WETLANDS ENGINEERING MANUAL

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WETLANDS ENGINEERING

REASONS FOR THIS PUBLICATION

LACK OF TRAINING

Biologists learn the habitat needs of various wetland critters, but rarely do they know how to design engineering structures to create that habitat. For example, a waterfowl biologist can determine the depths of water needed to produce different waterfowl food plants, but seldom is trained to design management systems that will allow the water control necessary to produce the desired habitat. Unfortunately, the engineering assistance needed to successfully complete a habitat project is often unavailable to a field biologist or refuge manager.

ON-THE-JOB TRAINING

When installing a water control structure, most biologists and managers rely on trial and error to determine if a structure is a good fit for the job at hand. "OJT" (on-the-job training) is better than no training, but it can be inefficient and expensive. The management problems inherent with unsuccessful installations will haunt managers for years to come.

OJT also contributes to the "if it ain't broke, don't fix it" philosophy of habitat management. It isn't easy to abandon a familiar structure design and/or management scheme to test new designs and systems. Consequently, the best way to do a job may never be considered.

PROPER DESIGNS

This publication provides basic information about various types of water control structures. It was written to help new biologists, refuge and wildlife area managers, and others "in the field" prevent costly mistakes due to trial and error structure installation. More experienced managers may find the information on newer designs helpful. Our hope is that this publication will provide the engineering assistance needed to do a better job in creating waterfowl habitat.

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TYPES OF WATER CONTROL STRUCTURES

DROP PIPES

Drop pipe structures *(Figure #1)* are pipes that allow the water level to be lowered or "dropped." Often used as side inlets to creeks and canals, drop pipes also can be installed in small dams. These pipes may be used to allow storage of storm runoff or to handle peak runoff from a storm event. Drop pipes are seldom used for waterfowl habitat management.

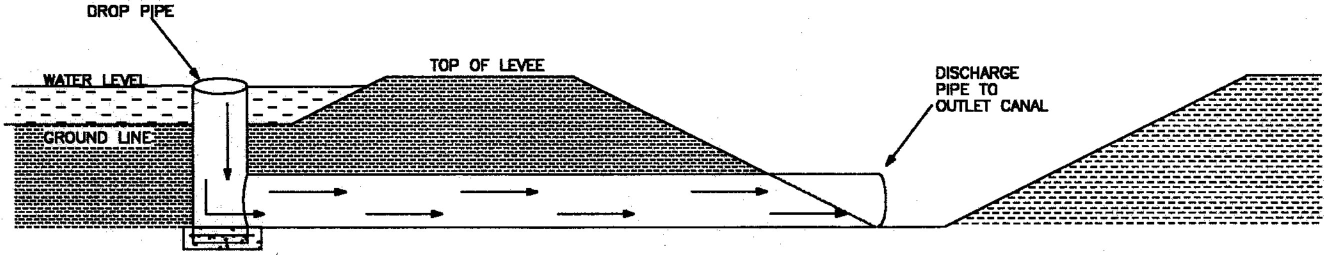
ADVANTAGES

1. Prevents erosion when water is lowered from an impounded area into a creek or canal.
2. Controls "high drops" of ten feet or more.
3. Can be adapted (with the installation of release gates) to allow full or partial drawdown of impounded area.

DISADVANTAGES

1. Water level can't be manipulated.
2. Overflow is lost eventually downstream.
3. Easily blocked by debris, unless a trashrack is included.
4. Different water flows in the riser and outlet pipe make structure design difficult. The riser must be correctly sized so that the outlet pipe can be primed without entering the orifice control. For correct design, a plot of the different flows is necessary.

Drop Pipe (Figure #1)



FLASHBOARD RISERS

Flashboard risers allow managers to control water levels. These structures are used in waterfowl areas for moist soil management because water depths can be regulated to permit feeding by waterfowl. Flashboard or stoplog risers *(Figure #2)* are half-round risers (large diameter pipes cut in half lengthwise) equipped with flashboards or stoplogs. These risers can be made of steel or corrugated pipe or may be metal boxes fabricated from flat steel.

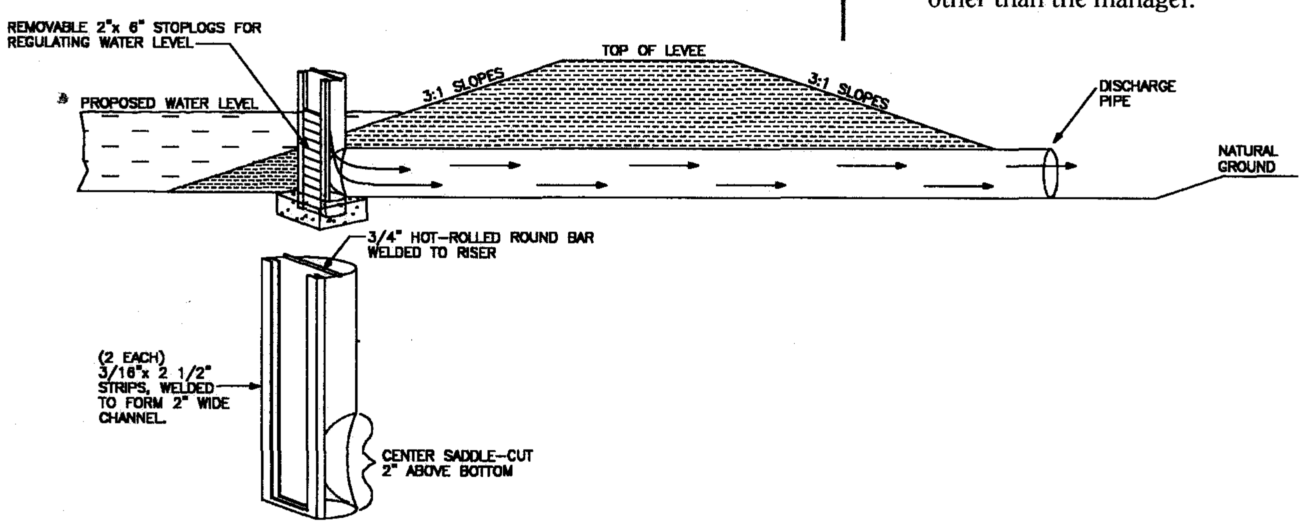
ADVANTAGES

1. Allows control of water level during flooding and drawdown. Depending on the size of the stoplogs or boards, water can be gradually stepped up or down to allow waterfowl access to new feeding areas.
2. Allows storm runoff to pass through the structure while maintaining the water level desired for management purposes.
3. Insures easy management of water levels through insertion or removal of boards. No attention is required during most storm events.

DISADVANTAGES

1. Structure protrudes into impoundment, usually necessitating a catwalk or boat for access.
2. Running water attracts beavers that may dam the riser opening.
3. Exposed stoplogs can be vandalized or added/removed by someone other than the manager.

Flashboard Riser (Figure #2)



FLASHBOARDS OR STOPLOGS

Flashboards or stoplogs are wooden or metal slats that are inserted into 2 1/4-inch channels at the open front of the riser *(Figure #3)*. Varying the number of boards in the riser allows managers to control water levels during flooding and drawdown. Boards of 6 inches or less are best, but stoplog size may vary from 2 inches to 12 inches. If funds are available, 2" x 6" x 3/16" tubular steel should be used for stoplogs. Steel stoplogs are easier to remove and they are permanent. Since they will not swell or float like lumber, annual replacement will not be needed. If more subtle water level changes are desired, a 2" x 2" or a 2" x 4" board may be used in combination with steel stoplogs.

ADVANTAGES

1. Ability to raise or lower water levels in impoundments by small increments.
2. Steel stoplogs do not swell or float.

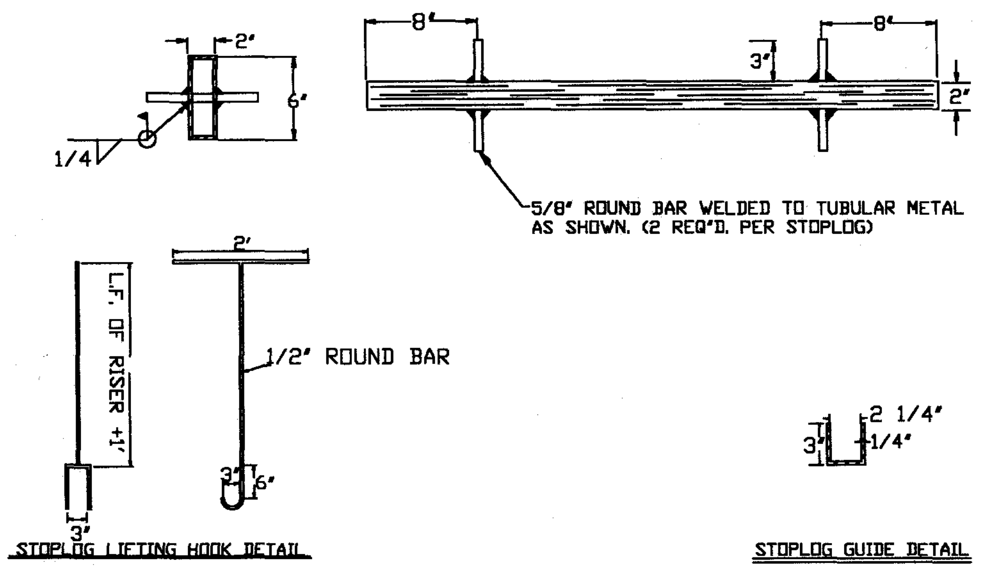
DISADVANTAGES

1. Wooden stoplogs swell and can be hard to remove.
2. Does not provide a complete air-tight seal.
3. Heavier/more expensive.

NOTE:

Leaks can be sealed by adding straw, sawdust, or debris to the front of the stoplog and letting the water take it to the leak to form a seal. In more arid regions where water loss is critical, some methods to reduce leaking around the stoplogs are: 1) to use a latex caulking between the boards or 2) foam in the can (insulation).

Metal Stoplog (Figure #3)



FULL-ROUND RISER

Full-round risers *(Figure #4)* are a combination of a drop pipe and a flashboard riser. The riser is round like a drop pipe inlet, but it also provides stoplog control. These pipes are used primarily in areas where beavers are active.

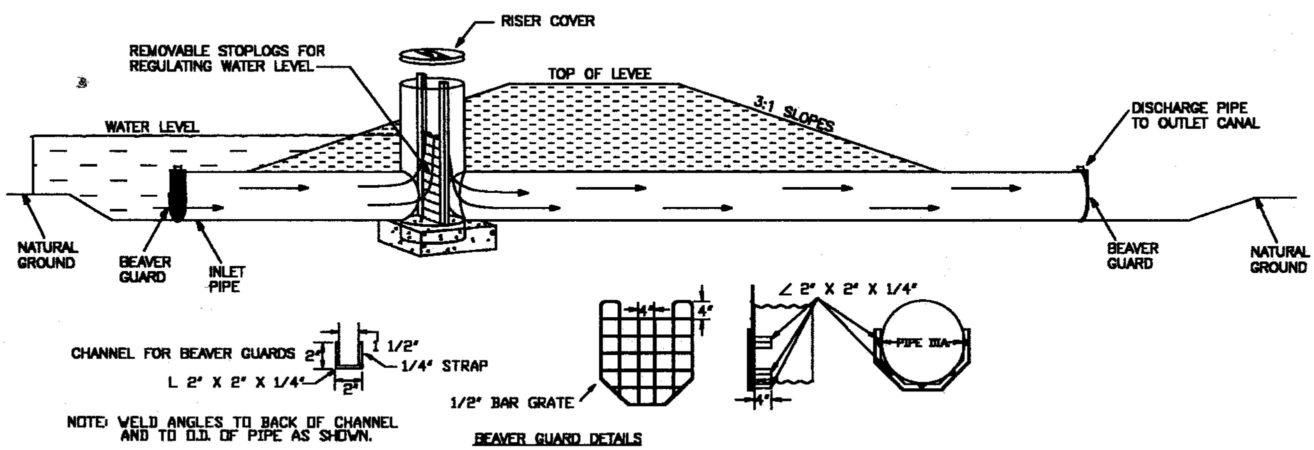
ADVANTAGES

1. Allows control of water levels during flooding and drawdown. Depending on the size of the boards, water can be gradually stepped up or down to allow waterfowl access to newly flooded feeding areas.
2. Allows storm runoff to pass through the structure while maintaining the water level desired for management purposes.
3. Provides some level of beaver control, probably because:
   a. beaver can't see water exiting the impoundment,
   b. the sound of running water is muffled when a lid is installed on the riser top, and
   c. the inlet is below the bottom of the impoundment, meaning that beavers will not see the structure inlet until most of the water has been withdrawn from the site.
4. Allows easy manipulation of stoplogs from the top bank. No catwalk or boat is necessary.
5. Deters vandalism since stoplogs are concealed.
6. Prevents beavers from entering and plugging the structure when grates are installed over inlet and outlet.

DISADVANTAGES

1. Initial cost is slightly higher than that of a flashboard riser.

Full-Round Riser (Figure #4)



SCREW GATE STRUCTURES

Gated pipes are used for water control in many waterfowl areas *(Figure #5)*. These structures consist of a regular overfall pipe with an attached screw gate which can be open or closed as needed. Sliding gates can be used, but these gates tend to stick after some time and are not easily maintained.

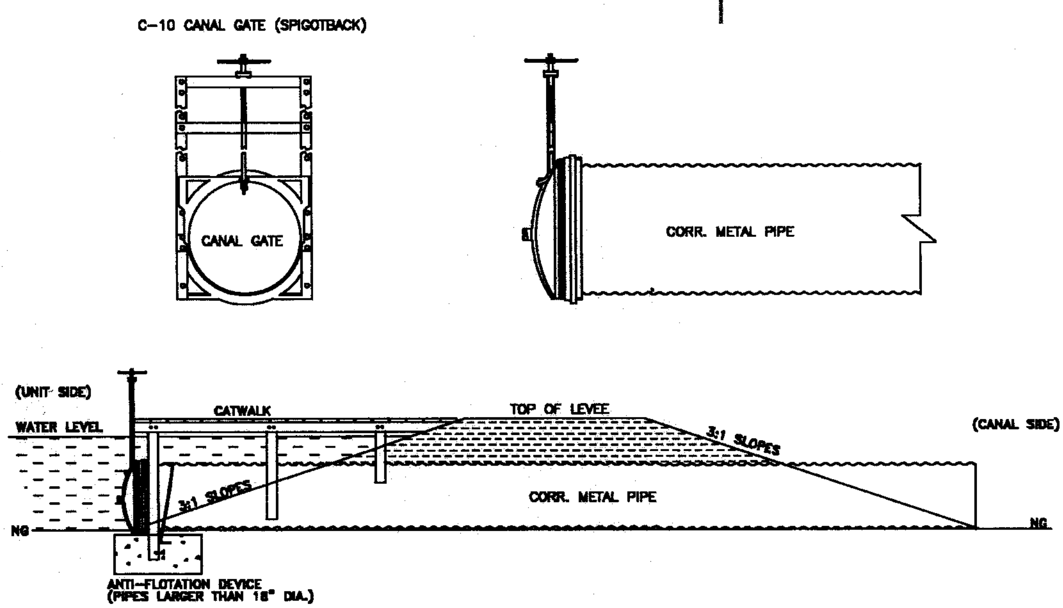
ADVANTAGES

1. Allows easy and complete drainage of an area. Opening the gate provides full pipe flow for the main structure.

DISADVANTAGES

1. All or none structure. Once the gate is opened, the entire area will be drained unless the gate is closed again. Therefore, this structure is management intensive when gradual changes in water levels are desired.
2. When closed, all the water received must be stored or passed via an emergency spillway. Otherwise, the gate will have to be opened to allow excess water to drain.
3. Cannot manipulate the water level gradually unless the structure is constantly attended.

Screw Gate (Figure #5)



FLAP GATE STRUCTURES

Flap gate structures *(Figure #6)* are normally installed in tidal locations or where varying stream flow occurs. During low tides, or rainfall events that raise the impoundment, water can be drained from the unit. They can also be used to add water to an impoundment during periods of high tides or high stream flow.

NOTE:

On the coast gates are used inside impoundments in combination with half-rounds with stoplogs. Gates are installed on the saltwater (tidal) side to prevent salt water intrusion, while allowing rainwater to drain over logs at low tide.

Dual flap gates (Figure 6) can be used to control the direction of water flow. When placed inside a full-round riser, one flap gate can be opened to allow water to enter or leave a unit. The other flap gate prevents the water from backdraining when the storm event or tide recedes. If these structures are recessed below ground level, a stoplog structure can be combined with the flap gate structure so that water levels can be manipulated within the unit. Additionally, the gate can be fabricated so that it can be installed or removed via the stoplog channels, allowing for easier gate maintenance.

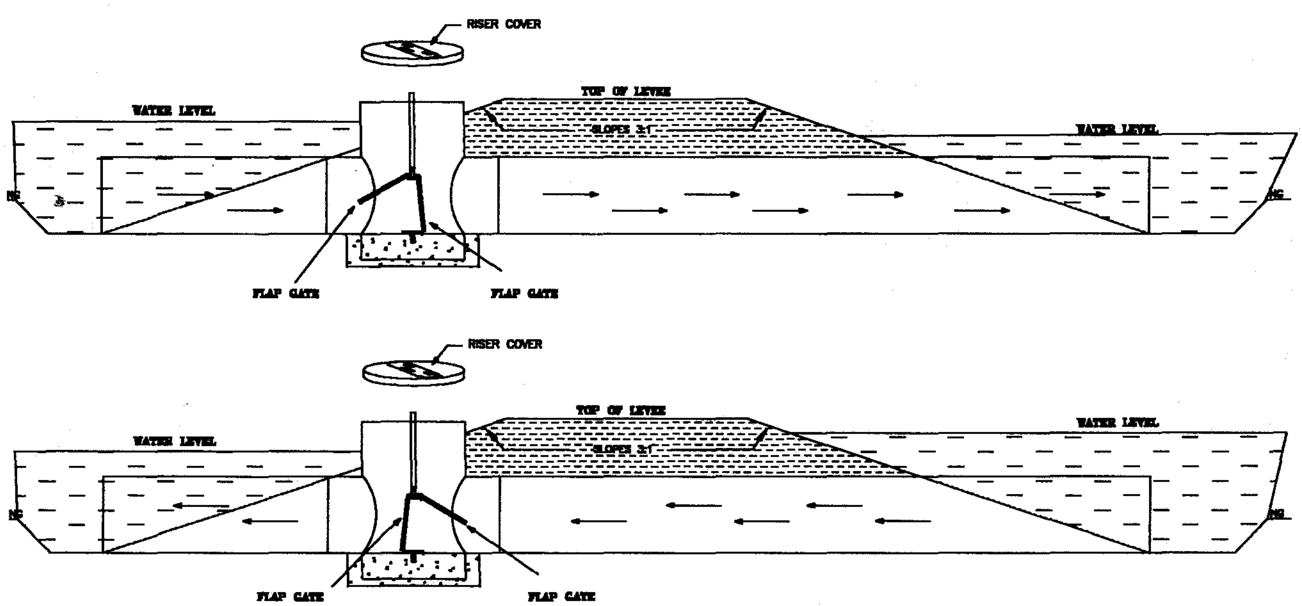
ADVANTAGES

1. Gate or structure closes automatically during low tides to allow water to drain from the impoundment.
2. Gate or structure opens automatically during rainfall or high tides to allow filling of the unit.

DISADVANTAGES

1. All or none structure. During high tides or rainfall you must receive the water.
2. Difficult to manipulate the water level without constant attention.
3. Trash can prevent the gate from completely closing/sealing.

Dual Flap Gate (Figure #6)



WHAT'S NEXT

Now that you know about the various structures that are available, how do you go about getting them designed and installed?

SURVEYS

A good topographical survey (normally one that delineates a minimum of 1 foot contours) is needed to determine the desired depth of water within the impoundment, height of the structure, and size of the structure. Often, if the area is frequently flooded, flags can be placed where the water level is adequate and the survey can be completed later, when the area is dry. During the survey, look for the following control points that are essential to structure design.

1. WATER LEVEL

When surveying, determine the maximum elevation at which you want to hold water. Remember, find the maximum elevation, not where you would normally hold water. Give yourself a little room. Consider the requirements of the species for which you are managing.

2. TOP OF LEVEE AND/OR EMERGENCY SPILLWAY

Once you have determined the maximum water level, determine how high the levee needs to be by answering the following questions.

a. Are there high spots on the sides of the area to be flooded which can be tied into the top of the levee?
b. Must the levee extend around the entire area?
c. Is there a good place for an emergency spillway? If at all possible, the spillway should be on natural ground rather than constructed fill.
d. Will it be cheaper to build the levee higher for protection and storage or to install an emergency spillway?

A general rule is that the top of the levee should be a minimum of 1 foot above the maximum water level or 1 foot above the emergency spillway. Actually the height of the levee above water level will be determined by the type of structure you select. For example, a gated pipe must have an emergency spillway to pass storm runoff while the gate is closed. Flashboard and full-round risers are designed to allow for storm runoff to pass over the top boards. The design and width of the stoplogs will determine the height of the levee needed above the maximum water elevation.

3. INLET ELEVATION

During surveys determine the elevation of the inlet and outlet pipes. How low does the inlet pipe need to be set to drain the area? Does it need to be submerged because of beaver activity? Generally the outlet pipe should be within 1 or 2 feet of the outlet channel bottom to prevent erosion or a blowout.

DESIGN

When a site has been surveyed and the elevations for the top of levee, water level, and inlet and outlet have been determined, a structure can be designed. We will briefly describe the various flow conditions that occur with different structures, but will not attempt to provide detailed formulas or designs. Instead, charts are provided for selection of pipe sizes (Table 1).

Keep in mind that the charts have limitations. It is best for an engineer to properly design water control structures, but, if engineering assistance is unavailable, the charts can be used for guidance.

1. DESIGN DISCHARGE

The most important consideration in designing a water control structure is determining the conditions under which a structure must operate. If the designer chooses a flow that is too high it may prove too costly to install a pipe large enough to carry that flow. On the other hand, if a designer calculates too low of a flow, the pipe may be insufficient to carry the flow and result in the pipe being blown out.

Pipes can be designed to carry peak storm events or to remove a certain amount of storm runoff from the area. Where storage for all or part of the storm runoff is not available, pipes should at least be designed to pass the *25-year, 24-hour storm event. If funds are available, it is best to increase the structure size to carry a larger storm event. Normally, an engineer should design structures which will handle peak storm events, since the drainage area, slope of the drainage area, condition of the ground cover, etc., must be considered in developing the flow.

Where storage for part or all of the storm runoff is available, pipes and levees can be designed for lesser flows. The charts in Table 1 show required pipe sizes for removal of 2-inch and 4-inch storm runoffs, as well as removal of acre feet of water per day. See Table 1 for a full explanation of the charts and their use.

When requesting a design, the manager should consider the size of the storm event that the structure must accommodate. In some cases, structure designs for different storm events should be obtained to compare costs and determine which best fits budget restraints. Within reason, bigger is better. As a general rule, it is best to spend the money up front for the larger structure, avoiding an inadequate design that could cause problems in the future, when funding might not be available.

* The 25-year, 24-hour storm event is basically the amount of rainfall you would expect over a 24-hour period once ever 25 years.

DESIGN (Continued)

2. PIPE FLOW

The first step in the design is to choose a pipe size that will carry the required discharge for the selected storm event. Correct pipe size is determined by using a formula to calculate pipe flow. The amount of water flowing over the center of the inlet pipe determines the amount of flow that the pipe will carry. The higher the water, the more pressure on the pipe and the greater the flow. In contrast, the amount of water on the outlet end will restrict the amount of flow through the pipe. If the water on the inlet must push against the water on the outlet, it will reduce the flow. In wetland designs, always assume that the flow in the pipe will be controlled by the tailwater on the outlet end. This assumption will reduce your calculated flow and provide a safety factor in the design.

3. WEIR AND ORIFICE FLOW

Weir flow occurs when water begins flowing over the riser rim or stoplog and continues until the water gets high enough for orifice or pipe flow to control it. To better define weir flow, think about pulling the plug in a sink. The water flows for a while, then starts swirling, and finally runs over the rim of the drain. Weir flow is comparable to water running over the edge of the drain, orifice flow occurs when the water is swirling, and pipe flow occurs when the water first starts flowing (i.e., when the pipe is full).

A properly designed pipe and riser combination will cause water to start in weir flow and then go into pipe flow. Orifice flow is not desirable because it causes vibrations in the pipe that may lead to failure. To prevent orifice flow, the riser is usually made larger, allowing more flow over the weir. The greater flow over the weir will prime the pipe, resulting in pipe flow instead of orifice flow.

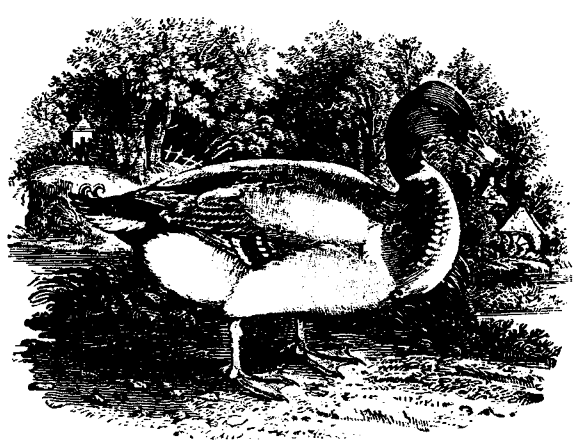


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TABLE 1

CHARTS FOR DETERMINING PIPE SIZES

NOTE: Do not use these charts to size pipes where storage of the storm event is not available. Consult an engineer for those designs requiring passage of peak flows.

CHART #1

When no conditions exists downstream that affect the flow of water thru the pipe.

PIPE		RISER			REMOVAL RATE		
					4"	6"	AC-FT
Size (Inches)	Gage	Size (Inches)	Gage	Height (Feet)	24 Hrs. (Acres)	24 Hrs. (Acres)	Day
15	16	24	14	0.85	29	19	10
18	16	30	14	1.00	45	30	15
21	16	36	12	1.15	68	45	22
24	16	42	10	1.29	94	63	32
30	14	48	10	1.72	166	111	55
36	14	60	10	2.03	266	177	88

CHART #2

When tailwater exists in the outlet end that affects the flow of water thru the pipe.

PIPE		RISER			REMOVAL RATE		
					4"	6"	AC-FT
Size (Inches)	Gage	Size (Inches)	Gage	Height (Feet)	24 Hrs. (Acres)	24 Hrs. (Acres)	Day
15	16	24	14	0.79	26	17	8
18	15	30	14	0.87	37	25	12
21	16	36	12	0.95	51	34	17
24	16	42	10	1.03	67	45	22
30	14	48	10	1.27	105	70	35
36	14	60	10	1.41	153	102	51

STEPS IN SIZING A PIPE:

1. First determine the drainage area or acres of impoundment
2. Then enter the proper chart and select the appropriate removal rate
3. Under the proper removal rate find the flow where the acres are greater than yours. Then look to the left for the recommended pipe and riser sizes.

See page 11 for definition of columns and examples.

EXPLANATION OF TABLE 1

DEFINITIONS AND EXAMPLES OF COLUMNS

1. The charts assume corrugated metal pipes. Steel, plastic, or concrete should have a slightly higher flow due to smooth walls on the pipes.
2. The pipes are sized to carry various removal rates from the area. It is assumed that the entire storm runoff can be stored behind the riser. If not, an emergency spillway must be installed.
3. Chart 1 is to be used when no downstream flooding of the area exists. In other words, the pipe can flow freely at all times without having to push against a downstream level of water. Chart 2 is to be used when downstream flooding conditions exists. In wetlands the latter is usually the case, and I would suggest using Chart 2 at all times as a safety factor in design.
4. The column labeled height under the riser is the maximum amount of opening required for water to prime the pipe. This should be noted when designing for a pipe that does not have storage capacity.
   a. Example: From Chart 1, for an 18" pipe with a 30" riser one should leave 1.0 feet of opening at the top of the riser to allow enough water to flow over the top board and prime the pipe.

      By having this 1.0 foot of opening, it would be the same as having no boards installed and the pipe flowing full. Note this would also require you to store the entire storm runoff within that top 1.0 foot.

   b. On areas where the area is surrounded by a levee and no upstream drainage enters, then this column would not be used. If a 6" rain occurs, then you would only have 6" of water running over the top board.
5. Removal rates are shown in 3 columns. The best way to explain their uses is by example.
   a. 40 acres of drainage, you wish to remove a 4" rain in 24 hours. From Chart 2 a 21" pipe with a 36" riser is needed. Chart 2 a 24" pipe with 42" riser is needed.

   b 400 acres totally enclosed by a levee. Water depth is 0.5 to 1.5 feet deep. Assume average 1.0 feet deep. You wish to remove the water within 20 days after the season and provide for some overflow during rain events. 400 x 1.0 = 400 acre-feet of water. To remove in 20 days = 400/20 = 20 acre-feet/day to remove. From Chart 2 a 24" pipe with a 42" riser is needed.

MATERIALS AND APPURTENANCES

LIFE EXPECTANCY

Information on the durability and service life of various corrugated metal pipe materials is diverse. Often influenced by particularly harsh or mild environmental conditions, service life is usually considered to be a function of the pipe material, the environment where it is installed, and additional measures taken to protect the pipe from deterioration.

TYPES OF PIPES

1. **Galvanized pipe** is the predominant type of material used for water control structures. It is cheap and readily available. The only problem with galvanized pipe is the life expectancy; uncoated galvanized pipe has a life expectancy of 10-to-15 years. Coating the pipe lengthens life expectancy. The two predominate types of coatings for galvanized pipes are bituminous and polymer films. Various reports give differing life expectancies of these coatings, but it is generally accepted that a bituminous coating will add 10 years to the life of the pipe and a polymer coating will add up to 30 years.
2. **Aluminized steel pipe**, Type 2, is fabricated from steel coils that have been hot-dipped in aluminum. Reports vary on the life expectancy of this pipe, but it is generally assumed to have twice the life expectancy of galvanized pipe. Aluminized coating should not be used in soils with low resistivity (< 1500) or a pH outside the range of 5-9. In cases where severe degradation to the pipe may occur, an aluminum pipe can be used.
3. **Used steel pipe** can also be used for water control structures. Structures made of this material have much longer life expectancies than other types of pipe due to the thickness of the steel. The only negative aspects of using used steel pipe is the unreliable availability of various sizes and the weight of the material.
4. **Aluminum pipe** can be used in saltwater areas or as a substitute for galvanized coated pipe, but the cost is usually higher than that of the pipe types discussed above. Aluminum pipe is lighter than galvanized and extra care should be taken during construction.
5. **Plastic pipes** are being used more and more due to the ease of installation and the availability. They come in PVC or black corrugated with a smooth interior. The problem with corrugated plastic pipe at present is the lack of a water tight band when the pipe is under pressure.

GAGE

The gage is the thickness of the pipe, with higher gages corresponding to less thickness. The thicker the pipe, the longer the life expectancy of the structure and also the higher the cost. When pricing pipe, the material supplier will usually quote a price based upon the higher gage (the cheaper material). For longer lasting pipe, thicker metal should be used. We recommend the following reference chart for corrugated metal pipe and riser gages.

Recommended Gages for Culverts		Recommended Gages for Risers	
12"-24"	16 Gage	12"-21"	16 Gage
30"-36"	14 Gage	24"-30"	14 Gage
42"-60"	12 Gage	36"-42"	12 Gage
66"-	10 Gage	48"-72"	10 Gage

ANTI-SEEP COLLARS

Anti-seep or cut-off collars are available for corrugated pipe. The number and spacing of collars varies with designer, but normally 2 are installed. Currently, the trend is to not use these collars, but many agencies still install them to prevent seepage around corrugated pipe. In some cases, a sand collar has proven very effective. These collars allow water to pass, but trap the clay particles against the sand, eventually forming a seal. In areas with dispersive clay soils, these collars have proven beneficial.

SITE PREPARATION

Site preparation is the work required to prepare the site for earthwork. It consists of any clearing, grubbing, topsoil excavation, tree cutting, etc., to remove debris prior to excavation and filling operations. It is important to remove all vegetation prior to placement of fill. By taking care to remove debris prior to excavation, the soil that is removed will be free of foreign matter and can be reused as backfill.

EXCAVATION

When excavating for a water control structure or pipe, cut the banks to slope on 2 feet horizontal to 1 foot vertical (2:1) or flatter. Flatter-sided slopes allow better bonding of the soil during backfill. Gouging or roughing the side slopes will also provide for a better bond. Never allow a vertical cut through an existing levee. Such a cut can result in improper bonding of the soils and lead to failure cracks in the embankment. Additionally, the bottom flat area where the pipe or water control structure is to be installed should be at least 6 feet wider than the pipe or structure. This margin allows room to compact soil around the pipe or structure during backfill.

FILL/COMPACTION

Prior to any backfill, the surface should be scarified and moistened. Backfill around structures and pipe should be accomplished by hand compaction for a distance of 2 feet from the pipe circumference. Initial backfill should be deposited in horizontal, uniform layers not exceeding 6 inches in thickness before compaction, and each layer should be thoroughly compacted throughout to ensure thorough tamping of backfill under the haunches and around the pipe. Hand compaction of fill material should be accomplished by application of motor-driven hand tampers or other approved equipment so that every point of the surface of each layer will be compacted.

The degree of compaction required will depend upon the type of structure installed. If testing labs or machines are available, it is always best to test the soils and compact to 95% of the standard proctor. However, you can proceed without soil tests. In such a situation, each layer should be compacted by routing the hauling and spreading equipment (minimum ground pressure 7.0 psi) over the fill in such a manner that every point on the surface of each layer of fill will be traversed by not less than 1 tread track of the spreading and hauling equipment. The soil should be deposited in layers from 6 - 8 inches, depending upon soil type.

Probably the single most important factor in compaction is the moisture content of the soils. The recommended moisture content should be within a range of -1% to +3% of the optimum moisture content of the soil. Without tests, it is impossible to know the proper moisture content, but a rule of thumb is that the soil should have enough moisture to form a ball. Actually, a somewhat wetter soil is preferred, but as long as the equipment can backfill without mudding the area , compaction should be obtained.

FILL/COMPACTION *(Continued)*

Since most areas where water control structures are installed will be in wetlands, the predominant soil will be clay, which can be difficult to work with. When dry, clay cracks and forms small balls and when wet, it sticks together. The wetter the soil, the better the compaction. Unfortunately, clay soil is hard to manipulate when wet.

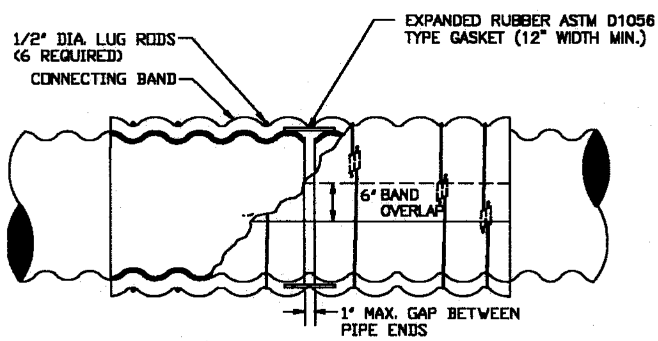
For initial backfill directly around the pipe, the U.S.D.A. Natural Resources Conservation Service has developed procedures for "mudding-in" or "earthfill slurry." These are methods of installing pipe in heavy clay soils by using mud or a water/soil mixture for the initial backfill instead of the traditional hand compaction methods. When dried, this mud or slurry forms a bond around the pipe. While specific methodologies and limiting criteria are subject to change, water packing is believed to have a high potential for reducing the risk of failure due to piping along the pipe, particularly in dispersive soils.

INSTALLATION

During installation watch for damages that may occur to the protective coatings of the pipes or structures. Polymer or bituminous coating does no good if it is scratched or removed. Damaged spots will corrode, resulting in pipe failure at a later date. Any damages to coatings should be repaired with materials supplied by the manufacturer.

Normally the structure will require a connecting band to join it to the pipe. Pipe must be rerolled to provide annular corrugations for banding, a process performed by the manufacturer. Take care when installing the connecting band to produce a water-tight seal. We normally specify a 10-corrugated band for connecting corrugated pipe *(Figure #7)*.

Connecting Band (Figure #7)



NOTES: 1) 6" BAND OVERLAP SHALL BE COATED WITH TAR PRIOR TO SECURING RODS.
2) AFTER BANDS HAVE BEEN TIGHTENED, A COAT OF TAR SHALL BE PLACED AROUND THE PIPE AT THE ENDS OF THE CONNECTING BAND.

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WELLS, PUMPS & POWER UNITS

After completion of the levees and structures, your next need is a reliable source of water. While the majority of the south has ample rainfall for migrating birds, the timing of the rainfall is sporadic. Early water for teal is often lacking and in some cases rainfall does not occur. Plus the availability of a reliable water source for moist soil management is lacking. For this reason a well or relift pump should be considered for all waterfowl impoundments.

WELLS VS RELIFTS

Your decision to use groundwater or surface water will likely be determined by the location of the waterfowl impoundment. If no surface water supply is available then you must rely on rainwater or a well. However, if surface water is available one should consider the benefits available.

PUMPS

The three main types of pumps used for supplying water are centrifugal, turbine, and propeller pumps. The main thing to consider in selecting a pump is the pump curve. You should receive a pump curve from the manufacturer that shows that the pump will produce the desired volume at the desired head. In the case of deep well pumps, you would first need a test well to determine the depth to water and the volume that can be produced. The pump curve should show that the pump is operating at or near peak efficiency. Selection of a pump that does not operate under peak efficiency will result in higher operational costs to you.

Centrifugal Pumps:
Centrifugal pumps usually give efficient operation over a relatively wide range of operating conditions. The centrifugal pump sucks the water from the source to the pump and is limited to conditions where the distance is within limits of suction. Centrifugal pumps are normally used for relift of surface water.

Turbine Pumps:
Because it operates successfully under any head, the deep-well turbine pump is best adapted to use in wells. A pumping test should be run before selection of a deep-well turbine pump. This will provide you with the data to make the proper selection of a pump based upon the manufacturers pump curves.

ADVANTAGES OF GROUNDWATER

1. Provides clean water
2. Available at most sites

DISADVANTAGES OF GROUNDWATER

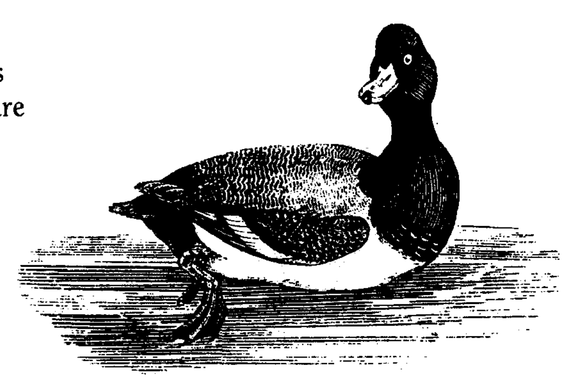
1. Depletion of aquifer available
2. Production not assured
3. High Cost—test well needed

ADVANTAGES OF SURFACE WATER

1. Lower cost
2. Source of invertebrates
3. Filtration of pollutants
4. Addition of nutrient rich water to wetland

DISADVANTAGES OF SURFACE WATER

1. Not always available
2. Trash buildup



PUMPS (Continued)

Propeller Pumps:
The propeller pump is adapted to delivering a large quantity of water under low heads. It can be adapted to different heads and discharges by adding additional stages. It is one of the more popular pumps used in relift situations.

POWER UNITS

The selection of the proper power unit should not be based upon the initial cost of the unit alone. One should consider the cost of fuel, repairs and maintenance, investment cost, and life of the system. In general, an electric unit can be installed much cheaper than a diesel unit, but the cost of power for the electric unit will be much higher than diesel. How long it takes to expend your initial savings on the unit will depend upon the amount of pumping you intend to do. To make it even more complicated, you need to consider that you will have more repairs, maintenance, and a shorter life expectancy for the diesel unit. Below are some factors to consider for electric and diesel units.

Electric Unit
1. What is the price of electricity based on the number of hours per year that the unit is going to run.
2. What is the connect charge.
3. Is power available and what is the cost to run it to the site.
4. What kind of life and maintenance costs are involved in the operation of the electric unit.

Diesel Unit
1. What is the difference between the electric and diesel unit, total cost.
2. What is the life of the diesel unit.
3. What are diesel fuel prices likely to do in the future.
4. Availability of service and parts for the engine being considered.
5. What are the maintenance costs of the engine.
6. What is the potential for vandalism or theft.

ADVANTAGES OF ELECTRIC POWER UNITS
1. Low maintenance
2. Cheaper initial cost
3. Can be automated

DISADVANTAGES OF ELECTRIC POWER UNITS
1. Availability
2. Generally higher fuel costs

ADVANTAGES OF DIESEL OR GAS POWER UNITS
1. Portable
2. Repairs can be made locally

DISADVANTAGES OF DIESEL OR GAS POWER UNITS
1. High maintenance
2. Easily vandalized/spillage
3. Access for fuel supply