have so great a depth of water as the rule $d=2r$ requires because of the greater cost of excavation at such depth, or because width rather than depth may be needed for other reasons.

When a trapezoidal channel is to be built, the general formulas $v = c\sqrt{rs}$ and $q = av$ may be used to obtain a rough approximation to the discharge, c being assumed from the best knowledge at hand. The formula of Kutter (Art. 118) or that of Bazin (Art. 122) may be used to determine c when the nature of the bed of the channel is known. For a channel already built, computations cannot be trusted to give reliable values of the discharge on account of the uncertainty regarding the coefficient, and in an important case an actual gaging of the flow should be made. This is best effected by a weir, but if that should prove too expensive, the methods explained in the next chapter may be employed to give more precise results than can usually be determined by computation from any formula.

The problem of determining the size of a trapezoidal channel to carry a given quantity of water does not require c to be determined with great precision, since an allowance should be made on the side of safety. For this purpose the following values may be used, the lower ones being for small cross-sections with rough and foul surfaces, and the higher ones for large cross-sections with quite smooth and clean earth surfaces:

For unplaned plank,	c = 100 to 120
For smooth masonry,	c = 90 to 110
For clean earth,	c = 60 to 80
For stony earth,	c = 40 to 60
For rough stone,	c = 35 to 50
For earth foul with weeds,	c = 30 to 50

To solve this problem, let a and p be replaced by their values in terms of b and d. The discharge then is

$$q = cd(b+d\cot\theta)\sqrt{\frac{d(b+d\cot\theta)s\sin\theta}{b\sin\theta+2d}}$$

Now when q, c, θ, and s are known, the equation contains two unknown quantities, b and d. If the section is to be the most advantageous, b can be replaced by its value in terms of d as above found, and the equation then has but one unknown.

Or in general, if $b=md$, where m is any assumed number, a solution for the depth gives the formula

$$d^5 = \frac{q^2(m\sin\theta+2)}{c^2s(m+\cot\theta)^3\sin\theta}.$$

For the particular case where the side slopes are 1 on 1 or $\theta=45°$, and the bottom width is to be equal to the water depth, or $m=1$, this becomes

$$d = 0.863\,(q^2/c^2s)^{\frac{1}{5}}$$

These formulas are analogous to those for finding the diameter of pipes and circular conduits, and the numerical operations are in all respects similar. It is plain that by assigning different values to m numerous sections may be determined which will satisfy the imposed conditions, and usually the one is to be selected that will give both a safe velocity and a minimum cost. In Art. 120 will be found an example of the determination of the size of a trapezoidal canal.

Prob. 117. If the value of c is 71, compute the depth of a trapezoidal section to carry 200 cubic feet of water per second, θ being 45°, the slope s being 0.001, and the bottom width being equal to the depth. Compute also the area of the cross-section and the mean velocity.

Art. 118. Kutter's Formula

An elaborate discussion of all recorded gagings of channels was made by Ganguillet and Kutter in 1869, from which an important empirical formula was deduced for the coefficient c in the Chezy formula $v=c\sqrt{rs}$. The value of c is expressed in terms of the hydraulic radius r, the slope s, and the degree of roughness of the surface, and may be computed when these three quantities are given. When r is in feet and v in feet per second, Kutter's formula for the Chezy coefficient c is

$$c = \frac{\dfrac{1.811}{n}+41.65+\dfrac{0.00281}{s}}{1+\dfrac{n}{\sqrt{r}}\left(41.65+\dfrac{0.00281}{s}\right)} \qquad (118)$$

in which n is an abstract number whose value depends only upon the roughness of the surface. By inserting this value of c in the Chezy formula for v, the mean velocity is made to depend upon r, s, and the roughness of the surface. The following values of n were assigned by Kutter to different surfaces:

$n = 0.009$ for well-planed timber,
$n = 0.010$ for neat cement,
$n = 0.011$ for cement with one-third sand,
$n = 0.012$ for unplaned timber,
$n = 0.013$ for ashlar and brick work,
$n = 0.015$ for unclean surfaces in sewers and conduits,
$n = 0.017$ for rubble masonry,
$n = 0.020$ for canals in very firm gravel,
$n = 0.025$ for canals and rivers free from stones and weeds,
$n = 0.030$ for canals and rivers with some stones and weeds,
$n = 0.035$ for canals and rivers in bad order.

The formula of Kutter has received a wide acceptance on account of its application to all kinds of surfaces. Notwithstanding that it is purely empirical, and hence not perfect, it is to be regarded as a formula of great value, so that no design for a conduit or channel should be completed without employing it in the investigation, even if the final construction be not based upon it. In sewer work it is extensively employed, n being taken as about 0.015. The formula shows that the coefficient c always increases with r, that it decreases with s when r is greater than 3.28 feet, and that it increases with s when r is less than 3.28 feet. When r equals 3.28 feet, the value of c is simply $1.811/n$. It is not likely that future investigations will confirm these laws of variation in all respects.

In the following articles are given values of c for a few cases, and these might be greatly extended, as has been done by Kutter and others.* But this is scarcely necessary except for special lines of investigation, since for single cases there is no difficulty in directly computing it for given data. For instance, take a rectangular trough of unplaned plank 3.93 feet wide on a slope of 4.9 feet in 1000 feet, the water being 1.29 feet deep. Here

* Flow of Water in Rivers and Other Channels. Translated, with additions, by Hering and Trautwine, New York, 1889.

$s=0.0049$, and $r=0.779$ feet. Then n being 0.012, the value of c to be used in the Chezy formula is found to be

$$c = \frac{\dfrac{1.811}{0.012} + 41.65 + \dfrac{0.00281}{0.0049}}{1 + \dfrac{0.012}{\sqrt{0.779}}\left(41.65 + \dfrac{0.00281}{0.0049}\right)} = 123$$

The data here used are taken from Table 116, where the actual value of c is given as 117; hence in this case Kutter's formula is about 5 per cent in excess. As a second example, the following data from the same table will be taken: a rectangular conduit in neat cement, $b=5.94$ feet, $d=0.91$ feet, $s=0.0049$. Here $n=0.010$, and $r=0.697$ feet. Inserting all values in the formula, there is found $c=148$, which is 8 percent greater than the true value 138. Thus is shown the fact that errors of 5 and 10 percent are to be regarded as common in calculations on the flow of water in conduits and canals.

Prob. 118. The Sudbury conduit is of horse-shoe form and lined with brick laid with cement joints one-quarter of an inch thick, and laid on a slope of 0.0001895. Compute the discharge in 24 hours when the area is 33.31 square feet and the wetted perimeter 15.21 feet.

Art. 119. Sewers

Sewers smaller in diameter than 18 inches are always circular in section. When larger than this, they are built with the section either circular, egg-shaped, or of the horse-shoe form. The last shape is very disadvantageous when a small quantity of sewage is flowing, for the wetted perimeter is then large compared with the area, the hydraulic radius is small, and the velocity becomes low, so that a deposit of the foul materials results. As the slope of sewer lines is often very slight, it is important that such a form of cross-section should be adopted to render the velocity of flow sufficient to prevent this deposit. A velocity of 2 feet per second is found to be about the minimum allowable limit, and 4 feet per second need not be usually exceeded.

The egg-shaped section is designed so that the hydraulic radius may not become small even when a small amount of sewage is flowing. One of the most common forms is that shown in Fig. 119, where the greatest width DD is two-thirds of the depth HM. The arch DHD is a semicircle described from A as a center. The invert LML is a portion of a circle described from B as a center, the distance BA being three-fourths of DD and the radius BM being one-half of AD. Each side DL is described from a center C so as to be tangent to the arch and invert. These relations may be expressed more concisely by

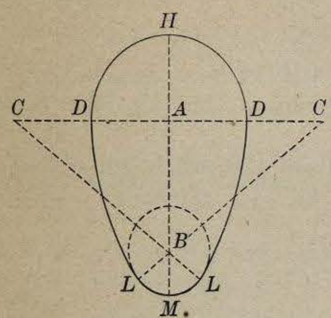

Fig. 119.

$$HM = 1\tfrac{1}{2}D \qquad AB = \tfrac{3}{4}D \qquad BM = \tfrac{1}{4}D \qquad CL = 1\tfrac{1}{2}D$$

in which D is the horizontal diameter DD.

Computations on egg-shaped sewers are usually confined to three cases, namely, when flowing full, two-thirds full, and one-third full. The values of the sectional areas, wetted perimeters, and hydraulic radii for these cases, as given by Flynn,* are

	a	p	r
Full	$1.1485\,D^2$	$3.965\,D$	$0.2897\,D$
Two-thirds full	$0.7558\,D^2$	$2.394\,D$	$0.3157\,D$
One-third full	$0.2840\,D^2$	$1.375\,D$	$0.2066\,D$

This shows that the hydraulic radius, and hence the velocity, is but little less when flowing one-third full than when flowing with full section.

Egg-shaped sewers and small circular ones are formed by laying consecutive lengths of clay or cement pipe whose interior surfaces are quite smooth when new, but may become foul after use. Large sewers of circular section are made of brick, and are more apt to become foul than smaller ones. In the separate system, where systematic flushing is employed and the pipes are small, foulness of surface is not so common as in the combined system, where the storm water is alone used for this purpose.

* Van Nostrand's Magazine, 1883, vol. 28, p. 138.

In the latter case the sizes are computed for the volume of storm water to be discharged, the amount of sewage being very small in comparison.

The discharge of a sewer pipe enters it at intervals along its length, and hence the flow is not uniform. The depth of the flow increases along the length, and at junctions the size of the pipe is enlarged. The strict investigation of the problem of flow is accordingly one of great complexity. But considering the fact that the sewer is rarely filled, and that it should be made large enough to provide for contingencies and future extensions, it appears that great precision is unnecessary. The practice, therefore, is to discuss a sewer for the condition of maximum discharge, regarding it as a channel with uniform flow. The main problem is that of the determination of size; if the form is circular, the diameter is found, as in Art. 114, by

$$d = (8\,q/\pi c\sqrt{s})^{\frac{2}{5}} = 1.45\,(q/c\sqrt{s})^{\frac{2}{5}}$$

If the form is egg-shaped and of the proportions above explained, the discharge when running full is

$$q = ac\sqrt{rs} = 1.1485\,D^2c\sqrt{0.2897\,Ds}$$

from which the value of D is found to be

$$D = 1.21(q/c\sqrt{s})^{\frac{2}{5}}$$

Thus, when q has been determined and c is known, the required sizes for given slopes can be computed. The velocity should also be found in order to ascertain if it is low enough to prevent scouring (Art. 135).

Experiments from which to directly determine the coefficient c for the flow in sewers are few in number, but since the sewage is mostly water, it may be approximately ascertained from the values for similar surfaces. Kutter's formula has been extensively employed for this purpose, using 0.015 for the coefficient of roughness. Table 119 gives values of c for three different slopes and for two classes of surfaces. The values for the degree of roughness represented by n = 0.017 are applicable to sewers with quite rough surfaces of masonry; those for n = 0.015 are applicable to sewers with ordinary smooth surfaces, somewhat fouled or tuberculated by deposits, and are the

TABLE 119. KUTTER'S COEFFICIENTS C FOR SEWERS

Hydraulic Radius r in Feet	$s = 0.00005$		$s = 0.0001$		$s = 0.01$	
	$n = 0.015$	$n = 0.017$	$n = 0.015$	$n = 0.017$	$n = 0.015$	$n = 0.017$
0.2	52	43	58	48	68	57
0.3	60	51	66	56	76	64
0.4	65	56	73	61	83	70
0.6	76	65	82	70	90	76
0.8	82	72	87	76	95	82
1.	88	77	92	80	99	87
1.5	100	86	103	89	108	93
2.	106	94	108	96	111	99
3.	116	103	118	104	118	105

ones to be generally used in computations. By the help of this table and the general equations for mean velocity and discharge, all problems relating to flow in sewers can be readily solved.

Prob. 119. The grade of a sewer is 1 foot in 1004, and its discharge is to be 130 cubic feet per second. What should be the diameter of the sewer if it is circular?

ART. 120. DITCHES AND CANALS

Ditches for irrigating purposes are of a trapezoidal section, and the slope is determined by the fall between the point from which the water is taken and the place of delivery. If the fall is large, it may not be possible to construct the ditch in a straight line between the two points, even if the topography of the country should permit, on account of the high velocity which would result. A velocity exceeding 2 feet per second may often injure the bed of the channel by scouring, unless it be protected by riprap or other lining. For this reason, as well as for others, the alignment of ditches and canals is often circuitous.

The principles of the preceding articles are sufficient to solve all usual problems of uniform flow in such channels when the values of the Chezy coefficient C are known. These are perhaps best determined by Kutter's formula, and for greater convenience Table 120 has been prepared which gives their values for three slopes and two degrees of roughness. By interpolation in this table values for intermediate data may also be found; for instance, if the hydraulic radius be 3.5 feet, the slope be 1 on 1000, and n be 0.025, the value of C is found to be 74.5.

TABLE 120. KUTTER'S COEFFICIENTS C FOR CHANNELS

Hydraulic Radius r in Feet	$s = 0.00005$		$s = 0.0001$		$s = 0.01$	
	$n = 0.025$	$n = 0.030$	$n = 0.025$	$n = 0.030$	$n = 0.025$	$n = 0.030$
0.5	38	31	41	33	47	37
1.	49	40	52	42	56	45
1.5	57	47	59	48	62	51
2.	64	52	65	53	67	54
3.	72	59	72	59	72	60
4.	77	64	77	64	76	63
5.	81	68	80	68	79	66
6.	86	72	84	71	80	68
8.	91	76	87	74	82	70
10.	96	80	91	80	85	73
15.	105	89	97	84	90	77
25.	114	100	101	92	95	82

As an example of the use of the table let it be required to find the width and depth of a ditch of most advantageous cross-section, whose channel is to be in tolerably good order, so that $n = 0.025$. The amount of water to be delivered is 200 cubic feet per second and the grade is 1 in 1000, the side slopes of the channel being 1 on 1. From Art. 117 the relation between the bottom width and the depth of the water is, since θ is 45°,

$$b = d\left(\frac{2}{\sin\theta} - 2\cot\theta\right) = 0.828d$$

The area of the cross-section then is

$$a = d(b + d\cot\theta) = 1.828d^2$$

and the wetted perimeter of the cross-section is

$$p = b + \frac{2d}{\sin\theta} = 3.656d$$

whence the hydraulic radius is $0.5d$, as must be the case for all trapezoidal channels of most advantageous section. Now, since d is unknown, c cannot be taken from the table, and as a first approximation let it be supposed to be 60. Then in the general formula for q the above values are substituted, giving

$$200 = 60 \times 1.828d^2 \sqrt{0.5d \times 0.001}$$

from which d is found to be 5.8 feet. Accordingly $r = 2.9$ feet, and from the table c is about 71. Repeating the computation with this value of c, there is found $d = 5.44$ feet, which, considering the uncertainty of c, is sufficiently close. The depth may then be made 5.5 feet, the bottom width is

$$b = 0.828 \times 5.5 = 4.55 \text{ feet,}$$

and the area of the cross-section is

$$a = 1.828 \times 5.5^2 = 55.3 \text{ square feet,}$$

which gives for the mean velocity

$$v = \frac{200}{55.3} = 3.62 \text{ feet per second.}$$

This completes the investigation if the velocity is regarded as satisfactory. But for most earths this would be too high, and accordingly the cross-section of the ditch must be made wider and of less depth in order to make the hydraulic radius smaller and thus diminish the velocity.

The following statements show approximately the velocities which are required to move different materials:

0.25 feet per second moves fine clay,
0.5 feet per second moves loam and earth,
1.0 feet per second moves sand,
2.0 feet per second moves gravel,
3.0 feet per second moves pebbles 1 inch in size,
4.0 feet per second moves spalls and stones,
6.0 feet per second moves large stones.

The mean velocity in a channel may be somewhat larger than these values before the materials will move, because the velocities along the wetted perimeter are smaller than the mean velocity. More will be found on this subject in Art. 135.

Prob. 120. A ditch is to discharge 200 cubic feet per second with a mean velocity of 3.4 feet per second. If its bottom width is 16 feet and the side slopes are 1 on 1, compute the depth of water and the slope of the ditch.

Art. 121. Large Steel, Wood, and Cast-iron Pipes

Long pipes of large size are usually regarded as conduits even when running under pressure, for in formula $(97)_2$ the ratio h/l may be replaced by the slope s and the diameter d is four times the hydraulic radius r; then it becomes

$$v = \sqrt{8g/f}\sqrt{rs} = c\sqrt{rs}$$

which is the same as the Chezy formula. Values of c may be directly computed from observed values of v, r, and s, and this has been done by many experimenters. When values of c are known, all computations for long pipes may be made exactly like those for circular conduits.

In the following Table 121a* are shown the results of experiments on a number of steel pipes ranging from 33 to 108 inches in diameter and from new to 15 years of age. The experiments were made at velocities ranging from 1.0 to 6.0 feet per second, and the values given in the table are those read from mean curves of the plottings of the results of the experiments. In the column headed "Material and Joint" the letters S and W refer to steel and wrought iron respectively, while the letters B, C, and T refer to the style of the joint used in the construction of the pipe, B indicating butt, C cylinder, and T taper joint, respectively. The experiments bracketed together in the first

* Following are the sources from which the results tabulated in this table have been obtained:

Nos. 1, 2, and 10. Transactions American Society of Civil Engineers, Vol. 26, p. 203.

Nos. 3, 4, 5, 6, 7, 8, 11, 12, 13, 15, 16, 24. Herschel's 115 Experiments, New York, 1897.

Nos. 9, 14, and 17 are here shown through courtesy of Morris R. Sherrerd, Chief Engineer, Department of Public Works, Newark, N.J.

Nos. 18, 19. Transactions American Society of Civil Engineers, Vol. 40, p. 471, and Vol. 44, p. 34.

Nos. 20, 21, 22, and 23. By courtesy of The Jersey City Water Supply Co., Paterson, N.J.

TABLE 121*a*. ACTUAL COEFFICIENTS C FOR RIVETED STEEL PIPES

Reference Number	Diameter in Inches	Location	Material and Joint	Age in Years	Velocity in Feet per Second 1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0
1	33	Oregon	SC	0						123		
2	35	Oregon	SC	0					127	127		
3	36	New Jersey	SC	0	86	91	95	99	103	111	117	124
4	36	New Jersey	SC	4							106	
5	36	New York	WC	14		82						
6	38	New York	SC	0					115	109		
7	42	New Jersey	ST	0	96	103	108	111	113	113	111	110
8	42	New Jersey	ST	0	101	103	104	105	106	108	108	108
9	42	New Jersey	ST	11	72	79	84	86	87	88		
10	42	Oregon	SC	0				116				
11	48	New Jersey	ST	0	97	99	100	102	102	104	105	105
12	48	New Jersey	SC	0	101	105	109	111	113	113	112	112
13	48	New Jersey	SC	4	78	85	90	92	93	94	94	95
14	48	New Jersey	SC	15					84	84		
15	48	New Jersey	SC	0	101	105	109	111	113	113	112	112
16	48	New Jersey	SC	4	97	101	103	105	105	104	104	104
17	48	New Jersey	SC	15	76	83	87	89	90	91		
18	72	Utah	SB	0	110	111	110	108	108	111		
19	72	Utah	SB	2	82	92	98	101	102	104	105	105
20	72	New Jersey	ST	$\frac{1}{6}$	111	110	109	109	109	109		
21	72	New Jersey	ST	$1\frac{1}{3}$	95	99	100	100	100	101		
22	72	New Jersey	ST	$2\frac{1}{3}$	87	93	95	96	97	98		
23	72	New Jersey	ST	$6\frac{1}{2}$	90	92	92	92	91			
24	108	Massachusetts	WC	5	116	113	110	109	108	106		

column were made at different ages as shown on the same pipe and indicate the deterioration which is to be expected with age. (See Art. 107.) Experiments numbered 12 and 15 are one and the same and are shown twice in order that comparison may more readily be made with experiments 13 and 14 and 16 and 17. Experiments 12 and 15 were made on the entire length of the pipe referred to, while 13 and 14 were made on its upper end and 16 and 17 on its lower end.

As illustrating the values of n in Kutter's formula for some of the experiments shown in Table 121*a* the following, for experiments 18 and 19, are here given:

Velocity in feet per second	= 1.0	2.0	3.0	4.0	5.0
Exp. 18,	n = 0.013	0.014	0.015	0.014	
Exp. 19,	n = 0.018	0.016	0.015	0.015	0.015

For wooden stave pipes the gagings of Noble and those of Marx, Wing, and Hoskins, already referred to in Art. 108, furnish the following values of the coefficient c, those given for the 6-foot diameter in the first line being for new pipe and those in the second line after two years' use.

Velocity in feet per second, v =	1	2	3	4	5
3.7 feet diameter c =			(109)	113	116
4.5 feet diameter c =	(112)	122	126	128	
6.0 feet diameter c =	100	115	122	125	
6.0 feet diameter c =	116	120	121	122	122

Here the two values in parentheses have been found by a graphic discussion of the results of the observations. For the first of these pipes the valve of Kutter's n ranges from 0.013 to 0.012, while for the second and third it is practically constant at 0.013.

Many gagings have been made on cast-iron pipes, and the results show great variations which can be ascribed to many causes; among these may be mentioned the progressive deterioration due to age as well as that due to the particular kind of water carried by the pipe, the care with which the pipe has been laid, and with which the joints have been made. In Table 121*b* are shown the values of the coefficient c for certain pipes of different diameters and ages and for varying velocities. The friction factors for these same gagings are given in Art. 106.

TABLE 121*b*. ACTUAL COEFFICIENTS C FOR CAST-IRON PIPES

Diameter in Inches	Age in Years	Velocity in Feet per Second				Reference
		1.0	2.0	3.0	4.0	
12	0	101	110	115	118	Trans. Am. Soc. C.E., vol. 47
12	15	65	58			Hering's Kutter *
12	22	49	46	45		Hering's Kutter *
20	5		115	109		Trans. Am. Soc. C.E., vol. 35
20	25		61	60	59	Hering's Kutter *
36	$1\frac{1}{4}$				130	Trans. Am. Soc. C.E., vol. 44
36	$3\frac{1}{3}$				66	Trans. Am. Soc. C.E., vol. 44
48	0				141	Trans. Am. Soc. C.E., vol. 35
48	7		96			Trans. Am. Soc. C.E., vol. 28
48	16		107	105	105	Trans. Am. Soc. C.E., vol. 35

Prob. 121. Compare the diameter of a cylinder joint riveted steel pipe 25 000 feet long to carry 30 000 000 gallons daily at a loss of head of 5 feet per mile with the diameter of a cast-iron pipe for the same service.

ART. 122. BAZIN'S FORMULA

In 1897 Bazin proposed a formula for open channels as the result of an extended discussion of the most reliable gagings.† In it the coefficient c is expressed in terms of the hydraulic radius and the roughness of the surface, but the slope does not enter:

$$v = c\sqrt{rs} \qquad c = \frac{87}{0.552 + m/\sqrt{r}} \tag{122}$$

This is for English measures, r being in feet and v in feet per second, and the quantity m has the following values:

$m = 0.06$ for smooth cement or matched boards,
$m = 0.16$ for planks and bricks,
$m = 0.46$ for masonry,
$m = 0.85$ for regular earth beds,
$m = 1.30$ for canals in good order,
$m = 1.75$ for canals in very bad order,

* Hering and Trautwine's translation of Ganguillet and Kutter's Flow of Water in Rivers and Other Channels, New York, 1889, p. 155.

† Annales des ponts et chaussées, 1897, 4^e trimestre, pp. 20–70.

Table 122 gives values of c computed from (122) for these values of m and for several values of r, from which coefficients may be selected for particular surfaces. It may be noted that for a perfectly smooth surface where $m = 0$, the formula gives $v = 158\sqrt{rs}$, which cannot be correct since uniform velocity could not obtain on such a surface. For this extreme case Kutter's formula appears to be more satisfactory, for if $n = 0$ the value of c is infinite. However, no empirical formula can be tested by applying it to an extreme case.

TABLE 122. BAZIN'S COEFFICIENTS C FOR CHANNELS

Hydraulic Radius r in Feet	$m = 0.06$	$m = 0.16$	$m = 0.46$	$m = 0.85$	$m = 1.30$	$m = 1.75$
0.5	136	111	72			
1.	142	122	86	62		
1.5	145	127	94	70	54	
2.	146	131	100	76	60	49
3.	148	135	107	84	67	56
4.	149	137	111	89	72	61
5.	150	140	115	94	78	67
6.	151	141	117	96	80	69
8.	152	143	122	101	85	73
10.	152	144	125	106	91	79
15.			131	113	98	87
25.				121	107	97

A comparison of the values of c obtained from the formulas of Kutter and Bazin only serves to emphasize the uncertainty regarding the selection of the proper coefficient in particular cases. Kutter's $n = 0.010$ corresponds to Bazin's $m = 0.06$, and for several different hydraulic radii the coefficients for this degree of roughness are as follows:

Hydraulic radius r in feet,	1	3	5	7
From Bazin's formula,	c = 142	148	150	151
From Kutter, $s = 0.01$,	c = 156	179	187	191
From Kutter, $s = 0.001$,	c = 155	178	187	192
From Kutter, $s = 0.00005$,	c = 140	178	193	203

While the agreement is fair for a hydraulic radius of one foot, it fails to be satisfactory for larger radii. This is perhaps a severe