted the water surface immediately becomes a perfectly level plane in another position. This is because the water particles
have immediately moved to other positions of equilibrium, on the same principle that a ball rolls down an inclined board until it strikes against something which sustains its weight. The slightest tendency to tilt the surface of a body of water leaves myriads of these molecular bodies supported as it were only partially on the under side. This causes them to roll and slide towards a lower level, crowding forward by their weight particles lower down in the body of water. The bed of a stream having more or less inclination causes this rolling and crowding of the individual particles toward the lower level, resulting in the onward flow of the entire mass.

The rate of flow or velocity with which water moves whether running in a channel or issuing from an orifice depends primarily upon the fall or vertical distance through which the water has fallen at the time the velocity is determined. If, in a vessel containing water a hole or orifice is made in the bottom, or side, in order that the water may escape, the velocity of the water as it issues from the orifice is theoretically that of a body which has fallen freely through a distance equal to the head, or distance between the center of the opening and the surface of the water in the vessel, water being supposed to be furnished to the vessel as fast as it flows out. This has been proven both by mathematics and experiment. It can also be explained, however, upon the assumption, previously mentioned, that there is no friction or cohesion between the molecules. Assuming this, it may be supposed that the water which flows from the orifice is composed of particles which have fallen through the mass of the water, from the surface. Owing to absence of friction and cohesion the particles will not be retarded in their descent and upon issuing from the orifice each will have a velocity the same as though they had fallen freely through a distance equal to the head on the orifice. The velocity of a falling body is said to be uniformly accelerated; that is, the body moves over a uniformly increasing distance during each second of its descent. Hence at the end of a given time, or after the body has fallen
through a certain distance, its velocity may be determined from the well known formula that the velocity is equal to the square root of the distance through which it has fallen, multiplied by twice gravity, or sixty-four.*

This formula is expressed mathematically by the equation $V = \sqrt{2gh}$, where $V$ is the velocity in feet per second, $2g$ is the constant factor or 64, and "h" is the head or distance in feet through which the body has fallen. The velocity of the water being known, the amount which will pass through the opening in a second will be the product of the area of the opening multiplied by the velocity in feet per second. This is equivalent to saying that if the water were a solid mass and a piece of it, so to speak, were pushed through the opening with a velocity of, for instance, 10 feet per second, the length of the projecting piece at the end of the first second would be just ten feet. If the area of the opening were one square foot the amount of water issuing in one second would be 10 cubic feet. This same idea can be applied to the flow of water in open channels. Let it be supposed that we have a square trough whose dimensions on the inside are one foot in depth and one foot in width. In this trough water is flowing level with the top at a mean velocity of one foot per second. That is, anything floating in the water and moving at the average rate of the mass would move through a distance of one foot in one second. The discharge then of this trough or the amount of water passing a given point in one second would be said to be one cubic foot per second.

It may be well to explain at this point that the volume of water discharged in a given time from an opening in a vessel or reservoir is not actually what it would be as computed by theory. The reader may have noticed that a jet of water flowing from an opening of which the edges are sharp is smaller in dimensions a short distance from the opening than the opening.

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*A falling body moves through 16 ft. in the first second of its descent, 48 ft. in the next second, 80 ft. in the third second and so on, the distance moved increasing by 32 ft. in each succeeding second. The amount, 32 ft., by which the distance increases in each second is termed gravity and is represented in mathematical formulae by "g"
The Measurement of Water for Irrigation.

This phenomenon is called "contraction of the jet." Its cause is easy to explain. The water particles as they approach the opening from different parts of the mass move in lines converging toward the opening. After the particles pass through they tend to retain their directions for a short distance beyond the plane of the opening, which causes the contraction of the jet where the lines converge. The velocity of the water at this contracted section it has been found is nearly the theoretic velocity, hence the discharge of the opening must be computed from the area of this contracted section. The area of this section is approximately 62 per cent of the area of the opening and the velocity of the water is about 2 per cent less than the theoretic velocity. The amount of water discharged per second is therefore about 61 per cent of the theoretic discharge, or the formula would be $Q = 0.61a\sqrt{2gh}$, where $Q$ is the amount of water in cubic feet discharged in each second, "a" is the area of the opening in square feet, $2g$ is a constant or nearly 64, and "h" is the head on the center of the orifice in feet. These values are for an orifice having a sharp inner edge or where the opening is in a thin plate. An orifice with rounded edges would discharge more than one with square edges, as would also one beveled on the inner side. The amount by which the discharge is increased in such cases has not been well determined, hence in any measurement by means of an orifice or opening where the results are to be accurate the conditions should be similar to those for which constants have been determined, that is, the inner edge of the opening should be sharp and after having once passed the inner edge, the jet of water should flow clear of the sides of the opening. If the wall through which the opening is made is thick the outer edge may have to be beveled so as to prevent any interference with the jet. These principles are applied in the construction of the weir described later.

The velocity of water flowing in rivers and canals cannot be found as in the case of an orifice, by finding the head or vertical distance through which the water has moved at the
time the velocity is determined, which for the case of an orifice is at the instant that it issues from the opening. The velocity of water flowing in channels depends upon the vertical distance moved the same as for orifices, but in the former case is subject to many factors changing to a great extent the theoretic velocity due to the fall. Although the water particles themselves can move over each other with practically no friction or cohesion, yet when in contact with other bodies they are subject to nearly the same frictional resistances as are solid bodies in contact. Hence we find in a river or canal channel that the water flows much more slowly next to the bottom of the channel than at the surface of the water and more slowly at the surface than at about two-thirds of the depth from the bottom, for air as well as the material of the channel retards the flow to a greater or less extent. The rougher the bed of the channel the more slowly will the water move, and if a strong wind is blowing up stream the water may sometimes cease to flow and be backed up the channel. Other conditions also tend to retard the flow, such as the presence of accumulations of silt, waterplants, etc., in the stream’s bed and contractions and windings of the channel.

For these reasons water flowing in an open channel at a constant depth has a velocity which is uniform instead of accelerated. The velocity due to the fall in a certain length along the channel being partly overcome by frictional resistances in that length.

UNIT OF MEASUREMENT.

The standard or unit used in the measurement of flowing water is the cubic foot per second of time. This is such a quantity as flowed in the trough above referred to. To get a concrete idea of how much water is represented by a flow of one cubic foot per second we may imagine the trough before described discharging into a pail holding 7½ gallons. A pail of this size would be filled every second by such a stream, one
cubic foot of water being very nearly equal to 7½ gallons. With the unit well in mind no difficulty will be found in understanding what is meant when the flow of a stream is said to be a certain number of cubic feet per second.

THE MEASURING WEIR.

The means best adapted for the accurate measurement of moderate amounts of water with the least trouble and outlay of money after once established are the weir and rating flume. The first of these, the weir, is most limited in its application to different channels, but where it can be installed its use is attended by fewer inaccuracies in results and greater simplicity. The measuring weir is simply a notch of a certain shape and size in a dam placed across a stream, the arrangement being such that all the water flowing in the stream has to pass through the notch. By merely reading off on a scale in inches or feet the depth of water on the bottom of the notch and referring to a table computed for the particular size of the weir the amount of water in cubic feet per second passing over the weir can be immediately found. There are several classes of weirs known by the shape of the notch, as rectangular, triangular and trapezoidal. The last of these is the simplest, and is the one it is advisable to use in all cases where the weir can be installed.

This weir is the invention of an Italian engineer by the name of Cesare Cippoletti, and its introduction to the farmers of the west is due to Prof. L. G. Carpenter of the Colorado Experiment Station, who first described it in Bulletin 13 and subsequently in Bulletin 27 of that Station.

It will not be possible here to go into details regarding the principle involved in the use of weirs as measuring devices. The derivation of the formula involves higher mathematics. It may be explained, however, that with the weir, as in the case
Fig. 1. The Measuring Weir.
of the orifice previously explained, the amount of water which will pass in a second is dependent primarily upon the area of the opening and the head of water upon it. Various other factors taking into account the shape and position of the opening, and contraction of the water as it leaves the weir, enter into the computation of the discharge. These factors are all included in a mathematical expression which for the trapezoidal or Cippoletti weir, is: \( Q = 3.367bH^{\frac{3}{2}} \), in which "Q" is the discharge in cubic feet per second, "b" is the width of crest in feet, and "H" the head of water on the crest in feet. Such a weir with its box is shown in figure No. 1. It will be noticed in this that the opening, or notch as it is called, is of regular trapezoidal form; that is, the top and bottom are horizontal and the sides slant at a certain angle with the vertical. The notch is shown more in detail in figure No. 2. The line BC is called the crest of the weir, and the slope of the sides, AB and CD, is one inch horizontally for every four vertically. The length of the weir
is the length of the line BC, thus in a two-foot weir the line BC is two feet long.

As shown, the notch is chamfered so that a sharp edge is left on the up-stream side. This detail is very important, as upon it depends, among other things, the accuracy of the measurement. That the use and installation of the weir may be made perfectly clear it may be best to take a concrete case for illustration, giving the design of a weir and showing how to place it.

The first point to which attention must be given is the probable maximum amount of water that will pass over the weir. If the irrigator possesses a certificate from the Board of Control, defining the amount of water to which he is entitled, this amount may be made the basis of an estimate. If not, an estimate may be made on the amount of land which is to be irrigated, allowing 1 cubic foot per second for every 70 acres. Let it be supposed that we have some 200 acres to irrigate. About 3 cubic feet per second then will be the largest amount of water required.

Certain rules have been laid down which must be observed in determining the dimensions of weirs if the results are to be accurate. They are viz.:

1. The greatest depth of water which should be allowed on the crest of the weir should not be more than one-third, or better, one-fourth the length of the weir, and the least depth 3 inches.

2. That the distance from the crest of the weir to the bottom of the weir box should be at least three times the depth on the weir.

3. That the distance of the crest from the sides of the weir box be at least twice the depth of water flowing over the weir.

These rules are intended to eliminate an inaccuracy due to what is known as the velocity of approach. It can be seen that if the water in a stream approaches the weir with considerable
velocity, that the velocity of the water passing through the weir notch will be much greater than if the water behind the weir had been comparatively still. It is for this latter condition that weir formulas have been worked out, and consequently if there is considerable velocity of approach the weir formula cannot be used unless some correction is made for the increased discharge due to the increased velocity with which the water passes over the weir. The rules given above will be found by computation to provide a section of channel above the weir with area equal to about eight times the area of the weir opening. Consequently the velocity of the water in the channel behind the weir would be about one-eighth the velocity of the water passing through the notch. If this ratio is not exceeded no correction need be made for velocity of approach. It is always advisable, therefore, in placing weirs to see to it that the channel behind the weir is large enough to make the velocity of the water as it approaches to flow over the weir so small that the error will be insignificant.

Applying the above rules to the case in hand, we find first by rule 1, and by referring to the weir tables given on pages 80-83, that the length of the weir for a discharge of 3 cubic feet per second should be 2 feet, this giving a depth of about 7 inches on the crest.

The depth of the weir notch should be from one and one-half to two times the greatest depth which is to be allowed on the crest of the weir, which would make the depth of the notch in this case about 12 inches. Allowing a depth of notch of 12 inches and a depth of water on the crest of 7 inches, we find by rule 2 above, that the total depth of the weir box should be 2 feet 9 inches, or three times the depth on the weir plus the 12 inches due to the depth of the notch.

The width of the box should be four times the depth on the crest of the weir, plus 2 feet, (the width of the weir), which gives 52 inches as the total inside width. The length of the box is not of so much importance unless the channel of the ditch or
The construction of the weir box is shown fairly well by figure 1. The material, a bill of which is given below, should be of 2-inch lumber for the body of the box and end. The frame should be of 2 by 4 inch timber. Lumber which has been well seasoned and is free from knots is desirable. The weir shown in the cut has an apron on the sides and bottom. There is always a necessity for this apron when the weir must be placed in soil which cannot be puddled or tamped about the box well enough to prevent the water from finding a way under or around it. Burlap nailed to the bottom and sides of the box, secured to the sides and bottom of the channel with pegs and then covered with dirt makes an excellent apron as the soil is caught in the meshes of the burlap and held there, making it almost waterproof.

Provision must also be made to prevent washing of the bed of the stream by the falling water. A good way to do this is to provide a platform on which the water may drop and riprap the sides of the channel with rock. The platform may be a continuation of the floor of the box.

**Bill of Material for Two-Foot Weir Box.**

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Nails: 3 lbs 20d.; 5 lbs 10d.

Assuming that rough and dressed lumber sell at $25 and $35 per M., respectively, and nails at 5 cents per lb., we find that the total cost of material would be $6.10. The labor in
construction should not cost more than $3.50, which would make the weir cost about $9.60, exclusive of cost of haulage of lumber, etc.

A weir constructed throughout of 2-inch surfaced and grooved lumber would probably be cheaper in the long run, but in most cases first cost is what is considered in building such structures. For ditches of larger size the cost of a weir increases about in proportion.

The opening should be very carefully made. If the weir is to be two feet wide, the breadth of the bottom of the opening or crest as it is called, should be just two feet, after it has been beveled. The sides should slant at the rate of 1 inch horizontally to every four vertically and should also be beveled with the sharp edge up-stream. If the opening is 16 inches deep and the crest is two feet wide, the width of the opening at the top should be 2 feet 8 inches.

It being almost impossible to make a box water tight without calking, it is advisable to fill all cracks in the weir with oakum or putty. If this is not done water will find its way out of the cracks after the weir is set and eventually wash away the soil surrounding the weir box, destroying the accuracy of the measurement and endangering the stability of the box.

As previously stated, the weir is not applicable in all cases and considerable care should be exercised in placing it. The usual and best situation for a weir is in a straight portion of the channel where the banks are high and the fall considerable. In every case it is not possible to find such conditions naturally, in which case the ditch banks above the weir for some distance may need to be strengthened, so that the water as it backs up to flow over the weir may not break the banks. If the channel is narrower than the weir and tortuous, it should be widened to the width of the weir and straightened upstream for about 100 feet.

The weir box should be set level both ways and the crest of the weir should be perfectly level. This last condition, of
course, may be tested when the water flows over the weir. It will be noticed in the sketch that there is a scale placed some distance back from the weir, the object of which is to determine the depth of water flowing over the weir. The reason for its being placed so far back from the crest is that the water, as it passes over the crest, lowers the level of the surface for a short distance back from the weir so that if the depth of water is read on the crest of the weir itself, the head will be too small and the measurement will be inaccurate. The zero point of the scale, which may be marked in tenths and hundredths of feet, or in inches and sixteenths, as desired, should be on an exact level with the crest of the weir. If the zero point of the scale is placed even with the surface of the water at the instant that it commences to flow over the crest and then secured in that position by nailing or clamping, the depths can be determined quite accurately. The scale should be placed at least three feet back of the weir.

A weir placed directly across the channel of a small stream without a box is shown in figure No. 3. Here the banks are

![Fig. 3. Simple Weir in Small Stream.](image-url)
sufficiently high that the water may be backed up the stream a short distance, forming a small pond where the velocity of the water approaching the weir is checked and made so small as to produce no serious error from this cause.

Precautions are of course necessary in this case to prevent leakage past the weir and it must also be carefully placed so that the crest of the weir shall be level and the weir board plumb.

A stake is shown driven in the bed of the stream a short distance, not less than three feet, back of the weir. The top of the stake being placed level with the crest of the weir, the depth of water on the weir may be obtained by simply reading off the depth of water over the stake by means of a carpenter's rule, and by referring to the weir tables the amount of water passing over the weir is found.

The weirs described above are for cases where the whole stream is measured, and the weir is placed directly across the channel. The weir is likewise used where a certain proportion of water in the stream is to be measured out, as in the case of the customer of a canal company. Here the weir is placed next the bank of the canal and the depth of water on the crest of the weir is varied by the use of a gate also set in the canal bank, to suit the requirements of the customer.

Unless some device is used for automatically keeping the head constant the amount of water passing over the weir will of course vary with the rise and fall of water in the canal. Such devices so far invented have, however, been of little practical value. The nearest approach to a successful device of this sort is the Foote water meter, an adapted form of which is shown in figure No. 4. By this device the head on the weir is kept approximately constant, as the tendency to increase the depth of water in the box is partially counterbalanced by the increased flow over the long excess weir.
Fig. 4. A form of the Foote measuring device for maintaining a constant flow in a canal lateral.

D, Dam placed across canal. G, Gate to admit water from canal to weir box. W, Cippoletti weir, heads on which are varied to suit requirements of customer by raising or lowering the excess weir, E, by means of flash boards.

WEIR TABLES.

In the pages immediately following will be found weir tables. Owing to the fact that means are seldom at hand to enable the irrigator to measure the head on his weir in feet and tenths of feet and further because of the small number of persons who readily understand the decimal system of measurement we have thought it advisable to base these tables on the inch system, giving the discharges of Cippoletti weirs for every
The Measurement of Water for Irrigation

eighth of an inch from zero to 20 inches and for lengths of weir between 1 and 10 feet inclusive. This has involved a large amount of computation but it is hoped that the tables will be somewhat simplified and rendered more intelligible to the irrigator. Tables for the computation of the amount of water flowing through rectangular weirs are omitted from the present bulletin owing to the fact that they are more or less difficult to use and because for the purpose of the small ditch owner the Cippoletti weir is by all odds the most accurate and convenient. Quite complete tables have been published for these weirs, among them being those published by Prof. L. G. Carpenter of Colorado Experiment Station in Bulletin No. 27 and those in Bulletin No. 86 of the Office of Experiment Stations, U. S. Department of Agriculture.

For cases where extreme accuracy is required the velocity of approach must be taken into account for reasons briefly explained on pages 72 and 73. An auxiliary table has therefore been added to enable the correction to be made in an approximate way.

USE OF TABLES.

The use of the tables has been quite fully explained previously but a repetition is not out of place if a better understanding will result. The depth of water on the sill or crest of the weir is measured in inches and eighths some distance back of the weir to lessen the inaccuracy due to the surface curve. The depth may be determined with an ordinary carpenter's rule on a stake the top of which has previously been set on a level with the crest of the weir.

With the depth of water found we look in the tables and find the number of inches corresponding to the depth. Opposite these figures under the column indicating the width of the crest of the weir will be found the discharge in cubic feet in every second. It may be said in passing that by multiplying the discharge as found in the table by two, the depth in feet is
found to which an area of one acre would be covered by such a stream flowing continuously for 24 hours.

Where the water in approaching the weir flows with considerable speed a certain percentage must be added to the discharge as determined in the table of weir discharges. The velocity of the water back of the weir may be found approximately by timing floats. Entering this velocity as found in the first column of Table II and finding in the heading the depth of water on the weir, the corresponding correction in per cent is found. For example, let it be supposed that it is desired to determine the amount of water flowing over a 3 foot weir with a depth of 5\(\frac{7}{8}\) inches on the crest and a velocity of approach of one foot per second. In Table I it is found that the discharge for perfect weir conditions is 3.46 cubic feet per second. Referring now to Table II it is seen that for a velocity of approach of one foot per second and a depth of water on the weir of about 0.50 ft., the correction is 7.1 per cent. The percentage correction will be .246 cu. ft. per second and the true discharge therefore 3.706 cu. ft. per second.

**Table I.—Discharge of Cippoletti Weirs of Different Lengths, Computed from the Formula**

\[Q = 3.367LH^{3/2}\]

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**The Measurement of Water for Irrigation.**

81
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</tbody>
</table>
The Measurement of Water for Irrigation.

<table>
<thead>
<tr>
<th>Depth of water on crest</th>
<th>1-foot weir</th>
<th>2-foot weir</th>
<th>3-foot weir</th>
<th>4-foot weir</th>
<th>5-foot weir</th>
<th>6-foot weir</th>
<th>7-foot weir</th>
<th>8-foot weir</th>
<th>9-foot weir</th>
<th>10-foot weir</th>
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<tbody>
<tr>
<td>16%</td>
<td>33 828 30 449</td>
<td>38 806 34 805</td>
<td>42 850 47 940</td>
<td>49 960 56 700</td>
<td>50 820 56 780</td>
<td>56 780 58 790</td>
<td>58 790 60 830</td>
<td>60 830 64 890</td>
<td>64 890 68 960</td>
<td></td>
</tr>
<tr>
<td>16%</td>
<td>33 828 30 449</td>
<td>38 806 34 805</td>
<td>42 850 47 940</td>
<td>49 960 56 700</td>
<td>50 820 56 780</td>
<td>56 780 58 790</td>
<td>58 790 60 830</td>
<td>60 830 64 890</td>
<td>64 890 68 960</td>
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<tr>
<td>17%</td>
<td>34 829 31 449</td>
<td>39 806 35 805</td>
<td>43 850 48 940</td>
<td>51 960 57 700</td>
<td>55 820 60 780</td>
<td>60 780 62 790</td>
<td>62 790 66 830</td>
<td>66 830 70 890</td>
<td>70 890 74 960</td>
<td></td>
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<tr>
<td>17%</td>
<td>34 829 31 449</td>
<td>39 806 35 805</td>
<td>43 850 48 940</td>
<td>51 960 57 700</td>
<td>55 820 60 780</td>
<td>60 780 62 790</td>
<td>62 790 66 830</td>
<td>66 830 70 890</td>
<td>70 890 74 960</td>
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<tr>
<td>17%</td>
<td>35 829 32 449</td>
<td>40 806 36 805</td>
<td>44 850 49 940</td>
<td>53 960 59 700</td>
<td>57 820 64 780</td>
<td>64 780 66 790</td>
<td>66 790 70 830</td>
<td>70 830 74 890</td>
<td>74 890 78 960</td>
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<tr>
<td>17%</td>
<td>35 829 32 449</td>
<td>40 806 36 805</td>
<td>44 850 49 940</td>
<td>53 960 59 700</td>
<td>57 820 64 780</td>
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<td>74 890 78 960</td>
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<tr>
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<td>36 830 33 449</td>
<td>42 806 38 805</td>
<td>46 850 51 940</td>
<td>55 960 61 700</td>
<td>60 820 68 780</td>
<td>68 780 70 790</td>
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<td>42 806 38 805</td>
<td>46 850 51 940</td>
<td>55 960 61 700</td>
<td>60 820 68 780</td>
<td>68 780 70 790</td>
<td>70 790 75 830</td>
<td>75 830 79 890</td>
<td>79 890 83 960</td>
<td></td>
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<tr>
<td>18%</td>
<td>37 831 34 449</td>
<td>43 806 40 805</td>
<td>48 850 53 940</td>
<td>58 960 65 700</td>
<td>64 820 72 780</td>
<td>72 780 75 790</td>
<td>75 790 80 830</td>
<td>80 830 85 890</td>
<td>85 890 90 960</td>
<td></td>
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<tr>
<td>18%</td>
<td>37 831 34 449</td>
<td>43 806 40 805</td>
<td>48 850 53 940</td>
<td>58 960 65 700</td>
<td>64 820 72 780</td>
<td>72 780 75 790</td>
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<td>80 830 85 890</td>
<td>85 890 90 960</td>
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<td>18%</td>
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<td>44 806 42 805</td>
<td>50 850 56 940</td>
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<td>66 820 75 780</td>
<td>75 780 78 790</td>
<td>78 790 83 830</td>
<td>83 830 88 890</td>
<td>88 890 93 960</td>
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<td>38 832 35 449</td>
<td>44 806 42 805</td>
<td>50 850 56 940</td>
<td>60 960 67 700</td>
<td>66 820 75 780</td>
<td>75 780 78 790</td>
<td>78 790 83 830</td>
<td>83 830 88 890</td>
<td>88 890 93 960</td>
<td></td>
</tr>
</tbody>
</table>

*Table II.—Corrections in Per Cent for Velocity of Approach to be Applied to Values Given in Table I.*

<table>
<thead>
<tr>
<th>Velocity in feet per second</th>
<th>DEPTH OVER WEIR IN INCHES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3</td>
</tr>
<tr>
<td>.25</td>
<td>00</td>
</tr>
<tr>
<td>.50</td>
<td>00</td>
</tr>
<tr>
<td>1.00</td>
<td>00</td>
</tr>
<tr>
<td>1.25</td>
<td>00</td>
</tr>
<tr>
<td>1.50</td>
<td>00</td>
</tr>
<tr>
<td>1.75</td>
<td>00</td>
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<tr>
<td>2.00</td>
<td>00</td>
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<tr>
<td>2.25</td>
<td>00</td>
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<td>2.50</td>
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<td>2.75</td>
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<td>3.00</td>
<td>00</td>
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<td>3.25</td>
<td>00</td>
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<tr>
<td>3.50</td>
<td>00</td>
</tr>
<tr>
<td>3.75</td>
<td>00</td>
</tr>
<tr>
<td>4.00</td>
<td>00</td>
</tr>
</tbody>
</table>

*Taken with some omissions from Bulletin No. 27, Colorado Experiment Station.*
THE RATING FLUME.

The chief objections to the use of the weir are: Where the weir is used to measure water heavily laden with sediment this is deposited behind it and when enough accumulates may seriously impair the accuracy of the measurement by causing a large velocity of approach through the filling up of the channel back of the weir. Also in ditches having a slight fall it is often quite expensive to place a weir because of the work required to strengthen and heighten the banks for the distance upstream which the fall may necessitate.

The above objections are overcome by the use of the rating flume, but the water flowing through the flume cannot as in the case of the weir be found by simply reading off a certain depth on a scale and referring to a table computed from a formula covering all sizes of flumes. The principle underlying the use of the rating flume is very simple, being merely that increased flow will occur with increased depths of water in the flume and vice versa. The discharge of the flume is found by experiment for certain depths, and from these values tables may be made showing the discharge at all depths which may occur in the flume. The rating flume is simply a short section of the type of flume used to convey water across ravines, porous ground, etc. Its length should preferably be the width of the channel in which it is placed, but never less than ten feet, and it should be as wide and as deep as the channel in which it is placed. Transversely, it should be perfectly level and longitudinally, it should be set to the grade of the ditch. The floor should be placed slightly above the bottom of the ditch so that it may be kept free from sediment.

The channel above the flume should be as straight as possible for about 100 feet. Any contractions or obstructions in the ditch in this distance should be removed. All this must be attended to in order that the water may approach and pass
through the flume with as few eddies and disturbances as possible. A typical rating flume is shown in figure No. 5. The construction is quite simple and needs little explanation.

Fig. 5. Typical Rating Flume.

The smoother the lumber the better. Lumber planed on one side will give much better results than the same unplaned. The flooring should be laid lengthwise of course, and the uprights should be placed on the outside of the box instead of on the inside, as has been done in some instances. A bill of material is given below for a flume which is supposed to be placed in the same ditch and carrying the same amount of water, with a velocity of about one foot per second, as that in which the weir was installed; so that a comparison in cost between the two structures may be made.

The chief and perhaps the sole objection to the use of the rating flume for the use of the farmer is the fact that its discharge has to be determined by experiment before it can be used to measure the water flowing at different depths in the flume. No two flumes ever discharge the same amount of water for the same depths except where all physical conditions are precisely similar, which is almost an impossibility. Every flume must therefore be rated and its discharge determined for different depths. This is best done by an engineer but may be done approximately by the irrigator himself in the manner described later.
Bill of Material for Rating Flume.

Inside dimensions: 3 ft. wide, 8 ft. long, 2 ft. deep.

<table>
<thead>
<tr>
<th>Where used</th>
<th>Kind of lumber</th>
<th>No. Pieces</th>
<th>Dimensions</th>
<th>Board feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sides</td>
<td>One side dressed</td>
<td>4</td>
<td>1 in. x 6 in. x 16 ft.</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>1 in. x 6 in. x 16 ft.</td>
<td>24</td>
</tr>
<tr>
<td>Bottom</td>
<td></td>
<td>1</td>
<td>1 in. x 12 in. x 12 ft.</td>
<td>12</td>
</tr>
<tr>
<td>Apron</td>
<td>Rough</td>
<td>2</td>
<td>2 in. x 4 in. x 10 ft.</td>
<td>22</td>
</tr>
<tr>
<td>Posts</td>
<td></td>
<td>2</td>
<td>2 in. x 4 in. x 16 ft.</td>
<td>22</td>
</tr>
<tr>
<td>Ties</td>
<td></td>
<td>2</td>
<td>2 in. x 6 in. x 16 ft.</td>
<td>32</td>
</tr>
<tr>
<td>Sills</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Nails: 3 lbs 20d: 4 lbs 10d.

Assuming that dressed lumber sells at $35 per M. and rough at $25 per M., we find that the cost for lumber is about $4.00. The nails at 5c per pound will be 35c. The cost of labor in construction should not exceed $3. This makes a total of $7.35. For larger ditches the cost would probably be in proportion.

METHODS OF MEASUREMENT BY DIRECT DETERMINATION OF THE VELOCITY AND MEASUREMENT OF THE CROSS SECTION OF THE CHANNEL.

It is not always possible to place a weir in a stream to determine its discharge because of the size of the volume of water carried, the slightness of the fall, etc., in which case the velocity of the stream must be found by direct measurement and the discharge or amount of water carried found by multiplying the area of the channel by the mean velocity of the current. As has been stated previously the water at different depths and at different parts of the cross section of a channel flows at different rates by reason of friction between the water and the sides and bottom of the channel. The velocity of a piece of wood floating on the surface of a stream would not be an average of the velocity in all parts of the channel.

In determining the discharge of a stream these different
velocities must of course be determined. There are various mathematical formulas which determine the mean velocity of the stream quite accurately, but these formulas are very complicated and for that reason are not given here. The usual method of finding the discharge or amount of water flowing in a stream is by direct observation of the velocity, in different parts of the cross section of the channel. The area of the channel is found by practically dividing the cross section up into a number of trapezoidal shaped sections. The length of the base of the trapezoid is the interval between certain tags on a line stretched across the stream, and the sides of the figure are determined by measuring the depth of water at each of the tags. The area of the trapezoid is then found by multiplying the length of the interval between tags on the line by the average of the depths. The velocity of the water is found, by methods which will be described later, at approximately the middle of each of the trapezoids. The amount of water passing each of these areas may then be found by multiplying the area of the trapezoids by the velocity. The total discharge of the stream is the sum of the discharges of the several sections.

The velocity is determined by the current meter and by means of floats. The current meter is the most convenient and accurate but its cost precludes its use by those who do not make a business of measuring water. It is essentially a small wheel which is turned by the current when placed in a running stream for the same reason that a windmill is turned by the wind. The number of revolutions of the wheel in a certain time are determined for different velocities, consequently by counting the number of revolutions of the wheel in a certain time when placed in running water the velocity of the current may be determined.

The method of determining the discharge by floats we will describe more in detail, as the current meter is a bit of apparatus not likely to be found in a farmer's kit of tools. The best
form of float to employ is a rod weighted so that it will float upright with the lower end a short distance from the bottom of the channel. A float resting upon the surface of the stream is subject to inaccuracies due to the wind, and for this reason the rod float is always to be preferred.

In gaging a large sized stream by means of floats the procedure is as follows: A length along the stream is found which is quite straight where the section of the channel is, as nearly as possible, uniform in shape and depth and where the channel is free from weeds and watergrasses. A measuring chain, a wire marked off with tags at regular intervals, or even a rope similarly marked, is stretched across the stream at the beginning and end of the straight section. The distance between these two chains or wires should preferably be not less than 50 feet. The depth of water, in feet and tenths of feet, is now determined at regular intervals across the stream along the lines of both of the wires previously stretched. If the stream is wide these intervals may be taken at 4 feet. If a canal, the interval had better be 2 feet, or less, according to the width of the channel. The tags define the intervals.

The usual form of rod float is a tin tube, weighted at the lower end so that it floats upright. Quite as accurate results, however, may be obtained by using willows or sticks found on the spot, with a stone of such weight attached to one end that the stick will float upright with the upper end just projecting above the water. Such sticks should be about an inch or inch and a half through, straight, and of such length that they will nearly touch the bottom of that particular part of the channel in which it is intended they shall float. A leaf or bit of red cloth should be fastened to the upper end so that the float can be distinguished.

It requires two persons to make the measurement, one to time the passage of the floats from the upper to the lower wire and the other to manage the placing of the floats. The person managing the floats places the first of them in the water a short distance above the upper wire and starts it so that it will pass
The Measurement of Water for Irrigation.

as nearly as possible half way between the first tag and the shore, the man on the shore timing the passage of the float between the wires. The next float is then placed in the stream so that it will pass between the first and second tags, its time of passage through the distance found, and so on successively across the entire stream. Much difficulty is often experienced in getting the floats to pass straight down the stream so that the float that was started between two tags on the upper wire will pass between the corresponding tags on the lower wire. Slight variations are, however, allowable.

The time being taken in seconds the velocity of the float or the average velocity or rate of flow of the water in that particular part of the channel will be the distance in feet through which the floats were timed divided by the time in seconds. If the distance be 100 feet and the time occupied by the float in traversing this distance be 50 seconds the velocity of the float will be 2 feet per second. If the time were 20 seconds and the distance the same the velocity would be 5 feet per second, and so on. To compute the amount of water flowing it is necessary first to get the results in tabular form. The following table for results is convenient:

**Measurement of Canal, 1902**

<table>
<thead>
<tr>
<th>Station</th>
<th>Depth at upper section, feet</th>
<th>Depth at lower section, feet</th>
<th>Average depth, feet</th>
<th>Area between stations, sq. ft.</th>
<th>Time of passage, seconds</th>
<th>Velocity in feet per second</th>
<th>Discharge Cubic feet per second</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>.5</td>
<td>.25</td>
<td>3.6</td>
<td>26</td>
<td>1.92</td>
<td>5.11</td>
</tr>
<tr>
<td>4</td>
<td>1.6</td>
<td>1.5</td>
<td>1.55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1.7</td>
<td>1.8</td>
<td>1.75</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>1.4</td>
<td>1.3</td>
<td>1.35</td>
<td></td>
<td></td>
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<td>17.5</td>
<td>.3</td>
<td>.4</td>
<td>.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total discharge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50.22</td>
</tr>
</tbody>
</table>

The figures under station denote the distance in feet from the shore at which the depths were determined. The average
of the depths at the upper and lower wires gives the depths at a section which would be an average cross section of the channel in the distance through which the floats were timed. The average of the depths at two successive stations gives in turn the average depth of the trapezoid. This depth multiplied by the distance between stations, which in the above case was four feet, gives the area of the trapezoid in square feet. The velocity in the particular trapezoid having been determined, we multiply its area by this velocity and get the discharge in the section, which is placed in the column under discharges.

Where as is the case in the example above the distance between the last tag and the shore is not an even interval the area is the average depth multiplied by the distance between the last tag and the shore. If the depth of water at the shore is nothing, that is if the bed slopes evenly up to the edge of the water, the average depth at the section is simply one-half the depth at the last tag. The total discharge is the sum of the separate discharges.

It often happens that the stream is too shallow to allow of the use of rod floats, or the measurement is of so little importance that it is not worth the trouble. In such a case the velocity of the water may be determined with as much accuracy as desired by the use of surface floats. These are simply chips of wood or anything that will float and present but little surface to the wind. They are thrown into the stream and the time of their passage between two points on the banks of the stream a certain distance apart determined the same as for rod floats. The velocity of the stream determined in this way is not, however, the mean or average velocity because the water at the surface moves faster than at the bottom and slower than at about mid-depth, as has been explained previously. Hence the velocities determined in this way must be multiplied by 8-10 or a deduction of 20 per cent made. This coefficient has been determined for various streams and different conditions and is a fair average.
The Measurement of Water for Irrigation.

METHOD OF MEASURING SMALL DITCHES BY MEANS OF FLOATS.

The method of determining the velocity last described is practically the only one that can be used by the ranchman or farmer in determining the discharge of his small ditches when the weir can not be installed. In these small ditches the area of the channel is found in the same way as in the case of the larger ones previously described. In figure No. 6 below is represented the cross section of a small ditch of the form commonly met with. In order to get the area of the section of the channel we proceed as follows: Stretch a string across the stream, if a measuring tape is not at hand, with tags or knots at every six inches. Secure the string so that the first tag is just above the edge of the water at either one of the banks. Then with a carpenter's rule or square find the depth of water at each of the tags. In the figure the ditch is not an even number of intervals wide, in which case the distance between the last tag and the shore should be found. Now determine the average of the depths in each of the different parts into which the section was divided. Thus the average depth of the water between the edge of the water at the left bank and the second tag is two inches; between tags 2 and 3 is 4.5 inches or one-half of four plus 5; between tags 3 and 4 is 5 inches and so on. The average depths are shown in the figure on the dotted lines between the tags.

The area of the channel is now found by multiplying the
average depths by the distance between tags, which is 6 inches, and adding these several products together. In the above figure the area of the section between tags 2 and 3 is the average depth, which is 4.5 inches, multiplied by 6 inches, which gives an area of 27 square inches. The area of the portion between the last tag and the shore is 4 inches times the average depth, 1.5 inches, which gives an area of 6 square inches. The areas of the different sections are shown in the figure. The total area of the channel is the sum of the separate areas, which in the above case is 99 square inches. This method of determining the area of the channel should always be used where the section is of the form represented by the figure. Where the section is of a regular trapezoidal form as shown in figure No. 7, it is sufficiently accurate to measure the width of the channel at mid-depth and multiply this length by the average depth of the water. If inconvenient to get the width at mid-depth it will amount to the same thing if the width of the channel at the water surface and at the bottom is found and an average taken. In case the channel is of the form as shown in figure 6, it will not do as is frequently done to simply measure the depth at the middle of the stream and multiply this depth into the width of the water surface. If this were done in the example given above the area of the channel would be found to be 140 square inches, which is about 41 square inches larger than it actually is.

After the area of the channel has been determined the velocity of the water is found by the float method as has already
been described. The velocity of the water multiplied into the area of the channel gives the discharge of the ditch. It must be remembered, however, that the area of the ditch must first be reduced to square feet if the area has been found in square inches. The reduction is made by dividing the area in square inches by 144, the number of square inches in a square foot. The area of the ditch in the example above cited was found to be 99 square inches. The area in square feet would then be $99/144$, or about .68 square feet. If the length along the ditch through which the chips were timed were 20 feet and it took the chips an average of 18 seconds to traverse the distance their velocity would be $20/18$, or $1.11$ feet per second. Twenty per cent deducted from this amount would give about .81 feet per second as the velocity of the water. This last quantity multiplied by the area of the section would be $.68 \times .81$, which gives .55 cubic feet per second as the discharge of the ditch.

THE RATING OF MEASURING FLUMES.

The rating of a flume in order to determine its discharge for various depths is a process requiring considerable skill and technical knowledge. A gage being placed in the flume the amount of water passing in the flume at different depths on the gage is determined either by the current meter or by the float method as has been described. The discharge having been determined by actual measurement for several depths the method used by engineers in finding the discharge at all depths which may occur in the flume is to plot the depths at which the measurements were made as *ordinates, the corresponding discharges as *abscissas, on cross section paper, and draw a smooth curve which will pass as nearly as possible through each of the points plotted without breaking the smoothness of the

*These are terms used in geometry to denote the vertical and horizontal distances respectively that a point is removed from what is called the center of co-ordinates which is the intersection of vertical and horizontal lines called axes,
curve. The curve having been drawn, it is possible to determine the discharge of the flume for any depth which may occur in the flume within the limits of the depths at which the measurements were made.

An approximate method for establishing the rating of a flume is by a process of averaging. For example suppose that the discharge of the flume at a depth of 2 feet is 56 second-feet and at a depth of 1 foot is 30 second-feet. The discharge at a depth of 1.5 feet would be approximately 43 second-feet; at 1.25 feet depth, 36.5 second-feet, and so on. Of course this method is only very approximate. The points when plotted on cross section paper instead of being in a straight line usually follow a parabolic curve and consequently the discharge at a depth intermediate between two depths at which the discharges have been determined will not be one-half the sum of these two discharges.

HEADGATES.

The headgate is probably the most important structure on the ditch system. It must be so set and located that in times of low water the ditch may not be deprived of water and it must be so strongly made and well protected that spring floods may not carry it away and allow the water to overflow and wash out the banks of the ditch and flood the lands supplied by it. There are two types of headgates in general use, one with the sliding gate and the other with flash boards. The flash boards are inch boards 3 or 4 inches wide which are dropped into slots in the side of the headgate box and secured there. The water is by this means drawn from the surface of the stream and the water next to the bed which contains most of the silt is prevented from entering and depositing the sediment in the ditch.

*A parabola is a curve of the same character as the path taken by a ball thrown from the hand in a horizontal direction.
According to our Wyoming Statutes all headgates must be so constructed that they may be set and locked by the water commissioner. Provision must therefore be made when the headgate is constructed that this may be done.

Some provision should also be made when the sliding headgate is heavy for raising and lowering it. It is certainly unfair to the water commissioner going his rounds in the performance of his duties to find that some one has preceded him with a sledge and crow-bar and has set his headgate to suit himself, unmindful or in the majority of cases perhaps quite conscious of the fact that no one else with anything less than a six-foot crow-bar and a ten-pound sledge can raise that gate. An ordinary rack and pinion attachment will cost but very little and save a good deal of muscular effort. A screw with a nut is also a good device for raising and lowering a large gate, but the action is very slow.

A headgate suitable for a small ditch is shown in figure No. 8. Particular attention is directed to the flaring boards or apron as it is called at the end of the headgate next the river. This apron very materially strengthens the structure in times of high water and prevents leakage around and under the box, which more than anything else tends to weaken the strength of a headgate. After the apron has been constructed the space in front which must be excavated in order to build the apron should be filled in to the grade of the ditch and well tamped.

No attempt should be made to measure water by the opening in the headgate through which the water runs. Some people labor under the erroneous impression that a gate 24 inches wide raised 4 inches will allow twice as much water to pass as a gate of the same width raised 2 inches. Nothing could be further from the truth. It must be remembered that the amount of water passing depends upon the head or depth of water over the opening as well as the area and further that the amount of water varies also with the cube of the square root of the head instead of directly with the head. In other
words if we have two openings of the same size one with 24 inches of water upon it and the other with 12 inches we should not have one opening discharging twice as much water as the other.

Fig. 8. Headgate for Small Ditch.

Headgates therefore cannot be employed to measure water with any accuracy in the way in which they are ordinarily used, the proper way being to install a good substantial headgate at the head of the ditch and a short distance below the headgate place a weir or rating flume. The headgate can then be raised or lowered to admit a certain amount of water as determined by the measuring device.
Water Laws of Wyoming.

In the following pages is given an abridgement of the Wyoming law relating to the appropriation and distribution of water. Those provisions concerning the pay of water officials, duties, oaths, bonds, etc., and the adjudication of existing water rights are omitted as having no bearing upon the subject.

It has been thought that a more general knowledge of the law would greatly influence irrigators toward system in their use of water and lighten the cares of the water officials.

Special attention is directed to Sections 971 and 972, relating to the powers of the Water Commissioner to make arrests of persons unlawfully interfering with headgates, and to Section 930, relating to the establishment of devices for measuring water.

The water laws of Wyoming, complete with the exceptions of Sections 865, 891, 894, 930, 971, and 1959, which have been amended since its publication, will be found in Bulletin No. 96 of the Office of Experiment Stations, U. S. Department of Agriculture, which is distributed free to those applying for it, and from which the following has largely been compiled:

CONSTITUTIONAL PROVISIONS.

ARTICLE I.

Water Control in State.

Sec. 31. Water being essential to industrial prosperity, of limited amount and easy of diversion from its natural channels, its control must be in the State, which, in providing for its use, shall equally guard all the various interests involved.
ARTICLE VIII.

Water is Property of State.

Section 1. The water of all natural streams, springs, lakes, or other collections of still water, within the boundaries of the State, are hereby declared to be the property of the State.

Board of Control.

Sec. 2. There shall be constituted a board of control to be composed of the State engineer and superintendents of the water divisions, which shall, under such regulations as may be prescribed by law, have the supervision of the waters of the State, and of their appropriation, distribution, and diversion, and of the various officers connected therewith, its decisions to be subject to review by the courts of the State.

Appropriation.

Sec. 3. Priority of appropriation for beneficial uses shall give the better right. No appropriation shall be denied except when such denial is demanded by the public interests.

Water Divisions.

Sec. 4. The legislature shall by law divide the State into four water divisions and provide for the appointment of superintendents thereof.

State Engineer.

Sec. 5. There shall be a State engineer, who shall be appointed by the governor of the State and confirmed by the senate; he shall hold his office for the term of six years, or until his successor shall have been appointed and shall have qualified; he shall be president of the board of control and shall have general supervision of the waters of the State and of the officers connected with its distribution. No person shall be appointed to this position who has not such theoretical knowledge and such practical experience and skill as shall fit him for the position.

ARTICLE XIII.

May Acquire Water by Appropriation and Condemnation.

Sec. 5. Municipal corporations shall have the same right as individuals to acquire rights, by prior appropriation and otherwise, to the use of water for domestic and municipal purposes, and the legislature shall provide by law for the exercise upon the part of incorporated cities, towns, and villages of the right of eminent domain for the purpose of acquiring from prior appropriators, upon the payment
of just compensation, such water as may be necessary for the well-being thereof and for domestic uses.

STATUTORY PROVISIONS.

WATER DIVISIONS AND DIVISION SUPERINTENDENTS.

Water Divisions Defined.

Sec. 848. The State of Wyoming is hereby divided into four water divisions, as follows:

Water Division No. 1 shall consist of all lands within this State drained by the North Platte River and the tributaries of the North Platte River and the South Platte River, Snake River (a tributary of Green River) and its tributaries, and Running Water Creek and its tributaries.

Water Division No. 2 shall consist of all lands within this State drained by the tributaries of the Yellowstone and Missouri rivers north of the watershed of the North Platte River and Running Water Creek and east of the summit of the Big Horn Mountains.

Water Division No. 3 shall consist of all lands within this State drained by the Big Horn River and its tributaries and by Clarks Fork and its tributaries.

Water Division No. 4 shall consist of all lands within this State drained by the Green, Bear and Snake rivers and the tributaries thereof, except Snake River (a tributary of Green River) and its tributaries.

Division Superintendents, Appointment and Term of.

Sec. 849. There shall be one superintendent for each of the water divisions, who shall be appointed by the governor, with the consent of the senate, who shall hold his office for four years, or until his successor is appointed and shall have qualified, and who shall reside in the water district for which he is appointed. The superintendent of each water division shall have immediate direction and control of the acts of the water commissioners and of the distribution of water in his water division, and shall perform such duties as shall devolve upon him as a member of the board of control.

Duties.

Sec. 850. Said division superintendent shall have general control over the water commissioners of the several districts within his
division. He shall, under the general supervision of the state engineer, execute the laws relative to the distribution of water in accordance with the rights of priority of appropriation, and perform such other functions as may be assigned to him by the State engineer.

May Make Regulations.

Sec. 851. Said division superintendent shall, in the distribution of water, be governed by the provisions of this title, but for the better discharge of his duties he shall have authority to make such other regulations to secure the equal and fair distribution of water in accordance with the rights of priority of appropriation as may, in his judgment, be needed in his division; Provided, Such regulations shall not be in violation of the laws of the State, but shall be merely supplementary to and necessary to enforce the provisions of the general laws and amendments thereto.

Appeal from.

Sec. 852. Any person, ditch company, or ditch owner who may deem himself injured or discriminated against by any such order or regulations of such division superintendent shall have the right to appeal from the same to the State engineer by filing with the State engineer a copy of the order or regulation complained of and a statement of the manner in which the same injuriously affects the petitioner's interest. The State engineer shall, after due notice, hear whatever testimony may be brought forward by the petitioner, either orally or by affidavit, and, through the division superintendent, shall have the power to suspend, amend, or confirm the order complained of.

Water Commissioners to Report to Superintendent.

Sec. 853. All water commissioners shall make reports to the division superintendent of their division as often as may be deemed necessary by said superintendent. Said reports shall contain the following information: The amount of water necessary to supply all the ditches, canals, and reservoirs of that district; the amount of water actually coming into the district to supply such ditches, canals, and reservoirs; whether such supply is on the increase or decrease; what ditches, canals, and reservoirs are at that time without their proper supply, and the probability as to what the supply will be during the period before the next report will be required, and such other and further information as the division superintendent of that division may suggest.
Reports Filed, Duties of Superintendents.

Sec. 854. Said division superintendent shall carefully file and preserve such reports, and shall from them ascertain what ditches, canals, and reservoirs are, and what are not, receiving their proper supply of water; and if it shall appear that in any division of that district any ditch, canal, or reservoir is receiving water whose priority postdates that of the ditch, canal, or reservoir in another district, as ascertained from his register, he shall at once order such postdated ditch, canal, or reservoir shut down, and the water given to the elder ditch, canal, or reservoir, his orders being directed at all times to the enforcement of priority of appropriation, according to his tabulated statement of priority, to the whole division, and without regard to the district within which the ditches, canals, or reservoirs may be located. The reports of water commissioners to the division superintendents of irrigation shall be filed and kept in the office of the State engineer.

BOARD OF CONTROL—DUTIES AND POWERS.

Board of Control, Officers.

Sec. 857. There is hereby constituted a board of control composed of the State engineer and the superintendents of the four water divisions. Said board shall have an office with the State engineer at the capitol, at Cheyenne, and shall hold two meetings each year for the transaction of such business as may come before it, the first of said meetings to begin on the second Wednesday in March and the second on the third Wednesday in October. The State engineer shall be ex-officio president of said board, and shall have the right to vote on all questions coming before it, and a majority of all the members of said board shall constitute a quorum to transact business.

Secretary of Board.

Sec. 858. The superintendent of water division number one shall be the secretary of the State board of control, and it shall be his duty to keep a full, true, and complete record of the transactions of the said State board of control and of the special land commission, and shall certify, under seal, all certificates of appropriation of water made in accordance with law.

WATER COMMISSIONERS.

Districts.

Sec. 888. The board of control shall divide the state into water
districts, said water districts to be so constituted as to secure the
best protection to the claimants for water and the most economical
supervision on the part of the State; said water districts shall not
be created until a necessity therefor shall arise, but shall be created
from time to time as the appropriations and priorities thereof from
the streams of the State shall be adjudicated.

Commissioner, How Appointed—Term.

Sec. 889. For each water district there shall be appointed one
commissioner who shall be a resident of the district in which he is
to serve, and who shall be appointed by the governor, to be selected
by him from persons recommended to him by the superintendent of
the water division in which such water district is situated. Each
commissioner shall hold his office two years, and until his successor
is appointed and qualified, and the governor shall, by like selection
and appointment, fill all vacancies which may occur in the office of
water commissioner, and may at any time remove any water com-
mis sioner for failure to perform his duties as such water commis-
sioner, upon complaint in that respect being made to him in writing.

Duties.

Sec. 890. It shall be the duty of said water commissioner to di-
vide the water in the natural stream or streams of his district among
the several ditches taking water therefrom, according to the prior
rights of each, respectively, in whole or in part, and to shut and
fasten, or cause to be shut and fastened, under the direction of the
superintendent of his water division, the headgates of ditches head-
ing in any of the natural streams of the district when, in times of
scarcity of water, it is necessary to do so by reason of the priority
of rights of others taking water from the same stream or its tribu-
taries.

Duties, Continued—Appropriator's Right of Appeal.

Sec. 891. Said water commissioner shall, as near as may be, di-
vide, regulate, and control the use of the water of all streams within
his district by such closing or partial closing of the headgates as
will prevent the waste of water, or its use in excess of the volume to
which the appropriator is lawfully entitled, and any person who may
be injured by the action of any water commissioner, or by his failure
to act pursuant to this chapter, shall have the right to appeal to the
division superintendent, and from his decision the party aggrieved
may appeal to the State engineer. And from the decision of the
State engineer in said matter, an appeal may be had to the district
court of the county wherein the ditch or ditches over which the controversy arises are situated.

**When to Begin Work.**

Sec. 894. Said water commissioners shall begin their work at the written call of two or more appropriators, owners, or managers of ditches. Said water commissioner may begin at the written call of one appropriator if the reasons given for the same are deemed sufficient by the commissioner.

**Limitation on the Use of Water.**

Sec. 895. The priority of right to the use of water shall be limited and restricted to so much thereof as may be necessarily used and appropriated for irrigation or other beneficial purposes as aforesaid, irrespective of the carrying capacity of the ditch, and all the balance of the water not so appropriated shall be allowed to run in the natural stream from which such ditch draws its supply of water, and shall not be considered as having been appropriated thereby; and in case the owner or owners of any such ditch, canal, or reservoir shall fail to use the water therefrom for irrigation or other beneficial purposes, or shall refuse to furnish any surplus water to the owner or owners of lands lying under such ditch as hereinafter provided, during any two successive years, they shall be considered as having abandoned the same, and shall forfeit all water rights, easements, and privileges appurtenant thereto, and the waters formerly appropriated by them may be again appropriated for irrigation and other beneficial purposes, the same as if such ditch, canal, or reservoir had never been constructed; neither shall the owner or owners of any such ditch, canal, or reservoir have any right to receive from others any royalty for the use of the water carried thereby, but every such owner or owners having a surplus supply of water, and furnishing the same to others from any ditch, canal, or reservoir as hereinafter provided, shall be considered common carriers and shall be subject to the same laws that govern common carriers.

**County Commissioners Shall Regulate the Sale of Surplus Water.**

Sec. 896. The owner or owners of any ditch which carries a greater quantity of water than the owner or owners thereof necessarily use for irrigation or other beneficial purposes in connection with their own lands shall, when application is made to them for that purpose, furnish such surplus water at reasonable rates to the owners of lands lying under any such ditch for the purpose of re-claiming such lands and rendering the same productive; and in case
of refusal so to do, the owner or owners of any such ditch may be compelled by injunction suit to furnish such water on such terms as to the court may seem meet and proper; Provided, That the board of county commissioners in their respective counties shall have power, when application is made to them by either party interested, to establish reasonable maximum rates to be charged for the use of water, whether furnished by individuals or corporations.

When Land Owner Entitled to Right of Way—Damages.

Sec. 897. When any person owning claims in such locality has not sufficient length of area exposed to said streams to obtain a sufficient fall of water to irrigate his land or his farm, or land used by him for agricultural purposes is too far removed from said stream, and he has no water facilities on those lands, he shall be entitled to a right of way through the farms or tracts of land which lie between him and said stream, or the farms or tracts of land which lie above and below him on said stream for the purpose hereinafter stated; Provided, That in the construction, keeping up, and using any such ditch through the lands of another person, the person or persons constructing or using said ditch, or whose duty it shall be to keep the same in repair, shall be liable to the person owning or claiming such land for all damages accruing to such person by reason of said construction, keeping up, and using such ditch.

Extent of Right of Way.

Sec. 898. Such right of way shall extend only to a ditch, dyke, or cutting sufficient for the purposes required.

Petition to Commissioners—Notice of Appointing Appraisers.

Sec. 899. Upon the refusal of owners of tracts of land, or lands, through which said ditch is proposed to run to allow of its passage through their property, the persons desiring to open such ditch may present to the county commissioners of the county in which said lands are located a petition signed by the person or persons, describing, with convenient accuracy, the lands so desired to be taken as aforesaid, setting forth the name or names of the owner or other person interested, and praying the appointment of three appraisers to ascertain the compensation to be made to such owner or persons interested. Upon the receipt of said petition, the said county commissioners shall give notice, at least thirty days prior to the appointment of the said appraisers, by public notice in a newspaper, when published in the county, or by posting three or more notices in three different places in said county, stating that such appraisers will be appointed on the — day of ———.
Proceedings of Appraisers—Payment of Assessment.

Sec. 900. The said appraisers, before entering upon the duties of their office, shall take an oath to faithfully and impartially discharge their duties as said appraisers. They shall hear the proofs and allegations of the parties, and any two of them, after reviewing the premises, shall, without fear, favor, or partiality, ascertain and certify the compensation proper to be made to said owner, or persons interested, for the lands to be taken or affected, as well as all damages accruing to the owner or person interested in consequence of the condemnation of the same, taken or injuriously affected as aforesaid, making such deduction allowance for real benefits or advantages as such owner or parties interested may derive from the construction of any such ditch or flume. They, or a majority of them, shall subscribe a certificate of their said ascertainment and assessment, which shall be recorded in the county clerk's office of the county in which said lands are situated, and upon the payment of the compensation (if any), the said person or persons shall have the right of way to construct said ditch or flume.

Ditches to be Kept in Repair.

Sec. 901. The owner or owners of any ditch for irrigation or other purposes shall carefully maintain the embankment thereof, so that the waters of such ditch may not flood or damage the premises of others.

Vested Rights Preserved.

Sec. 902. Nothing in this chapter contained shall be so construed as to impair the prior vested rights of any mill or ditch owner, or other person, to the use of any such water course.

When Commissioners to Bridge Ditches—Expenses.

Sec. 903. When any such ditch or water course shall be constructed across any public traveled road, and not bridged within three days thereafter, it shall be the duty of the county commissioners of the county in which said ditch and road are located to put a bridge over said ditch or water course, and call upon the owner or owners of said ditch or water course to pay the expenses of constructing said bridge, and if payment thereof be refused, a civil action may be maintained for the recovery of the same, together with all accruing costs.

Claim for Right of Way May be Arbitrated.

Sec. 904. Upon the refusal of the owner or owners of land or lands through which any person or persons are desirous of construct-
ing any irrigation ditch or ditches, then it shall be lawful for the parties interested to settle the matter by the appointment of a board of arbitration consisting of three men, as hereinafter provided.

Appointment and Proceedings of Arbitrators.

Sec. 905. The creation of the board of arbitration shall be as follows: The person or persons desiring the construction of such ditch or ditches, and the owner or owners of the land or lands through which the construction of such ditch or ditches is contemplated, shall each choose one disinterested resident property holder of the county in which the land or lands mentioned above are situated, and the two so chosen shall designate a third person with like qualifications as themselves, and it shall be lawful for these persons to immediately proceed to hear the proof and allegations of the parties concerned. It shall be lawful for any two of such board of arbitration to make such assessment of damages as may in their judgment be deemed just and right, taking into consideration the benefits, if any, that may accrue to the owner or owners of the land or lands through which the construction of such ditch or ditches is contemplated.

Appeal to Commissioners.

Sec. 906. Should the verdict or assessment of such board of arbitration be unsatisfactory to either or both of the parties interested, then recourse may be had by an appeal made in writing, within ten days from the rendering of such verdict by such board of arbitration, addressed to the board of county commissioners of the county in which the contestants reside; in which case the party taking the appeal shall give bonds for all costs; then the case shall stand as though no action had been taken in the matter, and the parties may then proceed under this chapter in the same manner as though the proceedings to ascertain the compensation to be given had been taken before the county commissioners in the first instance.

If no Appeal is Taken, Award is Final.

Sec. 907. In case no appeal be taken as above provided by either of the parties interested, then the finding of such board of arbitration shall be binding and final; Provided, The sum of money agreed upon by the board of arbitration has been tendered or paid, or a deed for such right of way executed and delivered or tendered by the party or parties over whose land the right of way is sought.
PARTNERSHIP DITCHES.

District Court May Appoint Person to Distribute Water.

Sec. 908. Whenever two or more persons, joint owners in an irrigation ditch, their lessee or lessees, are unable to agree relative to the division or distribution of water received through such ditch, it shall be lawful for any such owner or owners, his or their lessee or lessees, or either of them, to apply to the district court of the district in which such ditch shall be located, by a verified petition setting forth such fact, asking for an order appointing some suitable person to take charge of such ditch for the purpose of making a just distribution of the water through the same, to the several owners or parties entitled to the use of the waters received through such ditch.

Clerk Shall Issue Summons, When.

Sec. 909. The petition mentioned in the preceding section shall be filed with the clerk of the district court of the county in which such ditch shall be located, or a portion thereof, and upon the filing of such petition it shall be the duty of said clerk to immediately issue summons as in other cases, notifying the owner or owners, lessee or lessees of such ditch other than those filing such petition, and requiring them to appear within five days from the date of the issuance of such summons, and to make answer to such petition; Provided, however, that such summons shall be served at least two days before the date fixed therein for the answer.

Hearing.

Sec. 910. The hearing provided for under this chapter may be heard either before the court, the judge thereof sitting in chambers, or the district court commissioner of said county, and shall be had upon the day fixed in the summons for making answer to the petition filed, or as soon thereafter as possible, and the decision of the court, judge or commissioner shall be final.

Duties of Person Appointed.

Sec. 911. Upon it being made to appear to the satisfaction of the court, judge, or commissioner hearing such application, that the protection of the rights to the use of the water in said ditch of the applicant or applicants requires the issuance of such order, he shall appoint some suitable person, not having a personal interest in such ditch, to divide and distribute the waters received through such ditch as in his judgment justice may require, in accordance to the rights of the several owners, or their lessee or lessees. The person
so appointed shall have exclusive control of such ditch for the purposes of dividing and distributing the water received into the same until such time as he may be removed by the order of the proper court, judge, or commissioner.

**Statement Required.**

Sec. 912. The person so appointed shall render to the court, judge, or commissioner appointing him, monthly, or oftener if required, a full and itemized statement of the services rendered by him, and the expenses, if any, incurred by him in the discharge of his duty, and upon the approval of such account or accounts, judgment shall be rendered at the next term of said court for any unpaid balance thereon against the several owners of such ditch who refuse or neglect to pay their pro rata share of such expense in favor of such person so as aforesaid appointed.

**Compensation.**

Sec. 913. The person appointed as hereinbefore provided shall receive as compensation for his services the sum of three dollars per day for each day or part of a day in excess of a half day, actually and necessarily spent in the performance of the duties of his office, together with actual expenses; and as security for the payment of his services and expenses as may be allowed, he may file in the office of the county clerk of the county wherein said ditch is located, the itemized account or accounts when allowed as above, provided it be accompanied with an affidavit as to the amount unpaid thereon, and when so filed it shall constitute a valid lien against the interest in said ditch of the owner in default of payment, which may be enforced in the same manner as provided by law for the enforcement of mechanics' and builders' liens.

**Fees.**

Sec. 914. The fees of the clerk, of the sheriff and commissioner, shall be the same as those allowed for similar services in other cases, and shall in the first instance be paid by the party or parties applying for the service, but ultimately as may by the court, judge, or district court commissioner be apportioned, for which judgment shall be so rendered.

**Majority of Owners May Maintain Ditch.**

Sec. 915. In all cases where irrigation ditches are owned by two or more persons, and one or more of such persons shall fail or neglect to do his, her or their proportionate share of the work necessary
for the proper maintenance and operation of such ditch or ditches, such other owner or owners, being a majority of the owners of such ditch, desiring the performance of such work, may, after having given ten days' written notice to such owner or owners who have so failed to perform their proportionate share of such work necessary for the operation and maintenance of said ditch or ditches, perform such labor and recover therefor from such person or persons so failing to perform his, her or their share of such work in any competent court having jurisdiction of the subject-matter, the expense or value of such work or labor so performed.

Lien for Work Performed on Ditch.

Sec. 916. Upon the failure of any co-owner to pay his proportionate share of such expense, as mentioned in the preceding section, within thirty days after receiving a statement of the same as performed by his co-owner or owners, such person or persons so performing such labor may secure payment of said claim by filing an itemized and sworn statement thereof, setting forth the date of the performance and the nature of the labor so performed with the county clerk of the county wherein said ditch is situated, and when so filed it shall constitute a valid lien against the interest of such person or persons who shall fail to perform their proportionate share of the work requisite to the proper maintenance of said ditch, which said lien when so taken may be enforced in the same manner as provided by law for the enforcement of mechanics' and builders' liens.

PROCEDURE RELATIVE TO THE APPROPRIATION OF WATER.

Application.

Sec. 917. Any person, association, or corporation hereafter intending to acquire the right to the beneficial use of the public water of the State of Wyoming shall, before commencing the construction, enlargement, or extension of any ditch, canal, or other distributing works, or performing any work in connection with said construction, or proposed appropriation, make an application to the State engineer for a permit to make such appropriation. Such application must set forth the name and postoffice address of the applicant, the source of the water supply, the nature of the proposed use, the location and description of the proposed ditch, canal, or other work, the time within which it is proposed to begin construction, the time required for the completion of construction, and the time required for the complete application of the water to the proposed use.
Duty of State Engineer.

Sec. 918. In case the proposed right of use is for agricultural purposes, the application shall give the legal subdivisions of land proposed to be irrigated, with the total acreage to be reclaimed, as near as may be. On receipt of this application, which shall be of a form prescribed by the State engineer, it shall be the duty of that officer to make an endorsement thereon of the date of its receipt, and to make a record of such receipt in some suitable book in his office. It shall be his duty to examine said application and ascertain if it sets forth all the facts necessary to show the location, nature, and amount of proposed use. If, upon such examination, the application is found defective, it shall be the duty of the State engineer to return the same for correction. The date of such return, with the reasons therefor, shall be endorsed on the application and a record made thereof in the book kept for recording receipts of such applications. A like record shall be kept of the date of the return of corrected applications and of the date of the refusal and return of applications rejected.

Approval of Application.

Sec. 919. All applications which shall comply with the provisions of this chapter and with the regulations of the engineer's office, shall be recorded in a suitable book kept for that purpose, and it shall be the duty of the State engineer to approve all applications made in proper form which contemplate the application of the water to a beneficial use and where the proposed use does not tend to impair the value of existing rights or be otherwise detrimental to the public welfare; but where there is no unappropriated water in the proposed source of supply, or where the proposed use conflicts with existing rights, or threatens to prove detrimental to the public interest, it shall be the duty of the State engineer to reject such application and refuse to issue the permit asked for.

Application, How Endorsed.

Sec. 920. The refusal or approval of an application shall be endorsed thereon and a record made of such endorsement in the State engineer's office. The application so endorsed shall be returned to the applicant. If approved, the applicant shall be authorized, on receipt thereof, to proceed with the construction of the necessary works, and to take all steps required to apply the water to a beneficial use, and to perfect the proposed appropriation. If the application is refused, the applicant shall take no steps towards the prose-
cution of the proposed work or the diversion and use of the public water so long as such refusal shall continue in force.

Additional Information.

Sec. 921. Before either approving or rejecting an application, the State engineer may require such additional information as will enable him to properly guard the public interests, and may, in the case of applications proposing to divert more than twenty-five cubic feet of water per second of time, or to reclaim over one thousand acres of land, require a statement of the following facts: In case of incorporated companies, he may require the submission of the articles of incorporation, the names and the places of residence of its directors and officers, and the amount of its authorized and of its paid-up capital. If the applicant is not an incorporated company, he may require a showing as to the name or names of the party or parties proposing to construct the work, and a showing of facts necessary to enable him to determine whether or not they have the financial ability to carry out the proposed work, and whether or not the said application has been made in good faith.

Limitation on Time of Completing Work.

Sec. 922. In his endorsement of approval on any application the State engineer shall require that actual construction work shall begin within one year from the date of such approval, and that the construction of any proposed irrigation work shall be completed within a period of five years from the date of such approval. He may limit the applicant to a less period of time for the completion of work than is asked for, and likewise the perfecting of the proposed right for a less period than named in the application. The State engineer shall have authority, for good cause shown, to extend the time within which irrigation or other works shall be completed under any permit therefor issued by said engineer.

Appeals.

Sec. 923. Any applicant feeling himself aggrieved by the endorsement made by the State engineer upon his application may, in writing in an informal manner and without pleadings of any character, appeal to the board of control for an examination and reversal of the endorsement of the State engineer; and if he shall deem himself aggrieved by the order made by the board of control with reference to his application, he may take an appeal therefrom to the district court of the county in which the point of diversion of the proposed appropriation shall be situated. Such appeal shall be taken within sixty days from the issuance of the order by the board of con-
control, and shall be perfected when the applicant shall have filed in
the office of the clerk of such district court a copy of the order ap-
pealed from, certified by the secretary of the board of control as a
true copy, together with the petition to such court, setting forth the
appellant's reason for appeal, and such appeal shall be heard and
determined upon such competent proof as shall be adduced by the
applicant and such like proofs as shall be adduced by the board of
control, or some person duly authorized in its behalf.

Maps to be Filed.

Sec. 924. Each application for permit to appropriate water for
beneficial uses must be accompanied by a map or plat in duplicate,
showing accurately the location and extent of the proposed work.
These maps or plats must be drawn on tracing linen, on a scale not
less than two inches to the mile; they must show the location of the
headgate or point of diversion by courses and distances from some
government corner; they must show the actual location of the ditch
or canal, or water line of the reservoir, and must show, wherever
section lines are crossed, the distance to the nearest government
corner. The map or plat must show the course of the river, stream,
or other source of supply, the location and area of all lands proposed
to be reclaimed, the position and area of all reservoirs or basins in-
tended to be created for the purpose of storing water; the location
of the intersection with all other ditches, canals, laterals, or reser-
voirs which are caused by this work, or with which connections are
made; but all streams and all intersecting ditches, canals, and reser-
voirs not connected with the proposed work must be represented
in ink of different color from that used to represent the proposed
work. These maps must contain the name of the proposed work,
and where possible the number of the permit. They must, in addi-
tion, have the name or names of the applicant or applicants, and a
certificate of the surveyor, giving the date of the survey, his name,
and postoffice address.

Engineer Must Examine Maps.

Sec. 925. It shall be the duty of the State Engineer to examine
these maps or plats and to ascertain if they agree with the descrip-
tion contained in the application, and when found to agree, or made
to agree, to approve the same, file one copy in his office, and return
the other, approved, to the party filing them.

Additional Description.

Sec. 926. In case of ditches or canals carrying more than fifty
cubic feet of water per second the engineer may require, in addition
to the maps or plats above described, the following: A longitudinal
profile of the ditch showing the bottom and proposed water line;
the horizontal scale of this line shall not be less than one inch to
one thousand feet, and the vertical scale not less than one inch to
twenty feet.

Plans.

Sec. 927. The engineer may require, in addition to the maps or
plats above described, a plan showing cross sections at a sufficient
number of points to show all the different forms which the ditch,
when completed, will take, and showing what proportion of the wa-
ter is to be conveyed in excavation and what proportion to be con-
veyed in fill. These plans shall be drawn on a horizontal and verti-
cal scale of one inch to twenty feet. Plans of any dams, cribs, emb-
ankments, or other proposed works to obstruct any river, stream,
lake, or pond, or other source of water supply, shall be drawn on a
longitudinal scale of not less than one inch to two hundred feet, and
for cross sections on a scale of not less than one inch to twenty feet;
and shall show what material is intended to be used and placed in
such work. Timber, brush, stone, or other material except earth
used in such works shall be shown in detail on a plan, the scale of
which shall not be less than one inch to four feet. The maps of all
proposed reservoirs shall show the surface of the ground under wa-
ter, and a sufficient number of lines of level shall be shown so that
the contents of the reservoir or basin may be accurately determined.
If the levels shall be shown by contour lines they shall be on a scale
sufficiently large to show vertical levels not exceeding five feet, and
with all such reservoir plans there shall be furnished a plan, on a
scale of not less than one inch to four feet, showing the method of
providing a waste way for such reservoir, and method of drawing off
the water from such reservoir or basin.

Certificate to Appropriator.

Sec. 928. Upon it being made to appear to the satisfaction of the
board of control that any appropriation has been perfected in accord-
ance with such application, and the endorsement thereon by the
State engineer, it shall be the duty of the board of control, by the
hand of its president, attested under the seal of the secretary, to
send to the county clerk a certificate of the same character as that
described in section eight hundred and seventy-three, which said
certificate shall be recorded in the office of the county clerk as pro-
vided in said section.
Date of Priority.

Sec. 929. The priority of such appropriation shall date from the filing of the application in the engineer's office.

Construction of Headgates and Measuring Devices.

Sec. 930. The appropriator of any of the public waters of the State shall maintain, to the satisfaction of the division superintendent of the district in which the appropriation is made, a substantial headgate at the point where the water is diverted, which shall be of such construction that it can be locked and kept closed by the water commissioner; and such appropriator shall construct and maintain, when required by the division superintendent, a flume or measuring device, as near the head of such ditch as is practicable, for the purpose of assisting the water commissioner in determining the amount of water that may be diverted into said ditch from the stream. And every owner or manager of a reservoir, located across or upon the bed of a natural stream, shall be required to construct and maintain, when required by the division superintendent, a flume or measuring device of a plan to be approved by the state engineer, below such reservoir at a point not to exceed 600 feet therefrom, and a flume or measuring device above such reservoir on each and every stream or source of supply discharging into such reservoir, for the purpose of assisting the water commissioner or superintendent in determining the amount of water to which prior appropriators are entitled and thereafter diverting it for such prior appropriators' use.

If any appropriator of public waters that have been adjudicated upon, should refuse or neglect to construct and put in such headgate, or measuring device, after ten days' notice to do so by the division superintendent, it shall be the duty of the water commissioner of the district in which such headgate is located, on order of the division superintendent, to close such ditch to the passage of water, and the same shall not be opened or any water diverted from the source of supply, under the penalties prescribed by law for the opening of headgates lawfully closed, until the requirements of the division superintendent as to such headgate or measuring device have been complied with, and if any owner or manager of a reservoir located across the bed of a natural stream shall neglect or refuse to put in such measuring device after ten days' notice to do so by the division superintendent, the water commissioner shall open the sluice gate or outlet of such reservoir and the same shall not be closed under penalties of the law for changing or interfering with headgates, until the requirements of the division superintendent as to such measuring device are complied with.
Dams, Plans of.

Sec. 931. Duplicate plans for any dam across the channel of a running stream, above five feet in height, or of any other dam intended to retain water, above ten feet in height, shall be submitted to the State engineer for his approval, and it shall be unlawful to construct such dam until the said plans have been approved.

Engineer's Authority to Inspect.

Sec. 932. The State engineer shall have authority to examine and inspect, during construction, any dam authorized under the provisions of this chapter, or any ditch, canal, or other work carrying over fifty cubic feet of water per second of time; and at the time of such inspection he may order the parties constructing such dam, or other works, to make any additions or alteration which he considers necessary for the security of the work, or the safety of any person or persons residing on or owning land in the vicinity of such works.

Inspection, When Desired.

Sec. 933. Should any person or persons residing on or owning land in the neighborhood of any irrigation works after completion, or in course of completion, apply to the State engineer in writing desiring an inspection of such works, the State engineer may order an inspection thereof. Before doing so he may require the applicant for such inspection to make a deposit of a sum of money sufficient to pay the expenses of an inspection, and in case the application appears to him not to have been justified, he may cause the whole or part of such expense to be paid out of such deposit. In case the application appears to the State engineer to have been justified, he may require the company to pay the whole or any part of the expenses of the inspection, and the same may be collected in the same manner as is provided for the collection of the expenses of constructing headgates and measuring flumes.

LANDS CONDITIONALLY CEDED TO THE STATE.

Water Rights Attach to Land.

Sec. 955. The water rights to all lands acquired under the provisions of this chapter shall attach to and become appurtenant to the land as soon as title passes from the United States to the State.

SPECIAL PROVISIONS.

Legal Standard.

Sec. 968. A cubic foot of water per second of time shall be the legal standard for the measurement of water in this State, both for
the purpose of determining the flow of water in natural streams and for the purpose of distributing the water therefrom.

**Ditch Owners to Protect Fish.**

Sec. 970. It shall be the duty of every person, corporation, or company who shall construct, maintain, or operate any ditch or canal under the provisions of this title to construct and maintain, at the point and place where the water is diverted from its natural channel, some fit and proper obstruction whereby all fish will be prevented from entering said ditch or canal. Any person, company, or corporation violating the provisions of this section shall be adjudged guilty of a misdemeanor, and on conviction thereof shall be punished by a fine of not more than one hundred dollars, or by imprisonment in the county jail not less than ten days nor more than sixty days, or by both such fine and imprisonment.

**Unlawful Interference With Headgate.**

Sec. 971. Any person who shall wilfully open, close, change or interfere with any headgate or water-box without authority, or who shall wilfully use water or conduct water into or through his ditch which has been lawfully denied him by the water commissioner or other competent authority, shall be deemed guilty of a misdemeanor, and, on conviction thereof, shall be fined in a sum not exceeding one hundred dollars or imprisonment in the county jail for a term not exceeding six months, or by both such fine and imprisonment; (and the possession or use of water when the same shall have been lawfully denied by the water commissioner or other competent authority shall be deemed prima facie evidence of the guilt of the person using it.)

**Power to Arrest.**

Sec. 972. The water commissioners or their assistants within their districts shall have power to arrest any person or persons offending and turn them over to the sheriff of the proper county; and immediately upon delivering any such person so arrested into the custody of the sheriff, it shall be the duty of the water commissioner making such arrest to immediately in writing and upon oath make complaint before the proper justice of the peace against the person so arrested.

**Destroying Water Improvements, Penalty.**

Sec. 973. Any person or persons who shall knowingly and wilfully cut, dig, or break down, or open any gate, bank, embankment, or side of any ditch, canal, or reservoir, flume, tunnel, or feeder, in
which such person or persons may be joint owners, or on the property of another, or in the lawful possession of another or others, and used for the purpose of irrigation, milling, manufacturing, mining, or domestic purposes, with intent maliciously to injure any person, association, or corporation, or for his or her own gain, unlawfully, with the intention of stealing, taking, or causing to run or pour out of such canal or reservoir, feeder, or flume any water for his or her own profit, benefit, or advantage, to the injury of any other person, persons, association or corporation lawfully in the use of such water, or of such ditch, canal, tunnel, feeder, or flume, he, she, it, or they so offending shall be deemed guilty of a misdemeanor, and on conviction thereof shall be fined in any sum not exceeding one hundred dollars, and may be imprisoned in the county jail not exceeding six months, or both, in the discretion of the court.

**Liability of Owners of Reservoirs.**

Sec. 974. The owners of reservoirs shall be liable for all damage arising from leakage or overflow of the waters therefrom, or by floods caused by breaking of the embankments of such reservoir.

**Relating to Bridges Across Ditches.**

Sec. 1959. Any person, company, corporation, or association of persons, operating or maintaining in whole or in part, either as owners, agent, occupant, or appropriator any ditch, canal or water course, not being a natural stream, for irrigation or any other, and different purpose, shall put in, construct, maintain and keep in repair at his, her, its, or their expense, for one year, where the same crosses any public highway or publicly traveled road, a good substantial bridge, not less than fourteen feet in width, over such ditch, canal, or water course where it crosses such road. Any violation of the provisions of this section shall be a misdemeanor, and upon conviction thereof, the person so offending shall pay a fine in a sum not exceeding one hundred dollars for each day such ditch, canal, or water course shall be unbridged, insufficiently bridged, or suffered to remain out of repair. Provided, That after the expiration of one year from the construction of said bridge, the road supervisor of the road district in which said bridge is located shall, upon being notified by the owner or owners of the ditch, canal, or water course over which such bridge is constructed, at once inspect such bridge, and if found in a good and lawful condition, shall accept the same for the county in which it is located, and said bridge shall thereafter be maintained by the said county.
These bulletins are sent free of charge to any address upon application to the Director of Experiment Station, Laramie, Wyo.

(Only the bulletins named below are available for distribution.)

No. 7—July, 1892. Insecticides.
No. 8—October, 1892. Irrigation and Duty of Water.
No. 9—December, 1892. Sugar Beets in Wyoming in 1892.
No. 11—February, 1893. Crop reports for 1892.
No. 12—April, 1893. Ground Squirrels (Gophers).
No. 15—December, 1893. The Winter-Killing of Trees and Shrubs.
No. 16—December, 1893. Grasses and Forage Plants.
No. 19—September, 1894. Squirrel Tail Grass (Fox-Tail).
No. 20—October, 1894. The Artesian Wells of Southern Wyoming.
No. 21—January, 1895. The Grain Smuts and Potato Scab.
No. 22—April, 1895. I. Onions. II. Crop Reports, 1894. 1, Potatoes; 2, Turnips and Other Root Crops; 3, Grasses and Forage Plants; 4, Cereals; 5, Other Crops. III. Cost and Profit of Growing Wheat. IV. Small Fruits at Laramie.
No. 23—May, 1895. Notes on Climate.
No. 24—August, 1895. Water Analyses.
No. 25—November, 1895. Results of Three Years' Experiments in Cost and Profit of Growing Wheat.
No. 26—December, 1895. Garden Peas.
No. 27—March, 1896. Meteorology for 1895, and Notes on Climate from 1891 to 1896.
No. 32—March, 1897. Potatoes.
No. 33—June, 1897. The Composition of Prepared Cereal Foods.
No. 34—November, 1897. Fruit Growing in Wyoming.
No. 35—December, 1897. Mechanical Analyses and Water Content of Wyoming Soils.
No. 36—April, 1898. Wyoming Sugar Beets.
No. 37—June, 1898. Stoning of Grains.
No. 38—September, 1898. Cultivated Shade and Forest Trees.
No. 39—December, 1898. Alkali Studies, II.
No. 41—November, 1899. Some Experiments With Subsoiling.
No. 42—December, 1899. Some Native Forage Plants for Alkali Soils.
No. 43—March, 1900. Alfalfa as a Hay Crop.
No. 44—April, 1900. Alfalfa as a Fertilizer.
No. 45—June, 1900. Artesian Basins of Wyoming.
No. 46—January, 1901. The Brome-Grasses of Wyoming.
No. 47—April, 1901. Lamb Feeding Experiment.
No. 48—May, 1901. Experiments in Wheat Culture.
No. 49—June, 1901. Alkali Lakes and Deposits.
No. 50—March, 1902. Native Vines in Wyoming Homes.
No. 51—May, 1902. I. Sheep Feeding on the Range. II. Lamb Feeding—Second Trial.
No. 52—April, 1902. Experiments in Evaporation.