TECHNICAL NOTES

U.S. DEPARTMENT OF AGRICULTURE CASPER, WYOMING NRCS

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AUXILIARY AND PRINCIPAL SPILLWAY PROPORTIONING GUIDE

This guide is intended to be used for water retention practices that have no criteria written in the practice standard for principal spillway pipe size.

Spillways are installed to bypass surface runoff water, around the dam, after a pond is filled. The proper function of a pond depends on the correct design and installation of the spillway system. No matter how well a dam has been built, it will probably be destroyed during the first severe storm if spillway capacity is inadequate. Designing an ordinary pond spillway to accommodate the peak rate of runoff from the most intense rainstorm ever known or anticipated is not practical. A pipe (principal) spillway is often used in conjunction with a vegetated earthen (auxiliary) spillway to control runoff. Auxiliary spillways were formerly called emergency spillways.

Per Wyoming State Engineers office, rules and regulations, Part I. Chapter V. (Reservoirs), Section 1.b.5 states: For reservoir with a dam height greater than 20 feet or reservoirs with a storage capacity greater than 50 acre-feet or reservoirs located in an area where extensive property damage or loss of life might result from over-topping or failure of the dam, the spillway shall have sufficient capacity to pass the flood flow for a projected 100 year storm. The design of the spillway shall be such that a minimum of 1½ feet of freeboard, between the top of the dam and the maximum water level in the spillway, is maintained.

The principal spillway is designed to reduce the frequency of operation of the auxiliary spillway; the most costly portion of construction of an ordinary pond is usually the purchase and installation of the principal spillway pipe. It is therefore incumbent on the designer to use their best judgment when sizing the principal and auxiliary spillways to maximize the longevity of the dam while providing the most economical design to the producer.

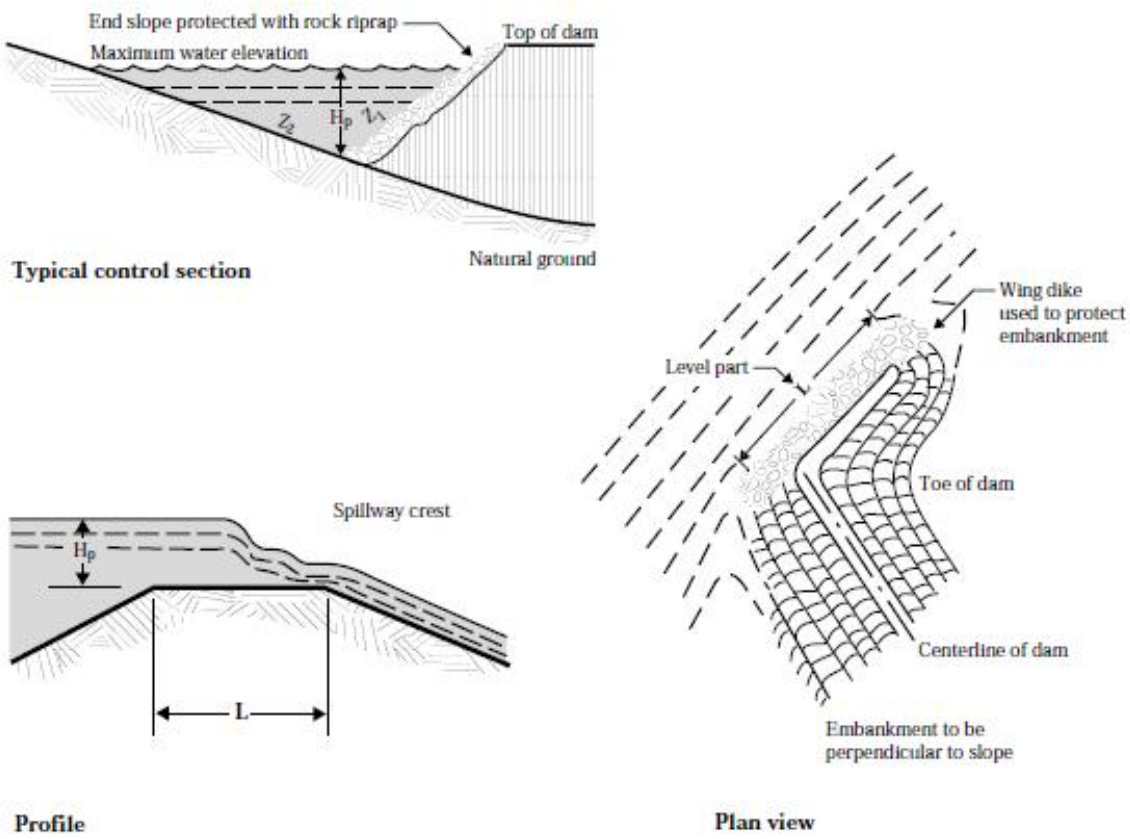
The function of an auxiliary spillway is to pass excess storm runoff around the dam so that water in the pond does not rise high enough to damage the dam by overtopping. Both the auxiliary and principal spillways must also convey the water safely to the outlet channel below without damaging the downstream slope of the dam.

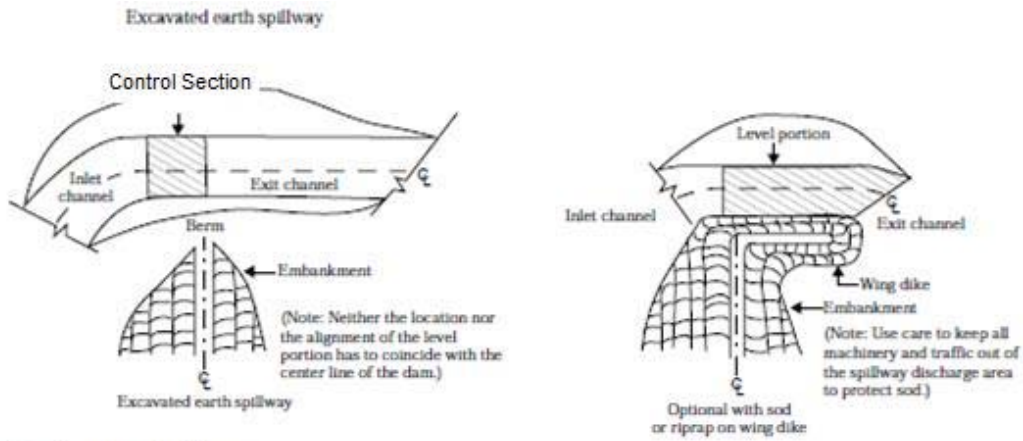
A trickle tube is a pipe spillway designed to only handle small water flows such as in spring fed ponds. Its purpose is to keep the auxiliary spillway dry so small channels will not form from the constant base flow. These small channels could cause damage to the auxiliary spillway during storm events. Trickle tubes should be installed in all small dams in Wyoming. The size of a trickle tube should be based on the quantity of base flow entering the pond.

There are two types of vegetated earthen auxiliary spillways designed for ordinary ponds: Natural Auxiliary Spillways and Excavated Auxiliary Spillways. All ordinary auxiliary spillways consist of three parts: Entrance Channel, Control Section, and Exit Channel. It is difficult to establish vegetative cover on auxiliary spillways in Wyoming. Therefore, when planning a location for a pond it is preferable to start by looking for the best auxiliary spillway exit channel. A natural spillway requires no excavation to conduct the pond outflow to a safe point of release. The best natural auxiliary spillways are those that transition smoothly (without drop-offs) into the dammed stream channel. If a short drop-off does exist where the auxiliary exit channel enters the stream channel, the designer can avoid causing the formation of a head cut in the auxiliary exit channel by releasing more water through the principal spillway pipe. The quantity of water released through the principal spillway pipe must be adequate place the drop off under water upstream from the auxiliary spillway entrance to the stream channel. Various types of structures may also be installed at the re-entrance to the stream to avoid head cuts from occurring further up the auxiliary spillway.

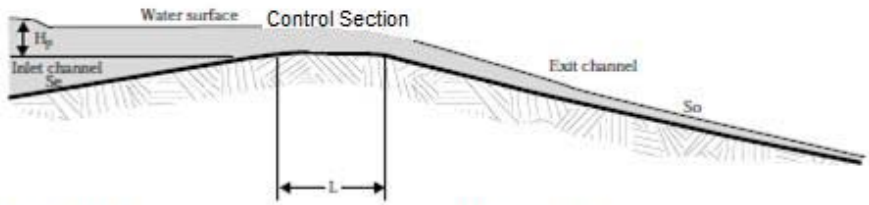
If spillway excavation is required, thorough initial planning investigations are required to determine whether the soils can withstand reasonable velocities without serious erosion. Avoid loose sands and other highly erodible soils. It is advisable to stockpile top soil which will later be spread in an excavated spillway to establish a good vegetated cover.

Plan, profile, and cross section of a natural spillway with vegetation





Plan view of earth spillways



Profile along centerline

Definition of terms:

H_p = depth of water in reservoir above crest
L = length of level portion
b = bottom width of spillway
So = slope for exit channel
Se = slope of inlet channel

Cross section of level portion

Soil erodibility is a descriptive feature based on the soil's allowable effective stress. Effective stress is defined as the maximum hydraulic stress that may be applied directly to the soil without the occurrence of unacceptable erosion. Soils resist erosion during channel flow in two ways:

1. Coarse-grained soils, such as sand and gravel, resist movement by the weight of individual particles. Generally, the heavier a particle, the greater its resistance to movement. Platy, elongated, and low density particles are moved more easily than dense particles of equal dimensions. Shale shall not be used in any situations. Any rock placed on the spillway shall be approved by the Engineering Geologist, State Conservation Engineer, or Area Engineer.

2. Fine-grained soils resist erosion as a mass held together by the cohesion between particles. Erosion resistance may be based on a soil's Plasticity Index (PI) and Unified classification. The higher the PI (up to 20), and the more clayey the soil, the greater its resistance to erosion. A clay (CL) with PI = 20 has greater erosion resistance than a clay (CL) with PI = 15. A clay (CL) with PI = 15 has greater erosion resistance than a silt (ML) with PI = 15. Easily eroded (fine grain) soil has a PI less than 10 or greater than 40. Fine grain soil that resists erosion has a PI between 10 and 40. The erosion resistance of fine-grained soils also increases with increased density. Density is indicated by void ratio (volume of voids divided by volume of solids within a unit sample of soil). A decreasing void ratio indicates increasing density. Coarse-grained soils that have cohesive fines resist erosion by both the weight of the sand or gravel

particles and the cohesion of the fines. Coarse-grained soils with non-cohesive fines have about the same erosion resistance as clean coarse-grained soil. Some very dense soils, such as dense glacial tills, have a high erosion resistance even though their particle-size and cohesiveness would not indicate so. A feeling for the relative erosion resistance of soils in your area can be gained by close observation of the performance of waterways, diversions, streams, and other channels.

COMPARATIVE EROSION RESISTANCE of SOILS

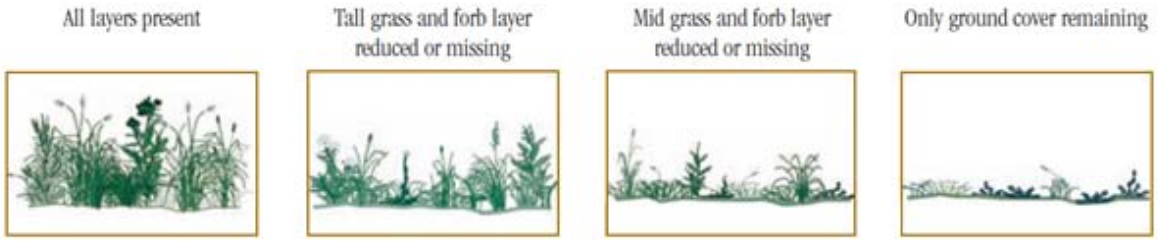
Most Resistant

Large Gravel	GW, GP
Clayey Gravel	GC
Highly Plastic Clay and Clayey Sand	CH, SC
Clays, Silty Gravel	CL, GM
Silts, Silty sand, Organic Silts	MH, OH, ML, SM, OL

Least Resistant

Geotextile soil reinforcement mats may be installed in earthen spillways. These mats allow higher velocities in the spillways. Maximum water velocity shall be based on manufacturer's recommendations but not to exceed 10 feet/second for erosion-resistant soils and 8 feet/second for easily eroded soils. Other factors that affect the erosion resistance of a soil include the presence of gypsum in the soil, mica in silt soils (**micaceous silts**), and other chemical composition of the soil (such as dispersive clays). Vegetal cover decreases the effective stress exerted by the flow of water on the soil within the auxiliary channel. Dense sod forming grasses, located in higher precipitation areas, provide better protection than sparser bunch type grasses found in lower precipitation areas. When auxiliary spillways must be excavated turf reinforcement can be used to increase protect of the soil until vegetation can be re-established.

Because many auxiliary spillways are located on grazed range sites it is important to look not only at the density of the plants from above but also at the general variety of plant cover. Over grazing will reduce the layers of vegetation and increase the stress of the soil surface. Are there different layers of vegetative cover on a site? Several layers of vegetation protect the soil better than only one.



AUXILARY AND PRINCIPAL SPILLWAY PROPORTIONING GUIDE

The chart is intended to be used as a guide with some flexibility.

In addition to the example shown at the bottom of the table, judgment should be used in the application of a rating under each of the headings. Consideration might well be given to “grading out” the drop-off at re-entrance, plus backfilling with good topsoil and seeding to eliminate the “drop-off” hazard.

Combination of spillway flow depths and spillway grades will require some interpolation for soils ranging between those that are easily eroded and those that are erosion resistant. Generally, erosion resistant soils are heavy clays or silty clays with strong structure; moderately erosive soils are silt loamy to silty clay loams with a medium structure and easily eroded soils are light loamy sands and loamy silts with weak structure.

Seepage losses from a reservoir site may be an additional factor to those shown in the spillway classification chart and may be used in determining the need and/or size of the principal spillway. Example: Where the seepage from the reservoir over a ten-day period is equal to or exceeds the total inflow from a 2-year storm, a dam may be designed with only a trickle tube even though the emergency spillway rates only as “good” (12-14 numerically).

Always install, at least, a trickle tube for long duration continuous flows such as snow melt or spring fed ponds. The size of the trickle tube may be estimated by noting bank-full indicators of the runoff channel into the pond and computing the open channel flow hydraulics into the pond. Size the trickle tube to handle this maximum base flow into the pond.

The best criteria for determining the rate of seepage loss from reservoirs is based on local experience where observations have shown that sites on certain soil formations under certain conditions lose water at a known rate. Where silting of the reservoir will be by fine-grained soils that will tend to seal the reservoir and cause the seepage losses to become ineffective, such effects must be evaluated and reflected in the design of the structure.

For “VEGETATIVE COVER (Existing or Potential) & ANNUAL RAINFALL” use the most limiting of the two criteria. For example, for a site with a poor stand or lacks potential for good stand and an annual rainfall of 13 inches the rating would have a numerical rating of “1”.

Examples

Example 1:

Description of Exit Channel:	Rating
Hp – 1.5’, Spillway Exit Channel Grade = 5.5 % (Erosion Resistant Soil)	3
Moderate Concentrated Flow in Exit Channel, 4 ft drop off 160 feet below control section	2
Fair vegetative stand - Average annual Rainfall 16 inches plus	2
Exit channel not fenced and heavily trailed	1
Total Numerical Rating	9
Adjective Rating	Fair

Therefore, use a 5 year - 24 hour storm for the principal Spillway

AUXILARY AND PRINCIPAL SPILLWAY PROPORTIONING GUIDE

NUMERICAL RATING	SPILLWAY FLOW DEPTH (Hp)	MAXIMUM SPILLWAY EXIT CHANNEL GRADES		AUXILARY SPILLWAY EXIT CHANNEL CONDITION AT RE-ENTRANCE TO STREAM CHANNEL	VEGETATIVE COVER (Existing or Potential) & ANNUAL RAINFALL	PROTECTION OF AUXILARY SPILLWAY EXIT CHANNEL
		EASILY ERODED [1]	RESISTS EROSION [2]			
5	1.0' 1.5' 2.0' 2.5'	5% 2%	8% 5% 3% 2%	No "Drop Off" 300 feet below auxiliary spillway control section. No flow concentration in spillway exit channel.	Very good stand of sod-forming grasses. 18 inches and up	Area fenced or no livestock and not used for vehicle crossing.
4	1.0' 1.5' 2.0'	6% 3%	10% 6% 4%	"Drop Off" height less than 3 feet, 250 feet + below control section. No flow concentration in spillway exit channel.	Good stand or high potential for good stand. greater than 16 inches	Cropland adjacent – no livestock and not fenced and not used for vehicle crossing.
3	1.0' 1.5'	7% 4%	12% 7%	"Drop Off" 3 feet-7 feet height, 150 feet + below control section. Shrubby banks—Slight flow concentration in spillway exit channel.	Medium stand or good potential for medium stand. greater than 12 inches	In pasture - Not fenced but not used as feeding or mineral area. Infrequently used for vehicle crossing.
2	1.0' 1.5'	8% 5%	14% 8%	"Drop Off" 3 feet-7 feet height, 150 feet + below control section. Moderate concentration in spillway exit channel.	Fair stand or good potential for fair stand. greater than 8 inches	Dam and spillway used for frequent crossing.
1	1.0' 1.5'	9% 8%	16% 9%	"Drop Off" 7 feet+ height, 150 feet + below control section. Slight flow concentration in spillway exit channel.	Poor stand or lacks potential for good stand. greater than 5 inches	Within heavy use area, not fenced, used for feeding and/ or mineral blocks, spillway trailed and/or used as road.

AUXILARY AND PRINCIPAL SPILLWAY PROPORTIONING GUIDE

SPILLWAY CLASS RATING		AUXILIARY SPILLWAY	PRINCIPAL SPILLWAY MINIMUM DESIGN REQUIREMENTS	
ADJECTIVE	NUMERICAL	PERMISSIBLE FREQUENCY OF SPILLWAY OPERATION See foot note 4	Without Storage - Pipe Capacity, Percent of Design Peak [3]	With Storage – Storm Frequency To Be Routed Below Emergency Spillway
Excellent	20-18	4/ Annual flow	Designed with trickle tube for base flow.	
Very Good	17-15	1 – 2 times per year	25	2 year – 24 hour
Good	14-12	Once per year	35	2 year – 24 hour
Fair	11-9	Once in 5 years	50	5 year – 24 hour
Poor	8-6	Once in 10 years	75	10 year – 24 hour
Very Poor	5-4	Once in 25 years	100 [5]	25 year – 24 hour

Notes:

[1] Easily eroded soil has a P.I. less than 10 or greater than 40.

[2] Soil that resists erosion has a P.I. between 10 and 40.

[3] Minimum combined capacity of the principal & emergency spillways must safely pass the peak flows of the 24-hour storm as shown in the appropriate standard.

[4] Indeterminate-Dependent upon storm frequency and net evaporation.

[5] For extreme spillway conditions, consideration may need to be given to providing for a principal spillway capacity in excess of the 25-year peak flow.

Criteria are somewhat flexible. Example: “Condition at re-entrance to main channel.” (a) “Drop Off” is 4.6 ft. – shrubby cover (less than mid-point of permissible height for a “3”numerical rating) (b) “Drop Off” is 215 ft. below control section, (Greater than mid-point between the “3” and “4” numerical rating). Conclusion: Rating may be advanced (raised) one step to “4”. Same Principle may be applied to other combinations such as “shrubby cover”, “concentration”, etc., in “raising” or “lowering” ratings. The grading of drop offs at a time of construction may be considered providing the potential for establishment of sod cover is adequate. “1” is the minimum numerical rating to be used for any element.

Example 2:

The spillway has been rated as "Good" on the spillway proportioning guide. The pond site is built in an inorganic silt soil with fine sand, from the table below; the seepage loss is estimated at 0.3 ft/day. The pond is on a spring feed site that has a drainage area of 18 acres. The runoff for a 2 year – 24 hour storm is 0.08 inches (from hydrology computations).

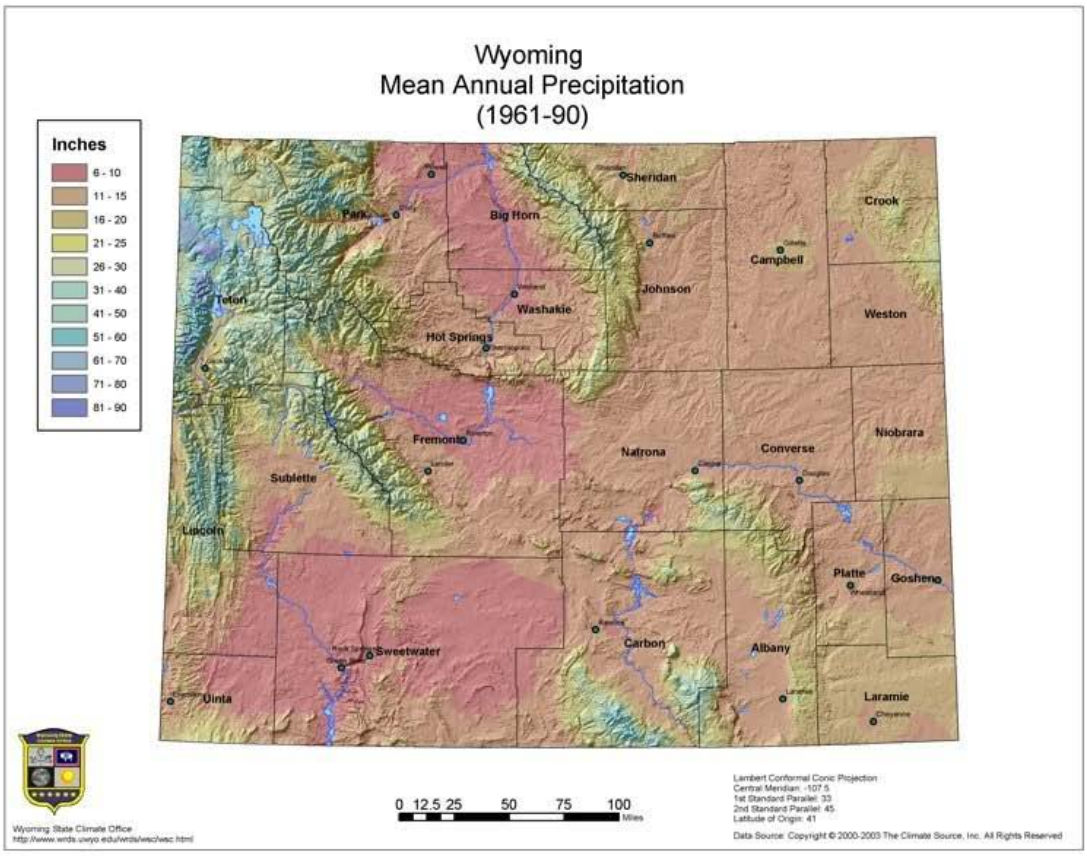
This pond has 0.3 ft/day x 10 days = 3 ft of loss due to seepage.

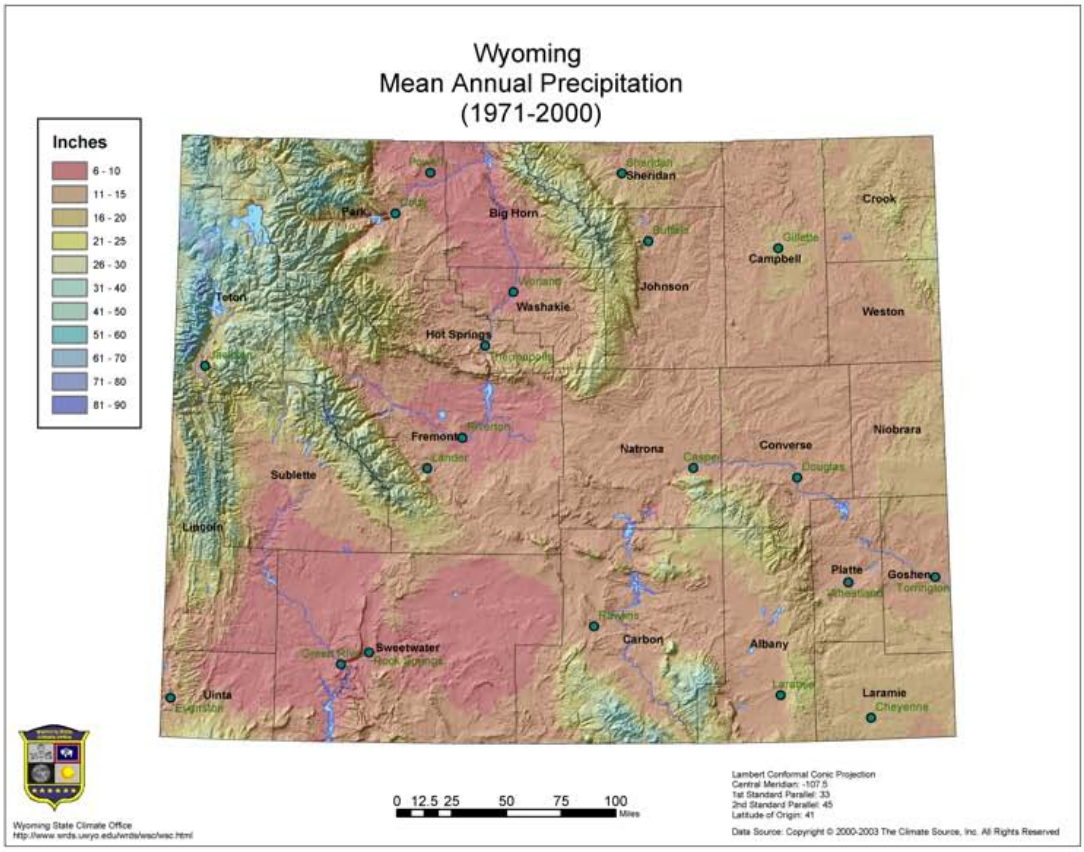
The runoff into the pond from a 2 yr – 24 hr into the pond is: 0.08 in ÷ 12 in/ft x 18 ac = 0.12 ac-ft.

The volume from the crest of the auxiliary spillway down 3 ft is 0.5 ac-ft.

Therefore, the pond may be designed with a trickle tube only. The pipe will not have to be designed to flow the 2 yr – 24 hr storm.

TYPICAL NAMES	PERMEABILITY FEET/DAY	UNIFIED SOIL CLASS
Well graded gravels, gravel and sand mixtures, little or no fines.	Greater than 30	GW
Poorly graded gravels, gravel sand mixtures, little or no fines.	Greater than 30	GP
Silty gravels, gravel-sand and silt mixtures.	3 to 0.003	GM
Clayey gravels, gravel-sand clay mixtures.	0.003 to 0.00003	GC
Well graded sands, gravelly sands, little or no fines.	Greater than 3	SW
Poorly graded sands, gravelly sands, little or no fines.	Greater than 3	SP
Silty sands, sand-silt mixtures.	3 to 0.003	SM
Clayey sands, sand-clay mixtures.	0.003 to 0.00003	SC
Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	3 to 0.003	ML
Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	0.003 to 0.00003	CL
Organic silts and organic silty clays of low plasticity.	0.003	OL
Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	.3 to 0.003	MH
Inorganic clays of high plasticity, fat clays.	0.003 to 0.00003	CH
Organic clays of medium to high plasticity. organic silts.	0.003 to 0.00003	OH


Wyoming
Mean Annual Precipitation
(1961-90)
Inches
6 - 10
11 - 15
16 - 20
21 - 25
26 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
Sheridan
Crook
Park
Big Horn
Campbell
Johnson
Teton
Washakie
Weston
Hot Springs
Fremont
Natrona
Converse
Niobrara
Sublette
Lincoln
Platte
Goshen
Sweetwater
Carbon
Albany
Uinta
Laramie
0 12.5 25 50 75 100
Miles
Lambert Conformal Conic Projection
Central Meridian: -107.5
1st Standard Parallel: 33
2nd Standard Parallel: 45
Latitude of Origin: 41
Data Source: Copyright © 2000-2003 The Climate Source, Inc. All Rights Reserved
Wyoming State Climate Office
http://www.wrds.uwyo.edu/wrds/wsc/wsc.html


Wyoming
Mean Annual Precipitation
(1971-2000)
Inches
6 - 10
11 - 15
16 - 20
21 - 25
26 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
Sheridan
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Park
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Laramie
0 12.5 25 50 75 100
Miles
Lambert Conformal Conic Projection
Central Meridian: -107.5
1st Standard Parallel: 33
2nd Standard Parallel: 45
Latitude of Origin: 41
Data Source: Copyright © 2000-2003 The Climate Source, Inc. All Rights Reserved
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