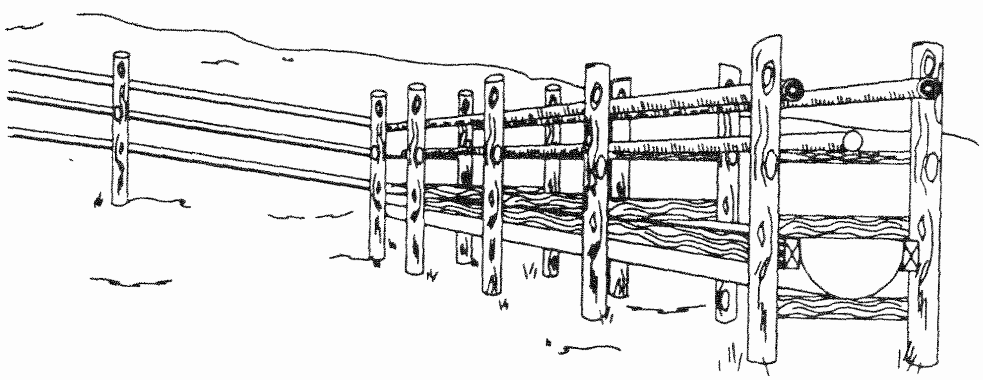
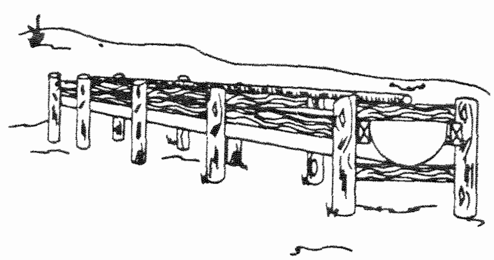
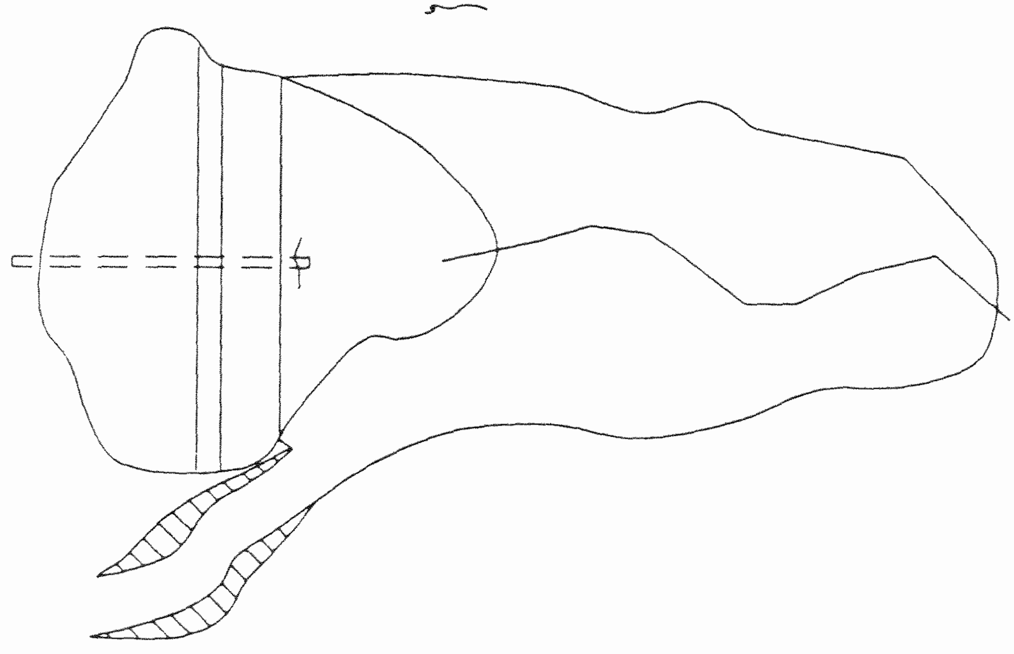
Water Developments







BLM MANUAL HANDBOOK 1741-2

Table of Contents

H-1741-2 - WATER DEVELOPMENTS

Chapters | Page

H-1741-2 - WATER DEVELOPMENTS

Chapters | Page

Chapter I

Chapter I - Identifying The Need For Water Developments

A. Introduction.

This Handbook supplements the renewable resource improvement and treatment guidelines and standards contained in Manual Section 1740 and the supplementing guidance and procedure discussed in Handbook H-1740-1. The guidance and instructional information in this Handbook addresses the installation and use of water developments, including applications, advantages, disadvantages, installation procedures, and considerations applicable to specific types of water developments. Coordination, investment analysis, modification, maintenance, and reconstruction guidelines applicable to all water developments are also discussed briefly.

B. General Considerations.

Before a proposed water development is given serious consideration as a "planned project awaiting installation," several questions should be answered. They are:

1. Have management objectives for the area and resources involved been developed and identified through an interdisciplinary resource management planning process?

2. Have site-specific management objectives been developed and incorporated in a proposed or final activity or action plan?

3. Have the development of management objectives and the proposal to develop water to help meet these objectives included discussions with affected users, cooperators, and other non-Bureau interest?

4. Were changes in management strategy or the development of a new management prescription considered in conjunction with, or instead of, water development projects?

5. Have differing types of water developments and their relative costs that would largely achieve the same objectives been considered?

6. Has the inventory of existing water developments in the area been reviewed to determine whether a new water development is needed?

7. Will development of water to serve one need generate new conflicts in the use of vegetation or habitat?

8. Can potentially adverse impacts be mitigated through project design and/or operation stipulations?

9. Is development of the water resource the most cost-effective means of achieving resource management objectives?

10. Will funds in the benefiting subactivity(ies) be available for project installation, maintenance, etc.? Is multi-subactivity funding needed or appropriate?

11. What is the relative priority of the affected allotment, habitat management area, etc., in relation to other management units?

12. Can the proposed development be designed and constructed to meet other activity needs/restrictions (wildlife, wilderness, wilderness study area, etc.)?

13. Have water rights been acquired from the State?

14. Can existing water developments such as pipelines be expanded to provide additional needs or serve other allotments? Can new developments serve more than one allotment and are resource staffs looking at this as an option?

15. Has a site specific technical evaluation or feasibility analysis been completed.

These questions provide a general framework for the thought and analysis process that should proceed making specific proposals for water developments. Other considerations may also be applicable. The guidelines and information contained in the other parts of this Handbook were developed to help assure that new water development projects are successfully planned, designed, and constructed. Use of a project planning checklist similar to that shown in Chapter 2 of H-1740-1 will help assure that projects are planned and used in the most effective and efficient manner. Managers shall not modify or depart from Bureau guidelines and standards unless analysis of site-specific resource concerns, management objectives, public input, new technology, etc., indicates that other means of accomplishing the objectives are possible and will not result in unacceptable adverse effects.

Chapter II

Chapter II - Coordination Standards

A. Planning and Environmental Analyses.

Decisions to use or to exclude a particular type of water development at or near a specific geographic site should always evolve from the interdisciplinary consideration of resource values, public needs, and issues identified during the land use planning Resource Management Plan/ Environmental Impact Statement process. Resource management (program) objectives must be defined before a means of achieving them is selected. Site-specific improvements should be identified and receive the appropriate environmental and other analyses during the activity and project planning process (see Manual Section 9101).

B. Internal BLM Coordination and Interdisciplinary Review.

Proposed water development projects must be coordinated among affected resource programs to assure that all resource values and needs are considered. The most efficient means of accomplishing this is to identify and analyze proposed water developments in the land use planning and/or activity planning processes. Use of the project planning and documentation checklist will usually assure that a project receives the appropriate interdisciplinary review and coordination. The basis for selecting and approving the installation and use of a particular water development should be readily apparent in the analyses of environmental, economic, and technical feasibility contained in a project file. Water developments will normally be planned and designed to meet multiple-use objectives. The following are program specific guidelines:

1. Energy and Minerals Development. Water developments should not be constructed/installed in areas where expected energy or minerals developments would effectively lead to their destruction unless:

    a. The principal features or components of the water project can be economically salvaged and used again, or

    b. The benefits yielded prior to removal and/or destruction will exceed the costs of project installation and maintenance.

2. Public Land Disposal. Water developments should not be constructed on lands identified for sale or exchange unless one of the conditions in "a" or "b" above is met or the residual value of labor, material, and equipment used during project installation will be reflected and recovered at the time of sale or exchange.

3. Recreation. Water developments must be consistent with recreation related land use planning decisions, since water development may affect the types and intensity of recreation use. Consideration must be given to whether or not the water will be available to recreation users and whether applicable water quality and safety standards are complied with.

4. Visual Resources. Where land use planning or other management guidance identifies that human intrusions on the viewshed are to be minimized or avoided, water developments must be designed, installed, and located in a manner that causes them to blend in with the surrounding scenery. Locating some facilities in a depression or "behind" vegetative screening, painting, and avoiding skylines are other options that should be considered. To minimize the visibility of project components, do not leave long traceable linear features. Use irregular shapes for clearings and rehabilitate areas where removal of vegetation is necessary. Sometimes, the presence and easy recognition of certain structures may be desirable.

5. Wild Horse and Burro Habitat. Water developments in wild horse and burro herd management areas must be designed and constructed to allow them to withstand the bumping and pushing caused by horses and burros when a herd comes to water and compete for available space. Provision of water to wildlife and/or livestock in areas where horses or burros are excluded may be necessary. The need to provide water to some species on a year-round basis should also be considered during project design.

6. Grazing Management. Each water development must be designed and constructed to provide adequate water for the kinds and numbers of livestock and wildlife that will depend on it. Factors such as season of use, existence of alternate water sources, storage requirements (a storage capacity of at least 3 days is recommended) and the use of waters to achieve vegetation management objectives should also be considered. Water developments proposed by other program or resource interests should be reviewed by a Bureau employee familiar with livestock and vegetation management objectives. Coordination with affected authorized users is also required.

7. Wildlife. Water developments should always be designed, installed, and operated consistent with planning guidance related to the management of wildlife species and their habitat requirements. Review applicable land use and activity plans during project planning. Consultation and coordination with specific user interests during project planning may be necessary, in addition to the coordination that occurred during land use planning. The following guidelines apply in most situations:

   a. Locate and install water developments in a manner that avoids the creation of new conflicts concerning use of vegetation and other resources.

b. Install escape ramps in open water troughs and tanks to protect water quality and to reduce wildlife loss.

c. Assure that water is available to wildlife and other species (e.g. wild horses and bison) when livestock are not using the facility when plan objectives identify the need.

d. Assure that water for wildlife is presented in a manner suited to the requirements of the target species. This may require the installation of separate storage or drinking facilities and fencing to exclude livestock or wild horses.

e. Document agreements with public land users and cooperating interest groups concerning responsibility for operation and maintenance of water developments.

f. Plan for the establishment and protection of seep areas for use by wildlife where that need exists.

g. Plan for wildlife enhancement measures where practical in project design (islands in reservoirs).

8. Health and Safety. Project planning and installation must include consideration of health and safety guidelines. Water quality analyses may be required to assure that applicable-use standards for humans and animals are complied with. (See Manual Section 1112, Handbook H-1112-1 - Operational Guidance, and Manual Section 9184.)

C. Statutory Requirements for Coordination.

1. Threatened or Endangered Plants and Animals. See Manual Section 6840 for guidance on consultation with the U.S. Fish and Wildlife Service if a proposed water development may affect a federally listed or candidate species. Memoranda of agreement with State government agencies should identify the procedure to follow concerning State listed species.

2. Cultural Resources. 36 CFR 800.4 sets forth the procedure to be followed when cultural resource inventories are needed. The content and format for a site-specific cultural resource inventory or clearance is also described in Manual Section 8111.14C (Class III inventories).

3. Wilderness Study Areas (WSA's) and Designated Wilderness. Manual Section 8550 and Handbook H-8550-1 (Interim Management Policy and Guidelines for Lands Under Wilderness Review) contain Bureau policy and guidance for management of: (1) lands for which the wilderness inventory process has not been completed, and (2) WSA's. The general standard is that these lands should be managed in a manner so as not to impair the suitability of such areas for preservation as wilderness. Handbook H-8550-1, Chapter II, discusses evaluation and notification procedures and recordkeeping requirements. "Guidelines for Specific Activities" are contained in Chapter III.

   Manual Section 8560 and Handbook H-8560-1 (Management of Designated Wilderness Areas) provide guidance concerning Prohibition of Certain Uses (8560.12), Minimum and Acceptable Tools (8560.13) and the use and maintenance of livestock grazing management improvements and facilities (8560.15G). The general standards are that the wilderness character of the area should be preserved and that livestock management improvements existing at time of designation and complying with an approved Allotment Management Plan may continue in use. Rangeland management guidance is discussed in Manual Section 8560.37. There is also a requirement that Wilderness Management Plans be prepared for all wilderness areas on public lands. These plans guide the preparation or revision of other activity and action plans and contain detailed information concerning project design, maintenance, and reconstruction, including standards and stipulations for fencing projects.

D. External Coordination.

1. Livestock Operators. During the planning process, permittees and lessees must be consulted and their cooperation sought concerning installation, modification, or removal of water developments on the allotments they use. This coordination and consultation are necessary whether the objectives involve grazing management or other resource and program objectives. Except where water developments are totally funded by the Bureau for non-livestock use purposes, they must be authorized by either a Cooperative Agreement or Range Improvement Permit which identifies construction and maintenance responsibilities, as well as ownership of improvement projects. When projects are developed on private land a water right and/or legal easement is required and shall be executed on behalf of the BLM.

2. District Grazing Advisory Boards. Where they exist, these boards must be consulted at least once annually and given an opportunity to offer advice and make recommendations concerning the development of allotment management plans (AMP's) and the utilization of range improvement funds. This requirement is applicable to all approved types of improvement and treatment projects and to coordinated resource plans that include the equivalent of an AMP.

3. <u>Conservation Organizations</u>. Coordination with conservation, environmental, and other interests which may be affected by installation, modification, reconstruction, or removal of water developments should occur during the planning process. Agreements reached during activity planning regarding participation in, or responsibility for, constructing, maintaining, or operating improvements should always be documented in a Cooperative Agreement.

4. <u>Federal, State, and Local Government Agencies</u>. Federal and State agencies such as the U.S. Forest Service, U.S. Fish and Wildlife Service; State lands, wildlife, and recreation agencies; and county and municipal officials should all have an opportunity to review or comment on proposed water developments that may affect the lands or interests for which they are responsible. The most efficient means of accomplishing this is by asking them to participate in the land use planning process. Annual coordination meetings with some State and local entities may be beneficial. Use the project planning checklist and environmental analysis procedures to identify coordination needs for specific water development projects.

5. <u>State Water Resource Administration</u>. It is the policy of the Bureau that States have the primary authority and responsibility for the allocation and management of water resources within their boundaries, except as otherwise specified by the Congress. This requires that the Bureau cooperate with State agencies having the responsibility to protect identified public land water uses and to comply with applicable State law for the appropriation of water needed for management of the public lands. When applicable, water rights must be appropriated prior to project construction/installation.

H-1741-2 - WATER DEVELOPMENTS

Chapter III

Chapter III - Investment Analysis Standards

Investment analysis is a part of activity plan development and is usually required. The analysis of all projects in a plan, and of alternative "plans" with differing mixes of projects and management strategies, is necessary to determine the most economic or most cost-effective package of projects. Analysis on a project-by-project basis is unnecessarily time-consuming, does not include consideration of cumulative effects, and does not meet the "all costs--all benefits" analysis rule. Investment analysis is also useful when some or all of the benefits cannot be quantified or valued. In situations like this, the analysis and information provided to decisionmakers should identify the package of improvements that will accomplish management objectives in the least costly manner.

Investment analysis includes the use of economic and other criteria to establish activity plan preparation priorities and to establish the priority of specific improvement and treatment projects associated with those plans (when preparing annual work plans and obligating funds). See Handbook H-1740-1 for general and program specific investment analysis guidelines. Also see the User Handbook or contact the Service Center user representatives for information about the Bureau's Investment Analysis Model which is designed for use on IBM compatible personal computers.

Chapter IV - Spring Development

A. Introduction.

"A spring is a place where, without the agency of man, water flows from a rock or soil upon the land or into a body of surface water." (Meinzer 1923)

This chapter presents some generalized concepts for the development of springs. Springs occur in an infinite variety of situations, and each situation presents its own unique development problems. For this reason, a cookbook approach to spring development is not presented here.

The obvious but not the proper reason for developing a spring is because "the water is there." The physical presence of water in the form of a spring provides a development opportunity that should be explored. However, the dependability and required amount of water needed, the type of acquifer, soil type, and maintenance, protection, and enhancement of the existing riparian area must be considered before a determination to develop is made.

Springs may be a good option to develop in places where wells, catchments, or reservoirs are impractical or relatively expensive to construct for the amount of water required. In such cases, the desirability of developing the spring is readily apparent. On the other hand, many springs exist in areas where other sources of water, such as streams or lakes, are abundant. In these areas, development of a spring may be a needless expense, unless the spring source is needed for livestock distribution or some other factor.

B. Advantages and Disadvantages.

1. Advantages.

The chief advantages of spring developments relative to other sources of water supply are:

- Low investment risk.

- Dependability.

- Cost.

- Versatility of construction.

The presence of water avoids the inherent risk of drilling a well into uncertain underground territory. Similarly, most reservoir and catchment construction is undertaken on hydrologic predictions that may or may not be accurate.

Although springs may vary in flow according to the season or climatic conditions, some springs are completely dependable from one year to the next. This is especially true of artesian springs or those that issue from regional aquifers. In general, seeps or weak flowing springs are typically the most unreliable.

Most springs are relatively inexpensive to develop. If heavy equipment is used, only the smaller backhoes, loaders, and crawler tractors are generally needed. Not only is the operating expense of the smaller equipment less, but also the transportation costs to and from the job site are less than for larger machines. Likewise, spring development materials are much less costly than for a well or catchment.

Another strong advantage is that a variety of materials and different construction methods can be used to develop a spring. Collection systems can consist of french drains, perforated pipes of different materials, driven sand points, or even horizontal wells. Spring boxes take many shapes and forms and can be constructed from many materials that may be on hand. Cutoff walls can be made from most impervious materials, ranging from plastic sheeting to concrete. Likewise, on many springs, hand labor can be substituted for machine work and vice versa. This is particularly advantageous where vehicle access is difficult or when a proposed development is a cooperative effort between BLM and a rancher who may not have specialized equipment.

2. Disadvantages. The main disadvantages of spring development versus development of other sources of water include the following:

- Uneven geographic distribution.

- Variable spring flow.

- Restricted season of use.

- Maintenance costs may be high.

Springs occur where geohydrologic conditions dictate--not necessarily where they fit the needs of management. This is probably the chief limitation of springs when compared to other water development alternatives.

Another shortcoming that must be realized is that certain types of springs will vary in amounts of flow and dependability. According to the season or the prevailing climatic conditions, one may visit a spring site that appears to be quite worthwhile for development. A second visit in another season may show a greatly diminished or non-existent flow. Because of this, it is important to understand the conditions governing the occurrence of springs and amounts of flow.

Along with the idea that some springs are variable in flow and dependability, comes the realization that there may be restrictions on the season of use for which the development is intended. For example, a spring with weak flow may freeze up during the winter. A less obvious example is the spring that may dry up during a wet summer because its recharge area may not have received sufficient snowmelt some months earlier. Again, an understanding of spring characteristics is essential.

The advantages of low cost and versatility of construction methods can exact their price; a poorly conceived design and/or use of unsuitable materials can lead to maintenance problems.

The following sections on the classification of springs and principles of development will help achieve more effective utilization of springs on the public lands.

C. Design and Installation.

Classification of Springs. Before designing and installing a spring development, the type of spring must be identified. Springs are usually classified according to the geologic structure and forces bringing water to the surface (Schultz and Cleaves, 1955). Two categories of springs are gravity and artesian.

1. Gravity Springs. Gravity springs are formed by the outcrop of water flowing under action of gravity. Some of the types of gravity springs are:

   - Depression springs.

   - Contact springs.

   - Fracture and tubular springs.

   a. Depression Springs - Characteristic Features.

      (1) Location. Along outcrop of water table at edges or in bottom of alluvial valleys, basins, depressions in moraines, and valleys cut in massive permeable sandstone or volcanic ash. See Illustration IV-1.

      (2) Type of Opening. Irregular spaces between grains of the material.

(3) Yield. Depends upon height and gradient of the water table, permeability of the water-bearing material, and size and intake opportunity of the tributary area. Flow may range from less than one to several gallons per minute (gpm).

(4) Type of Flow. May be either perennial or intermittent, depending upon rise or fall of the water table. If the tributary area is small, the flow will depend on local precipitation.

(5) Quality of Water. Usually fair to excellent, but may be mineralized if the aquifer contains soluble substances.

(6) Water Temperature. The temperature of the water will generally approximate the mean annual atmospheric temperature.

(7) Features Produced. Usually none in valleys. In humid areas, minor slumps, headcuts, or swamping may sometimes develop. In windswept arid and semiarid basins, the wetted areas and the vegetation growing around springs may cause deposition of material forming a mound.

b. Contact Springs - Characteristic Features.

(1) Location. May occur on hillsides, in valleys, or wherever the outcrop of an impermeable layer occurs beneath a water-bearing permeable layer. See Illustration IV-2.

(2) Type of Opening. Openings in sand or gravel are irregular, intergranular spaces. Openings in rocks are joints, fractures, or open bedding planes. Openings may be tubular in limestone, gypsum, and basalt.

(3) Yield. Volume of flow may range from less than one to several thousand gpm, depending upon the height and gradient of the water table, permeability fracturing or development of solution openings of the water-bearing material, the volume of aquifer tributary to the spring, and conditions of water intake.

(4) Type of Flow. Usually perennial for contact springs supplied by the area water table. If contact spring is supplied by a perched aquifer, the flow may be intermittent.

(5) Quality of Water. Usually fair to excellent, but may be mineralized if water-bearing material contains soluble minerals.

(6) Water Temperature. The temperature of the water will approximate the mean annual atmospheric temperature of the location. If movement of water occurs through passages that are open to the circulation of air, cooling to as much as several degrees below mean annual temperature will occur. If water is not in contact with circulating air and the depth to the water table is several hundred feet, the water will be a few degrees (generally about 1 degree for each 100 ft. depth) warmer than the mean annual temperature. Buried igneous rock, if still hot, will raise the temperature of ground water producing hot springs.

(7) Features Produced. Travertine ($CaCO_3$) may be deposited as described under "Fracture, Joint, and Tubular Springs."

c. Fracture, Joint, and Tubular Springs - Characteristic Features.

(1) Location. On hillsides, in valleys, or wherever land surface is below the water table. See Illustrations IV-3, IV-4, and IV-5.

(2) Type of Opening. Fractures and open bedding planes in all rocks, sometimes tubular openings in limestone, gypsum, and lava.

(3) Type of Water-Bearing Material. Fractured or jointed rocks.

(4) Type of Flow. Usually perennial, may fluctuate with precipitation if tributary area is small.

(5) Yield. Flow may range from less than one to hundreds of gpm depending upon the extent of fractures, solution passages, or joint system tributary to the opening.

(6) Quality of Water. Usually good to excellent. May be hard (contain $CaCO_3$) if spring issues from or percolates through limestone.

(7) Water Temperature. The temperature of the water will approximate the mean annual atmospheric temperature at the location with exceptions as discussed under "Contact Springs."

(8) Features Produced. If the water is warmer than the mean annual atmospheric temperature and has percolated through limestone on its way to point of discharge, travertine ($CaCO_3$) may be deposited about the spring opening. Water from other materials usually produces no surface features.

2. Artesian Springs.

Artesian springs are formed where the piezometric surface is above the land surface and the water flows under artesian pressure. Two types of artesian springs are aquifer outcrop springs and fault springs.

a. Aquifer Outcrop Springs - Characteristic Features.

(1) Location. May occur in any topographic position along outcrop of aquifer. See Illustrations IV-5 and IV-6.

(2) Type of Opening. Will depend upon nature of water-bearing material. If aquifer is sandstone, water may seep from spaces between grains, from fractures or from open bedding planes. If aquifer is limestone, water will issue from joints or tubular openings.

(3) Water-Bearing Material. May be sandstone, limestone, or jointed basalt.

(4) Type of Flow. Perennial, usually constant. Quickly affected by wells drawing from same aquifer. May be affected by long continued drought.

(5) Yield. Flow may range from a few grams per meter to several thousand grams per meter.

(6) Quality of Water. Usually good to excellent. Water may be hard or mineralized (contain $CaCO_3$) if aquifer is limestone.

(7) Water Temperature. The temperature of the water will approximate the mean annual atmospheric temperature of the location unless the aquifer is deeply buried. If so, temperature will be a few degrees above the mean annual temperature (about 1° for each 100 feet aquifer lies beneath the surface).

(8) Features Produced. If water is from a limestone aquifer and is warmer than the mean annual temperature, travertine ($CaCO_3$) may be deposited.

c. Fault Springs - Characteristic Features.

(1) Location. May occur at any location along a fault or related fractures. See Illustration IV-7.

(2) Type of Opening. Will depend on the nature of material at land surface. If surface is alluvium, water will issue from spaces between grains. If surface is rock, water will issue from fractures.

(3) Type of Water-Bearing Material. May be any kind of rock. Surface material may not indicate what the aquifer consists of.

(4) Yield. Volume of flow may range from a few gpm to several thousand gpm.

(5) Type of Flow. Perennial, constant, and only affected by long periods of drought. Quickly affected by pumping from wells drawing upon the source aquifer.

(6) Quality of Water. Usually good to excellent. Water may be hard or mineralized (contain $CaCO_3$) if aquifer is limestone.

(7) Water Temperature. See Aquifer Outcrop Springs.

(8) Features Produced. See Aquifer Outcrop Springs.

D. Development Techniques.

The objective of a spring development is to make natural outcroppings of ground water available for use. Proper development techniques and designs vary with the different types of springs, and should allow efficient removal of the amount of spring water needed. The development method used should allow the unused water to flow past the development without backing up and creating a new flow pattern around the development and should not drain the acquifer or dewater the natural riparian area.

Information about the spring should be collected prior to development. Important data would be:

- Volume and reliability of flow.

- Nature of the water-bearing material.

- Hydrogeologic conditions that cause the flow.

These data indicate whether the spring will meet the management goal and also are essential for proper design of the development.

The three essential components of a spring development are:

- Collection systems.

- Concentration facilities.

- Discharge systems.

These three components are always present although they may not be readily identifiable as such. For example, a pipe (perforated at one end) driven into a wet hillside could serve as collector, concentration point, and discharge facility.

1. Collection Systems.

With many springs, it is necessary to collect the flow issuing from several openings or seeping from the water-bearing material. Where possible, it is desirable to explore the water-bearing strata by digging trenches or augering holes to find the areas of maximum flow. The use of heavy equipment for this purpose should be done with caution because the spring could be destroyed during the exploration process.

Spring flow can be collected by several methods or combinations of methods, including:

- French drains.

- Perforated pipes and well screens.

- Cutoff walls.

- Well points.

- Horizontal wells.

- Manufactured drainage systems.

a. French Drains.

A french drain is a gravel-filled ditch dug in the water-bearing formation. Usually, a system of lateral ditches are dug more or less perpendicular to the flow path. These are graded to flow into a main collector ditch (or ditches) which in turn grades to the concentration point. After backfiling with gravel and enclosing the gravel with a filter fabric, the drains are covered with the excavated ditch material. Gravel used in the french drain should be washed and graded to optimize water infiltration into the drain. Water is collected from the drain by means of a perforated or screened section of pipe, a perforated spring box, or a gravel-filled sump area.

b. Perforated Pipes and Well Screens.

Perforated pipes and well screens or any combination of them are very efficient means of collecting water from a spring. However, their use is limited to tapping water from unconsolidated materials. As with french drains, ditches are dug into the water-bearing material in patterns designed to optimize the interception of water. The ditches should be dug to the bottom of the main water-bearing strata but must not perforate the impermeable layer below. If the water-bearing formation is very thick and the water flow is in excess of the need, this provision may not be necessary.

In the case of perforated pipe, graded, washed gravel is laid on a filter fabric in the bottom of the ditch. The pipe is then placed on the gravel bed and covered with more gravel which is covered with a filter fabric, so that an "envelope" of gravel surrounding the pipe and an envelope of filter fabric around the gravel is formed. The material from the ditch excavation is used for cover so that the original contour of the spring area is restored.

In the past, the only pipe available for collection systems was made of iron or clay. Metal pipes are subject to corrosion and are difficult to handle and install. Clay pipes are heavy and break easily. Fortunately, today's spring developer has plastic pipe on hand. Plastic pipe has the advantages of light weight and no corrosion. It is easy to cut and perforate, and joints are simply glued together.

Perforated "sewer pipe," commonly used in septic systems, is cheap and readily available in plumbing supply stores and lumber yards. For spring development, its only shortcomings are lack of collapsible strength and lack of a variety of diameters for the pipe and perforations. If the collector is subject to heavy hydraulic pressure, the aquifer material clogs the holes, or the pipe diameter is unsuitable (rare), PVC plastic pipe is the alternative.

PVC pipe is cheap, lightweight, relatively strong, and comes in a variety of diameters and wall thicknesses. The pipe can be easily cut with an ordinary hand saw. Joints are simply glued together. Perforations can be made to the size desired, depending upon the texture of the aquifer material. Holes are easily made with an electric drill, or slots can be made with a circular saw.

Until recently, there has been little use of well screens in spring collection systems. Screens are designed to allow the maximum amount of water from the aquifer to enter the collection system with the least amount of resistance. If water yield from a spring must be maximized, the extra cost of installing well screens in place of perforated pipe may be easily justified.

The two most common types of well screen are louvered and continuous slotted. Both are made of either plastic or metal, with the metal screen being the stronger of the two. For spring developments, plastic screen should be strong enough for all but the most rigorous applications. Louvered screen is cheaper, but slotted screen offers the advantage of very precise control over the size of the screen openings. This is important, because the purpose of the screen is to allow water to enter the collector, while keeping the aquifer material out.

If well screens are being considered for a spring development, advice should be obtained from a person with expertise in water well design. The water well section of this Handbook has a more comprehensive discussion of this subject.

c. Cutoff Walls.

A cutoff wall is used to capture spring flow downgradient from the source.

Springs in unconsolidated materials often seep out over a wide area with no apparent concentrations of flow. In such cases, a cutoff wall can be installed below the seep area to intercept and back up the water. With some springs, the wall may serve as the complete collection system. In other situations, the cutoff will not only collect flow, but also back up water to create a hydraulic head and make other parts of the system (such as drain pipes) more efficient.

Cutoff walls are often used where spring flow issues from consolidated formations (e.g., fractured rock), or where thin unconsolidated material precludes the use of drains, pipes, or screens. In these cases, a cutoff wall should be looked at as a small dam to store and concentrate the spring water.

A properly designed cutoff wall will have these features:

- Installed more or less perpendicular to the flow.
- Angled to concentrate the flow.
- Strong enough to contain the flow.
- Keyed in to prevent underflow or side flow (short-circuting).

The cutoff wall is oriented nearly perpendicular to the flow lines, to optimize the interception of water. However, at the same time, the gradient wall needs to be maintained so that the intercepted water will flow to the concentration point.

Cutoff walls can be of many different designs, but they must be strong enough to withstand the hydraulic pressures from upstream. When use of a cutoff wall is proposed, a qualified engineer should be consulted to ensure that the wall is properly designed.

Of equal importance is the concept of keying in the bottom and sides of the cutoff wall. The wall must be keyed in to a depth sufficient to prevent flow under or around the structure. This prevents escape of the spring water and the possibility that the wall might be undermined and washed out.

Cutoff walls can be made of many different materials, if they are impervious and strong enough to do the job. Commonly used materials include concrete, plastic, clay, soil-bentonite mixtures and steel sheet piling. Before any material is used, a qualified engineer should be asked to confirm that it will meet the needed requirements.

d. Well Points.

Well points (sometimes called drive points or sand points) are usually installed at shallow depths and only in soft formations which are relatively free of rock, so that the well point can be driven into the ground by hand. The auger drill is used where the formation is hard, and driving the well point is not possible.

(1) Driven points are especially adapted to development of hillside springs that issue from unconsolidated aquifers with few rocks. A typical well point installation serves as collector, concentration facility, and discharge system.

(2) The first step in installation is to bore a hole into the formation with a hand auger slightly larger than the well point. The hole should be bored into a flow concentration area or into the bottom layer of the water bearing material.

The hole should be on a grade so that water will freely run into the point and down the attached pipe. Once the hole is augered to the desired penetration, the point is inserted and driven into the hole. Short lengths of pipe are added as needed until the point reaches the end of the hole.

A well point is essentially a section (or sections) of metal well screen with a forged steel point attached to one end, with a threaded pipe shank at the other end. A short length of pipe is screwed onto the threaded shank. A drive cap is screwed on the end of the pipe so that the assembly can be driven into the aquifer. Short sections of pipe are added as needed until the desired penetration depth is achieved.

Three common types of (well) drive points (see Illustration IV-8) are:

- Brass jacket type.

- Brass tube type.

- Continuous-slot well screen type.

The brass jacket point consists of a perforated pipe covered with bronze wire mesh. The mesh is then covered with a perforated brass jacket to protect it from damage. The forged steel point carries a widened shoulder designed to push gravel or stones aside and reduce the danger of damage to the well point.

The brass tube type consists of a slotted brass tube slipped over perforated steel pipe. The slotted brass tube is not as easily damaged as the wire mesh jacket. It has about the same intake efficiency as the wire mesh type.

The continuous-slot well screen type is the most efficient from a water intake standpoint. It will withstand hard driving, but should not be twisted while being driven. This type of point should be used where efficient intake of water is essential. It should also be used where the water has low pH, since the dissimilar metals used in the other types of points will corrode due to galvanic action.

e. Manufactured Drainage Systems.

These systems provide for the collection, concentration, and discharge of the water in one complete system.

The system consists of a plastic core (design varies with company) which is sandwiched by filter fabric and serves as a filtration and collection layer and has an integral concentration conduit which discharges into central collectors or can be used as a discharge system itself.

The advantages:

- The material utilized in virtually every manufactured system is very light, easily transported and can be handled by one person.
- The fabric prevents the movement of fines out of the aquifer.
- In most cases, it eliminates the need for gravel and the equipment required to haul and place the gravel on site.
- Site disturbance is held to a minimum.
- A ditch trencher (4 inch cut) or a backhoe with a narrow bucket can be used, thus disturbing less material in the aquifer.
- Multiple laterals can be installed and connected into one integral system.
- The discharge system can be as simple as a valve installed on the outlet pipe. When closed (along with a simple cutoff collar) the water continues to flow through the aquifer.
- There is no head box or spring box. This eliminates the possibility of pollution of the water from rodents which crawl into the box and die.

2. Concentration Facilities.

Spring water flowing through the collection system is funneled to a central concentration point. The concentration facility performs one or more of the following functions:

- Store and regulate the spring flow.
- Provide access for maintenance.
- Settle out suspended material coming from the collector.
- Feed water into the discharge system.

A spring box (head box) is the most common structure used to concentrate the flow. Spring boxes come in many shapes and sizes, and are made of a great variety of materials. They are usually constructed so that drains or pipes feed into the box, and the discharge system feeds out of the box. Sometimes, the spring box also serves as the collection system. The design of spring boxes is limited only by the imagination. However, the designer must understand what functions he/she wants the box to perform, and must ensure that water from the collection system flows easily into and out of the box. A spring box should have a tight fitting lid to prevent contamination. The entire box is often buried to avoid vandalism, freezing, and contamination.

As mentioned in the section on collectors, the concentration facility may be a part of the collector, such as a driven point attached to a pipe. Another example is where two or more collector pipes come together in a wye or feed into a manifold. When a cutoff wall is used, a gravel filled sump, installed behind the low point of the wall, could serve as the concentration facility.

3. Discharge System.

The discharge system has two main parts:

- Discharge pipe (or pipes).

- Overflow pipe.

The discharge pipe conveys water from the spring to the point of use, or to the intake of the distribution system. Where the discharge pipe passes through a cutoff wall or the wall of a spring box, it must be sealed to prevent leakage around the pipe. A pipe union should be installed immediately downstream from the spring. This allows the lower end of the discharge pipe to be disconnected if maintenance or replacement is required. Discharge pipes should be designed to carry water to a point of use away from any existing riparian area. Excess water should be discharged back into the acquifer feeding the riparian area to prevent drying out the area. This area should be fenced to prevent trampling and preserve the riparian habitat. A qualified engineer should be consulted for advice on pipe sizes and material to be used.

Overflow pipes are installed to discharge excess uncontaminated spring flow away from the spring development and the use area and back into the acquifer immediately below the intercepting collection point. Cattle and other large animals can quickly transform an area of unprotected wet soil into a mucky bog. If parts of the spring development are located in the wet area, they will be trampled and broken or undermined if not protected.

If there is a risk of spring water overtopping a head box or cutoff wall, an overflow pipe should be installed at the spring. It should be located low enough to prevent overflow and should be large enough to carry the excess flow.

Usually, an overflow pipe is needed at the head box, the watering trough or other point of use. Here again, the pipe should be large enough and placed on a grade sufficient to carry any excess flow. A qualified engineer should be consulted to ensure that the overflow pipe will do the job.

Overflow pipes should carry the surplus water to a safe discharge point, where the resulting wet area will not interfere with the function or use of the spring development. Overflow water should be discharged back into existing riparian areas.

E. Special Considerations.

1. Flood Protection.

Many springs occur in the bottom or along the sides of watercourses. These watercourses vary from wide, meandering channels to narrow, deep gullies and all are subject to flooding. When a spring within a flood zone is developed, care should be taken that the development is not washed away with the first high water.

To protect a development from flood water, three principles apply:

- Avoid the flood.

- Avoid obstructing the flood.

- Design to withstand the flood.

Wherever possible, spring boxes, cutoff walls, pipes, and water troughs should be located above expected flood flows.

If parts of the development cannot be removed from the flood zone, they should be installed so that they do not obstruct flood flows. For example, in alluvial channels, spring boxes and cutoff walls can be installed so that their tops do not protrude above the original surface of the channel bottom. The discharge and overflow pipes would be buried in the channel alluvium, and any flood would merely pass over the whole installation. This assumes that the development is not located in a degrading reach of channel. If there is doubt, an engineer or hydrologist should be consulted.

If parts of the development cannot be installed to avoid floods (or avoid obstructing them), the installation should be designed to withstand the forces of floods. In these cases, one must understand the magnitude and frequency of flooding and have a knowledge of channel dynamics and water control structures. The design should be placed in the hands of qualified experts.

2. Protection from Livestock and Wildlife.

The lush vegetation that is associated with most spring sources is highly attractive to livestock and big game, such as elk. Unfortunately, as the animals graze in these wet areas, their trampling can soon turn a wet meadow into a muddy quagmire. This can result in contamination of the spring, destruction of the development, or even destruction of the spring. For these reasons, many of the wet areas surrounding a spring (including the routes of discharge and overflow pipes) should be fenced to exclude livestock and big game which tend to wallow or trample wet areas. The decision to fence should be based upon management objectives and animals using the area.

3. Use of Explosives.

Explosives are sometimes used to blast holes in bogs or sub-irrigated areas. The objective is to displace soil and organic matter and make "water holes." Although this is a legitimate water development technique, explosives should not be employed unless there is a clear understanding of how the blasting will affect the water-bearing strata. An excellent reference on this topic is "Explosives in Water Resources," USDI, BLM, Miles City District Office, 1985.

Generally, explosives should not be used to improve the flow of springs, especially those issuing from fractured rock. The use of explosives has ruined more springs than it has improved.

4. Use of Heavy Equipment.

Heavy equipment is commonly used to excavate trenches for collector systems, cutoff walls, and pipes, and to backfill a spring development after construction. Generally, small-to medium-sized backhoe-loader tractors (crawler or rubber tired) are the preferred machines. While these machines are great labor savers, they must be used with care and common sense.

Careless use of a backhoe could seriously disrupt or obliterate a water-bearing zone. Similarly, operating a machine on the surface of a spring could irreparably damage the spring, result in a quagmire, or otherwise render the spring unsuitable for development or use. Thus, while heavy equipment is a valuable tool, the use of these machines for spring development should be carefully planned and supervised.

Because of the potential for damage, equipment should almost never be used to prospect a spring for flow paths or water-bearing strata.

5. Spring-Fed Ponds.

Sometimes conditions are favorable to excavate a reservoir below a spring and create a spring-fed pond. A bulldozer, backhoe, loader or dragline could be used.

If the following conditions exist, an inexpensive, low maintenance spring development can be installed:

- A fairly strong and dependable flow.

- Deep, loamy soil.

- Gentle gradient.

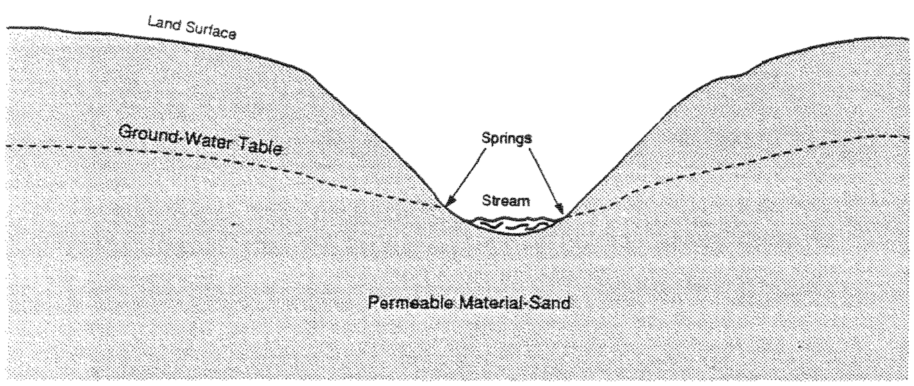
- Little sediment movement.

- Low flood risk.

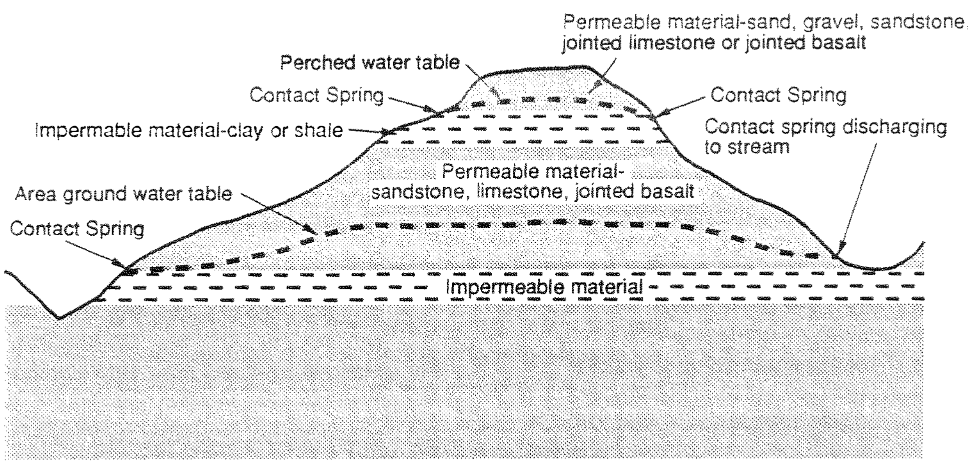
The excavation is made below the outcrop of water. Care must be exercised so that the flow is not disrupted. The spillway on the dam must be able to pass the spring flow plus runoff from upstream. Care must be taken not to use saturated material for enbankment material if an embankment is needed. Also, care must be taken to construct the pond so that the natural riparian area is not drained or the spring damaged.

Chapter IV

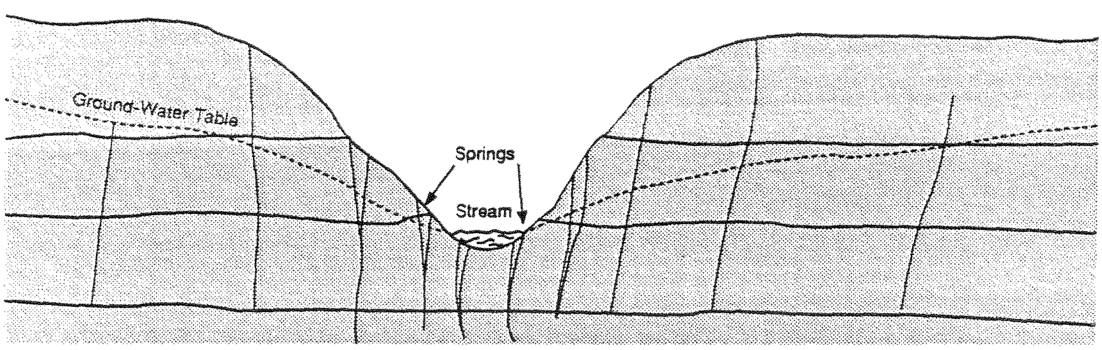
Depression Sring, Seepage or Filtration Type



Typical Contact Spring

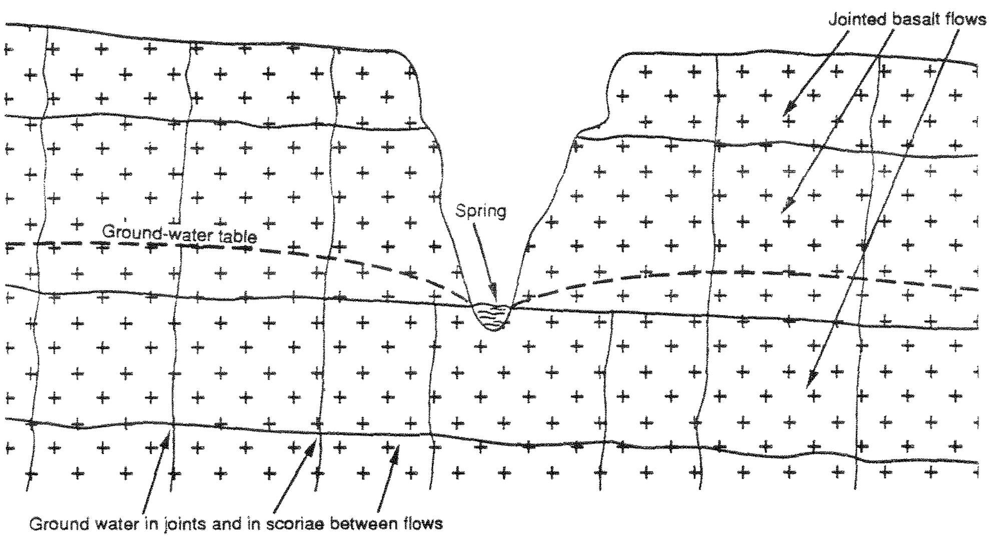


Spring in Jointed Sandstone

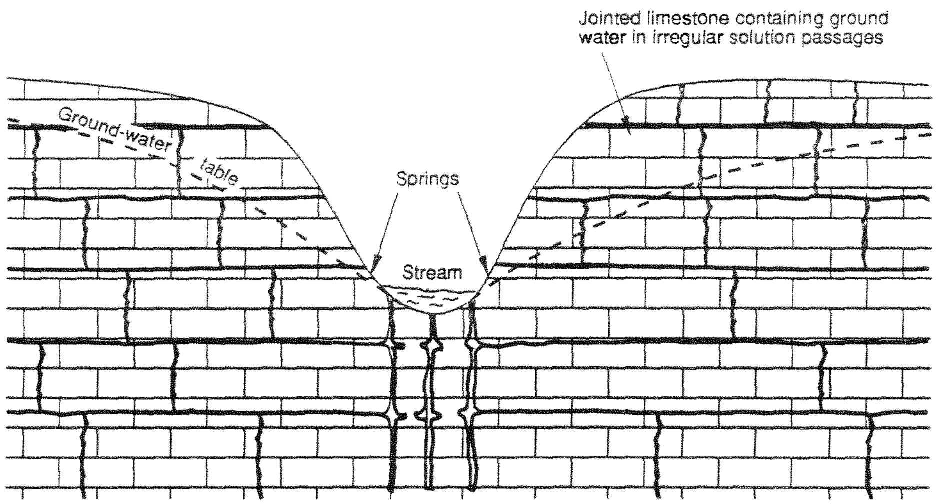


Ground water mainly in joints, fractures, and along bedding planes in sandstone

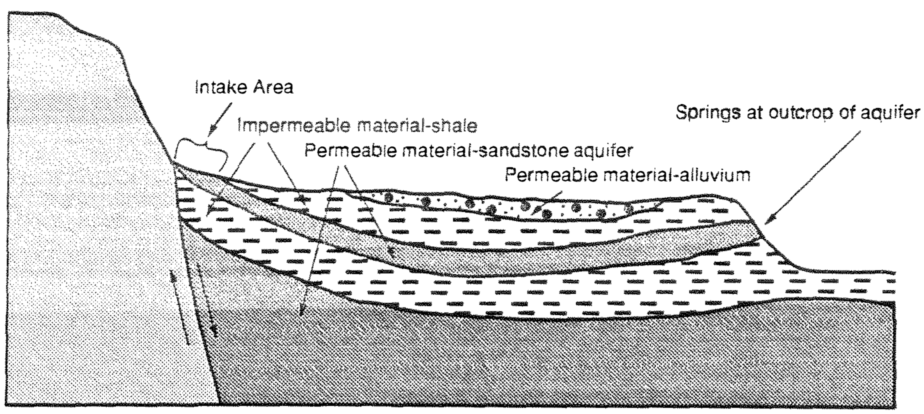
Spring in Jointed Basalt



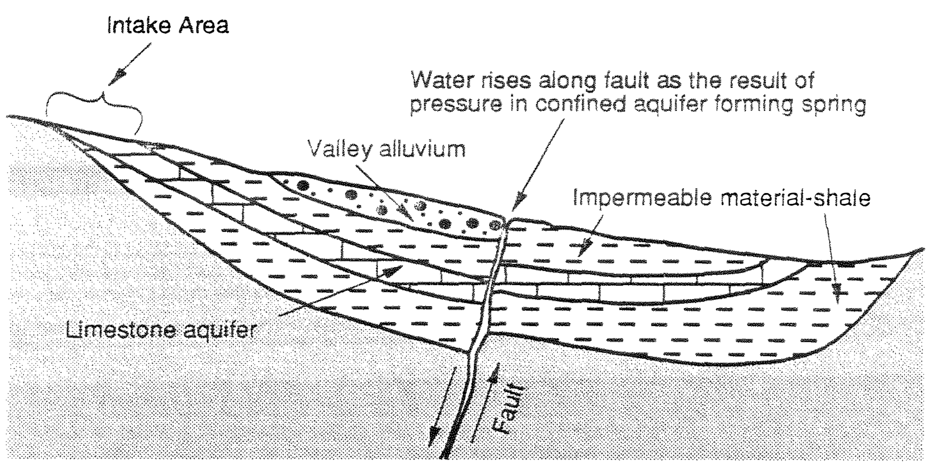
Spring in Jointed Limestone With Some Tubular Passage



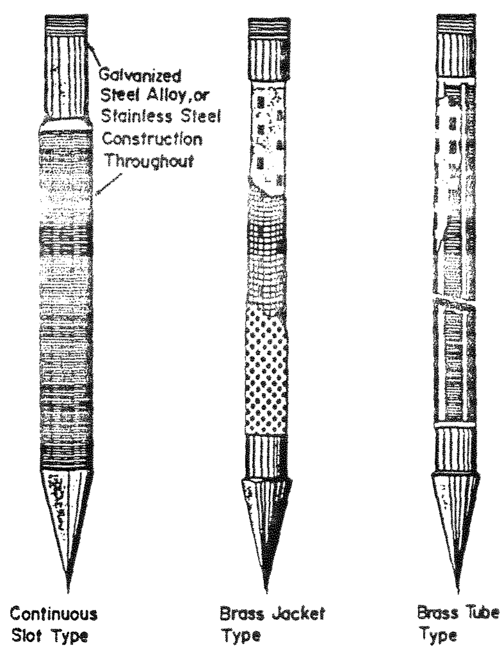
Artesian Spring at Outcrop of Aquifer



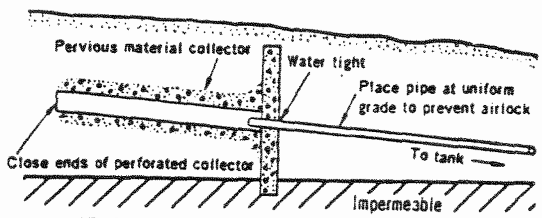
Artesian Spring Occurring Along a Fault



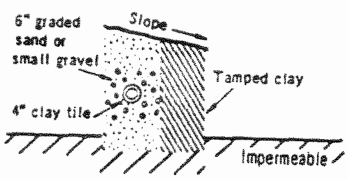
Different Kinds of Drive-Well Points



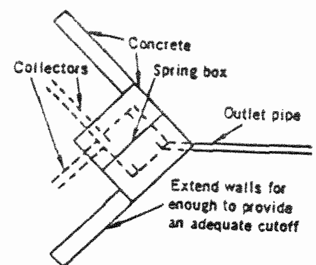
Simplified Spring Development



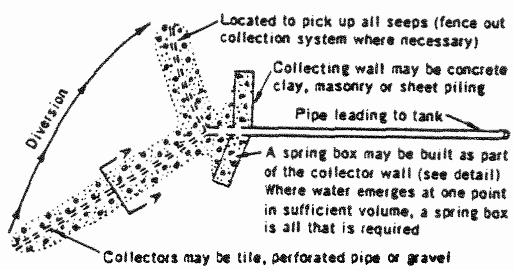
SECTIONAL ELEVATION OF COLLECTION SYSTEM



DETAIL of COLLECTOR
SECTION A–A

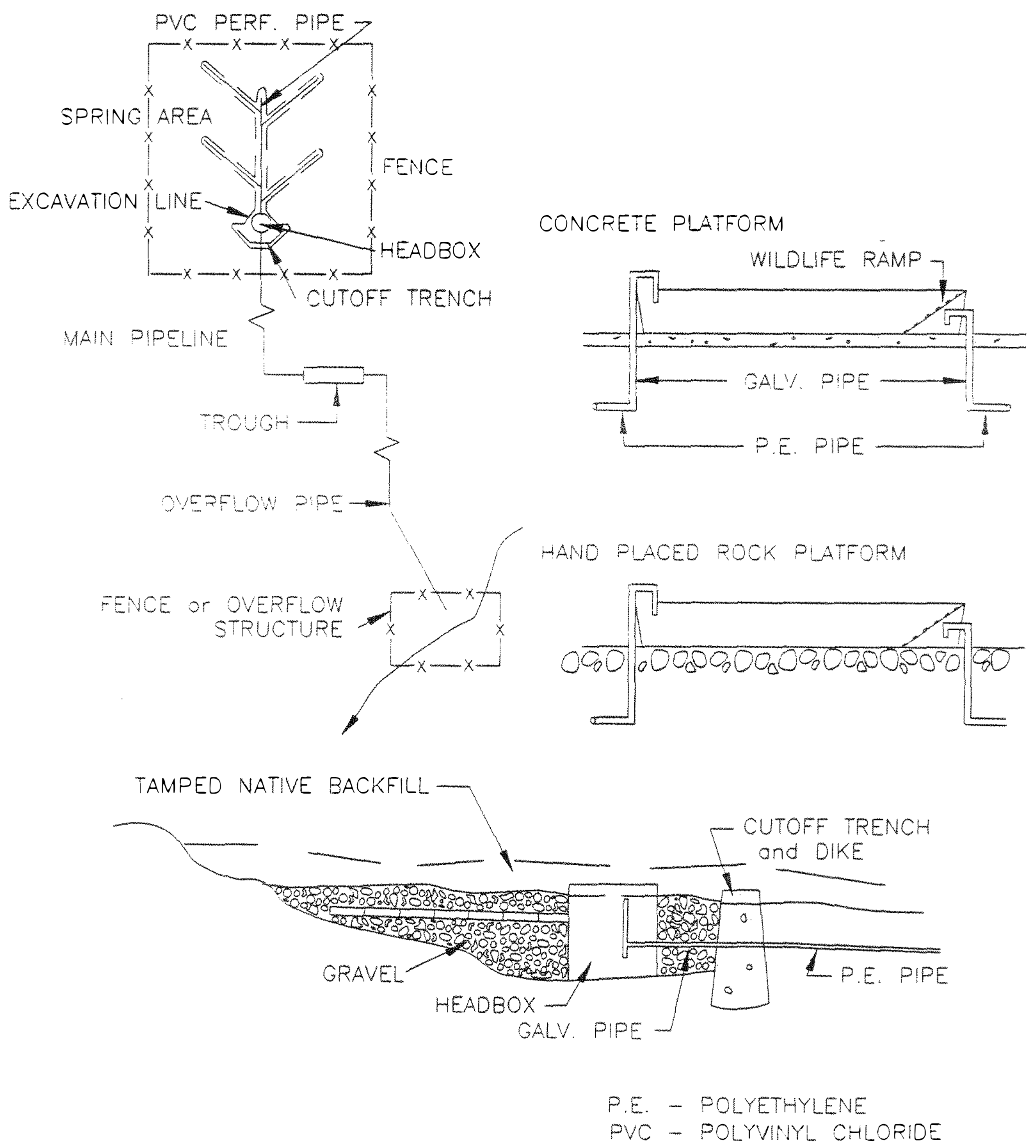


PLAN of SPRING BOX USED WITH COLLECTION SYSTEM

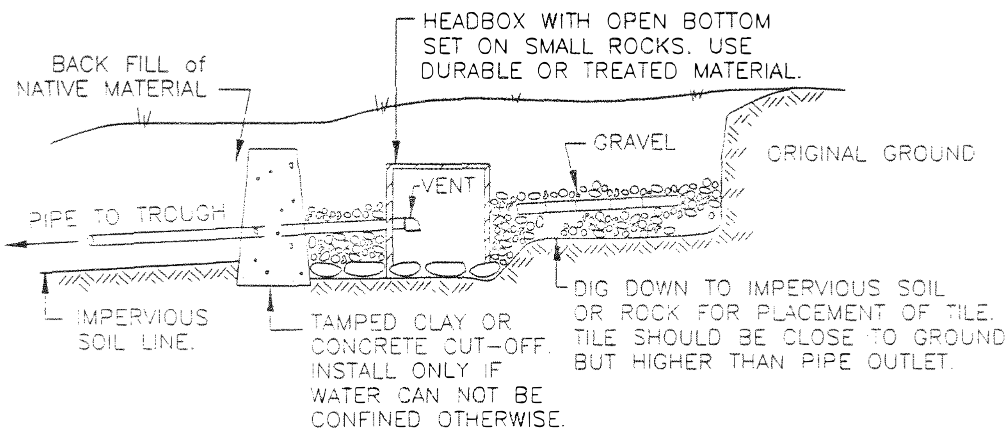


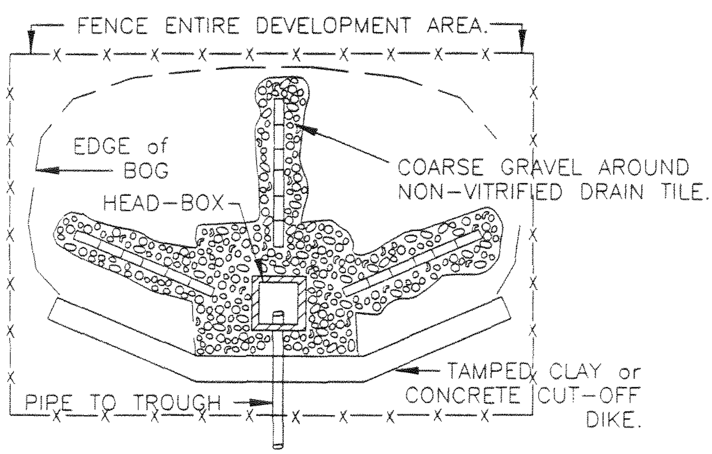
PLAN

Plan and Profile View of Spring Development



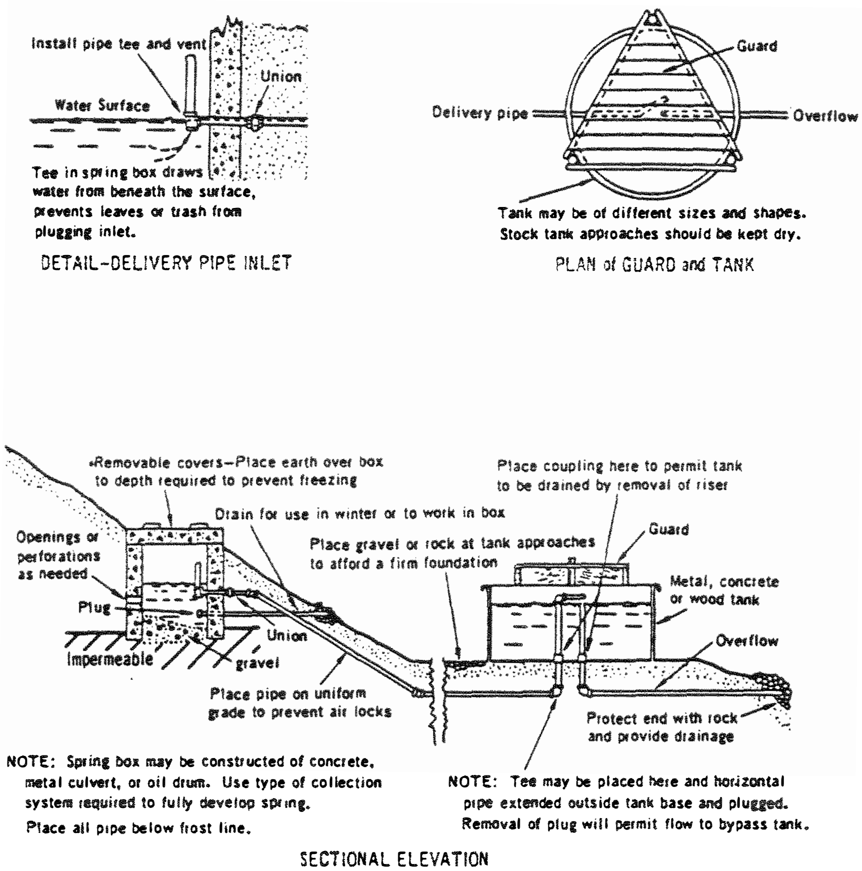
Collection of Seep Water



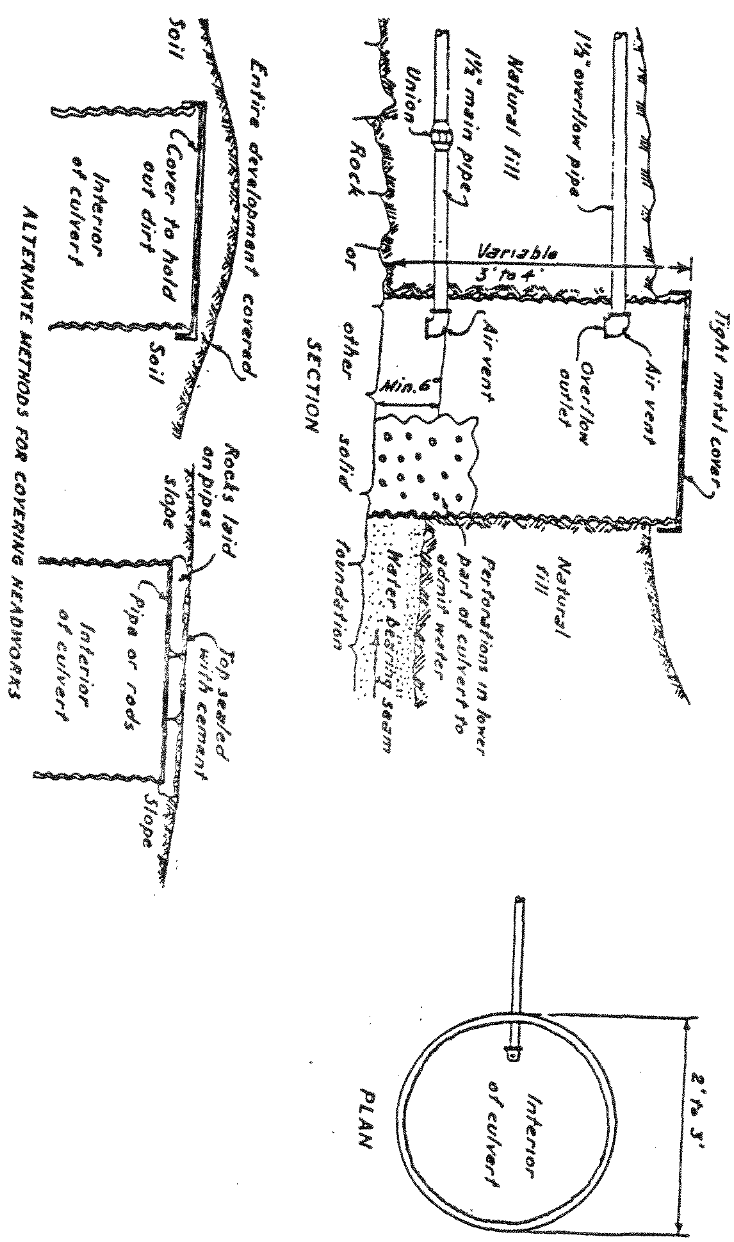


Chapter IV

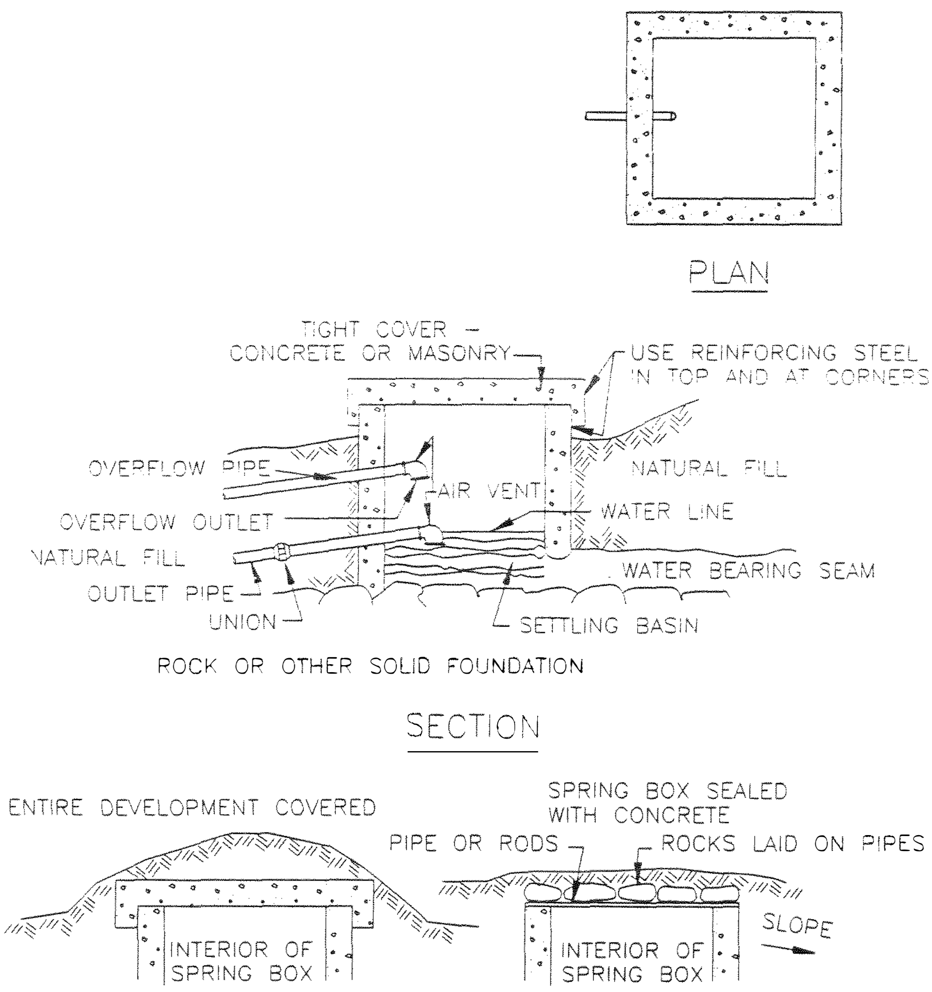
Spring Box and Pipe Arrangement



Spring Development Culvert Headworks



Spring Development Concrete Headworks



ALTERNATIVE METHODS FOR COVERING HEADWORKS

H-1741-2 - WATER DEVELOPMENTS

Chapter V

Chapter V - Reservoirs

A. Introduction.

The term "reservoir" as used in this Handbook refers to water impounded by a dam, typically an earth filled embankment with an adequate spillway. A reservoir may be formed by building a dam directly across a drainage or by enclosing a depression to one side of a drainage and constructing a diversion ditch into the impoundment area. (See Manual Section 9172.)

Reservoirs are a very effective means of providing water to grazing animals in many areas of the West. However, they can be very ineffective if they are poorly located or poorly designed. An important point to consider is that many of the best reservoir sites on BLM-administered public land have already been used. Future reservoir construction in BLM Districts must be carefully considered and fully evaluated to ensure that economic efficiency and management objectives are achieved for the project.

1. Small Retention Reservoirs.

Most small reservoir construction on public land has been completed for storing and providing water for livestock, wildlife, and wild horses.

Generally, reservoirs are built where runoff is from spring snow melt or high intensity rain storms. Either of these events can produce damaging floods that either wash the reservoir or spillway out or fill the reservoir basin with sediment.

Site selection is the key to a good reservoir. Reservoirs should be placed only where there is reasonable expectation of adequate frequency, quantity, and quality of water flow. A hydrologic study should be done to determine these parameters. The following are major points to consider in the selection of reservoir sites:

a. Select sites with deep, heavy clay soils where possible; carefully prepare the reservoir site, particularly, the earth-filled area of the dam; use water-tight material in the embankment and in the reservoir bottom; and compact the earth fill well. The site should be drained and the vegetation, stumps, debris, and loose rock removed before construction begins.

b. The watershed above the dam should be large enough to provide sufficient water to fill the reservoir but not so large that maximum flows will damage the spillway or wash out the dam.

c. The most economical site is one along a natural drainage where the channel is narrow, relatively deep, and the bottom is easily made watertight. The channel grade immediately above the dam should be as flat as possible.

d. Grazing animals (livestock, wildlife, and wild horses, etc.) should have easy access to the water.

e. The dam should be located, if possible, to take advantage of natural spillway sites. Otherwise, an adequate spillway must be constructed for the reservoir.

B. Advantages, Disadvantages, and Limitations.

Unless fed by perennial streams, seeps, or springs, small retention reservoirs generally provide only temporary or seasonal sources of water. Small reservoirs are relatively inexpensive to construct. They are, however, dependent on surface runoff or seepage, so may be empty when most needed in dry seasons. They require a drainage area of adequate size, a low ratio of surface area to storage capacity, protection against excessive silting (settlement basin or construction in areas of low sediment yield) and protection against excessive erosion of the face of the dam. Reservoir should be large enough to provide water for 2-3 seasons if permitted by State law and policy.

The principal problems associated with small reservoirs as rangeland water developments are the uncertainty of filling, poor quality of water, and losses through percolation, seepage, and evaporation.

C. Design and Installation.

The reservoir site should be surveyed and staked prior to construction. To determine the suitability of material for dam construction, soil tests should be made by a soil scientist or other qualified specialist. Trees and shrubs should be cleared from the dam site and flooded basin. The foundation area of the dam should be plowed or scarified in the direction of the main axis of the dam so there will be a good bond between the foundation and the fill material. On sites where stability and permeability of the foundation material is questionable, a narrow core trench must be dug lengthwise to the dam, then refilled with select backfill and compacted as the dam is constructed. Core trenches should extend into an impervious layer but be no less than 3 feet in deep. The minimum bottom width of the trench must be 12 feet with 1 to 1 side slope. Where suitable material is available above the dam, it should be obtained there so the borrow pit will become part of the reservoir and add depth to the impoundment. General specifications for the construction of dams must include these items:

1. The slopes of the dam must be a minimum 3 to 1 on the upstream face and a minimum of 2 to 1 on the downstream face.

2. Minimum width of the top of all dams must be 12 feet.

3. Freeboard (depth from the top of the dam to the high-water mark when the spillway is carrying the estimated peak runoff) must not be less than 3 feet or meet the State water law requirement. The spillway must be designed to minimize the risk of the dam being overtopped during the design life of the structure. A natural spillway is preferred. It should have a broad, relatively flat cross section, be located away from the fill, and re-enter the main channel some distance downstream from the fill. When a spillway is built, it should be wide and flat-bottomed.

   The entrance must be wide and smooth and the grade of the spillway channel mild so the water will flow through without cutting. The spillway should be no less than 25 feet wide to provide for snow or trash blockage.

4. Designed to meet a specific storm (50-year, 100-year, etc.) whichever the situation warrants. Include allowance for sedimentation.

5. The spillway must be capable of handling the peak discharge from the design storm. The surcharge area should be considered in determining the spillway size. Sedimentation buildup over the life of the structure should be considered in reducing the water storage capacity of the dam for flood routing. Consider installation of small outlet structure and trickle tube to reduce spillway erosion when inflow is expected to continue for an extended period of time each year.

6. Semicompaction is required as a minimum. Semicompaction means that compaction is obtained by placing the embankment material by scraper-type equipment in approximately horizontal layers, 6 inches in thickness, and distributing the equipment travel over the entire width of the embankment to obtain uniform compaction while placing the material. The best material available must be selected for the embankment. The material must contain sufficient moisture for the travel of the construction equipment effectively to consolidate the embankment. Should the borrow material be found undesirable, i.e., too dry, too wet, too high in organic content, or structurally unsound, corrective measures must be taken. These may consist of selecting alternate borrow areas, scheduling construction during periods when soil moisture conditions are most favorable, or adding water to the earth material.

Semicompacted fill heights may be increased by 10 percent to offset settlement. When the construction stakes are set, fills may be increased by 10 percent and slope stakes set accordingly. For dams with outlet pipes, which will impound more than 15 acre-feet of water and for all dams where failure would present a hazard to life or property, compaction to 95 percent of maximum density as obtained by American Association of State Highway and Transportation Organizations (AASHTO) T-99 is required.

In all other cases where the engineer determines added compactive effort is necessary to obtain stability and watertightness (including installation of outlet pipes), compaction must also be to 95 percent maximum density.

7. Topsoil should be stockpiled during every reservoir construction and spread uniformly over the disturbed areas. Topsoil must not be disturbed above the high-water line except for spillway excavations or when the borrow must be taken from other than the impoundment area.

8. Borrow areas should not be located within 25 feet of the toe of the upstream slope or in the bottom of the drainage within the high water level if there is a chance of exposing pervious layers.

   Further requirements and design standards are discussed in BLM Manual Section 9172, Water Control Structures and BLM Handbook H-9172-1, Water Control Structures, Guidelines for Design.

D. Special Considerations.

Larger reservoirs that are properly engineered can become good producers of fish life. A satisfactory reservoir must have an adequate water supply free from silt. This water supply may be runoff from lands managed under a soil conservation program or from springs, flowing wells, or very small streams. The pond should be impounded behind a well-constructed dam with a spillway adequate to carry off flood waters. For fish life, ponds must be deeper in the northern part of the West than in the southern portion in order that cold winters and thick ice do not result in loss of fish. Increased depth is also advantageous to regions characterized by long periods of dry weather.

1. Maintenance of adequate water depth to protect existing or proposed fish populations must be clearly stipulated on the cooperative agreement or provided for on reservoirs constructed by the Bureau.

For fish, the reservoir should be a minimum of 12 feet deep (marginal) to 15 feet deep (adequate) for 25 percent of the pond area in northern areas. In southern areas, the depth of 25 percent of the pond should be 10 feet deep (marginal), 12 feet deep adequate. Depth greater than this would only increase the fisheries suitability.

For waterfowl the average water depth, measured from normal ground when the impoundment is flooded, should not exceed 3 feet for dabbling ducks.

For diving ducks, it can be deeper than 3 feet. Dike heights should not exceed 6 feet, except where greater heights are necessary to cross narrow depressions. Construction of islands for waterfowl nesting and escape whenever opportunities exist may be done at the time the reservoir is initially constructed or when a low water level permits.

2. While working in the southwest, biologists for the U.S. Fish and Wildlife Service found that water-cut canyons offer suitable sites for small concrete dams and reservoirs to provide water for desert bighorn sheep. These small reservoirs were most effective where canyons narrowed down with steep, vertical sides of bedrock. Such arroyos make good construction sites, particularly on east or north facing drainages which provide protection from the sun and reduce evaporation. Dams should be firmly keyed into the bedrock on both sides and bottom. A pipe outlet should be incorporated into the dam. Water loss will be prevented if rock formations are checked for cracks and fissures. Rock sealing is, at times, an important phase of sound construction. Commercial sealers can be quickly applied to the dam after completion. Usually, such canyon dams should be under 40 feet long and not over 5 or 10 feet high. During the first several years after construction, the small ponds formed behind the dams will provide water for wildlife.

   After the reservoir becomes filled with gravel and sand washed in by floods, the water soaking into the gravel and sand is stored and protected from excessive evaporation. The stored water is piped through the dam to natural rock basins below or to cement troughs constructed away from the main water course.

3. Reservoirs or ponds with surrounding fences serve to protect vegetation which is desirable for wildlife food and cover. They also protect livestock from miring in the reservoir and drowning. The installation of troughs outside the fenced area help to provide water for livestock and simultaneously keep the animals out of the stored water (see special consideration illustration). Troughs may be supplied through gravity or pressure pipe through the dam or siphons over the dam.

4. When sealing the bottom of impoundment area - where the soil contains adequate amounts of silt and clay, rolling with a sheepsfoot roller often effectively seals the soil against seepage. Salting to attract livestock in the basin before it completely fills with water will help reduce seepage losses because the animals will trample, compact, and puddle the soil. Where additional treatment is required and the soil contains at least 50 percent of silt and clay, applying chemical dispersing agents helps in puddling and sealing the soil.

   Where construction of reservoirs on sandy or gravelly soil cannot be avoided, lining the water basin to slightly above the maximum water line with bentonite or other special clays or with flexible, impervious membranes can be considered. Reservoir basins requiring such special treatment should be fenced from livestock and big game to prevent erosion at the waterline and protect the linings, and the water should be piped out. Bentonite is applied at rates of 1 to 3 pounds per square foot depending upon the swelling ability of the particular batch. When thoroughly mixed by disking into the top 6 inches of the soil and then packing with a smooth roller, it is capable of expanding when wet, filling up the soil interstices and nearly eliminating seepage losses. However, bentonite is only 75 to 80 percent effective when used on sites with widely fluctuating water levels and prolonged dry periods.

   Although plastic and butyl rubber liners have been effectively used on irrigation reservoirs where the sites were well prepared and the linings were covered with soil to a depth of 6 inches or more, their use has not proven practical with small stockwater reservoirs. Lining water basins with concrete, soil cement, or asphalt paving is generally too costly to consider.

5. Snow fencing can make more water available by trapping blowing snow to increase water yield into streams and reservoirs. Snow fences are a practical means of storing snow to increase streamflow where there are large open areas having limited snow storage capacity. To minimize conveyance losses of melt water, snow fences should be located along primary stream channels or near reservoirs.

   The length of a snow fence is normally based on desired water yield after accounting for losses to evaporation, soil water recharge, and deep percolation. About 50 percent of a snow drift evaporates during the melt season. For small projects, usually assume about one-third of drift water can be recovered, thereby allowing for a 27 percent loss to soil water recharge and deep percolation (for more specific survey and design considerations, see reference 8 on page V-10).

6. To increase the life of old reservoirs, consider blasting potholes in the silted impoundment areas. This inexpensive approach should be strongly considered prior to building new pits below these old dams (for more specific information see reference 14 on page V-10).

E. Pit Type (Charcos) Reservoirs.

1. Introduction.

The pit type reservoir, also referred to as a "charco," "water hole," or "dugout," differs from the small retention reservoir in that most of its capacity comes from excavation. The purpose of a pit reservoir is to capture only a portion of the overland flow as the capacity of pits is limited; most contain between 2 and 3 acre-feet.

Pit reservoir sites are generally located in flood plains, dry lake beds (playas), water courses where there is no real defined channel or where the drainage is too wide to economically construct a dam-type retention reservoir, or behind large detention dams away from the drainage.

The pit reservoir is adapted to flat lands where some overland flow occurs. It is best suited to locations where a small water supply is sufficient and where the soil is impervious. Diversion ditches leading into the pit are often required. A hydrologist should be consulted to determine water availability.

2. Advantages, Disadvantages, and Limitations.

Unless fed by a perennial water source, pit type reservoirs generally provide only temporary or seasonal sources of water. Pits are relatively inexpensive, depending on size, to construct. They are, however, dependent on surface runoff or seepage, so they may be empty when most needed in dry seasons. They require a drainage area of adequate size, a low ratio of surface area to storage capacity, and protection against excessive silting. Pits have been successful in extending the life of an existing reservoir. Pits are relatively easy to clean out using heavy equipment which would become bogged down in a retention reservoir.

The principal problems associated with pits as rangeland water developments are the uncertainty of filling, lower quality of water, and losses through percolation, seepage, and evaporation.

3. Design and Installation.

Pit reservoirs are excavations for water storage. Pits with control inlets are preferable because they can contain erosion and provide water storage. Pits or dugouts with uncontrolled inlets should never be excavated in soils that will erode from the pit upstream and cause a gully or lower the bed of the drainage channel.

Investigate watershed characteristics to determine the availability of water for storage and expected sediment production.

Pits are adaptable to relatively flat areas. Three factors should be considered in selecting a location for a pit. They are: control of water entering the pit, discharge of water from the pit, and erosiveness and permeability of soils and the natural spillway. These factors must be investigated for data on which to base the design.

Pits should be large enough to meet storage capacity needs. Bottom dimensions should be large enough to accommodate construction equipment. Soil types and textures, surface terrain, evaporation, and storage requirements are factors which determine depth. General design guidelines are:

a. Depth. For efficiency, the minimum depth of the pit should be 8 feet. However, 10 feet is recommended for most BLM applications to ensure adequate water supply allowing for siltation and evaporation.

b. Slopes. Slopes into the watering area should be no greater than 4 to 1 to provide for livestock and wildlife safety.

c. Excavation. Excavated material and debris should not be placed closer than 25 feet from the edge of the pit, placed in a channel, or in a location and manner that will cause excessive erosion or result in a channel change. Where excavated materials are used to form an embankment downstream of the pit which increases the water depth by more than 6 feet, the pit must be treated as a reservoir and the requirements for minor dams apply. (When using excavated materials for the embankment, there will be approximately 20 percent shrinkage of the materials during compaction.) (Taken from Reference 10, BLM Manual Handbook H-9172-1, Water Control Structures, Guidelines for Design.)

4. Special Considerations.

a. Consideration must be given to the need for an outlet pipe, wildlife requirements (provide a nesting island where feasible or fence the upper portion of the reservoir), rehabilitation requirements, compaction and water for compaction, and construction timing to avoid heavy run-off periods and to use soil moisture conditions at their highest level. Does the reservoir site require sealing with a product such as bentonite? Does the drainage run high silt or debris? Consider a combination silt trap reservoir with an outlet pipe dropping water into a charco or second reservoir. These are expensive but very successful installations. Drainages and sites with heavy bentonite soils sometimes have water quality problems due to fine soil particles being held in suspension in the water. If the reservoir is sealed, consider fencing the area and installing a small pipeline through the fill and a drinking trough below the fill. Construction type equipment should probably be considered when evaluating all sites. Short hauls on fills and charcos may warrant using a dozer or front end loader, while long hauls would require a scraper or carry-all. Charcos in level drainages that are stable or well vegetated may have the excavation placed to the sides parallel to the drainage.

Run-off water will fill the charco and flush out any fouling material or debris.

b. Look at other reservoir sites in the general area for success or failure and design and maintenance considerations. Vegetation types are often indicators of poor or good soils for construction or subsurface problems. Cut banks in the area can often be used as a soil profile instead of deep borings. High water debris lines can be used as an indication of flood peaks. Heavy clay soils within reasonable hauling distance will seal problem soils. Use 4 to 1 upstream slopes when wind exposure could cause wave erosion. If the fill is to be used as an access road, widen the top width to accommodate vehicular traffic. Do not leave trap areas where livestock could become bogged down in mud.

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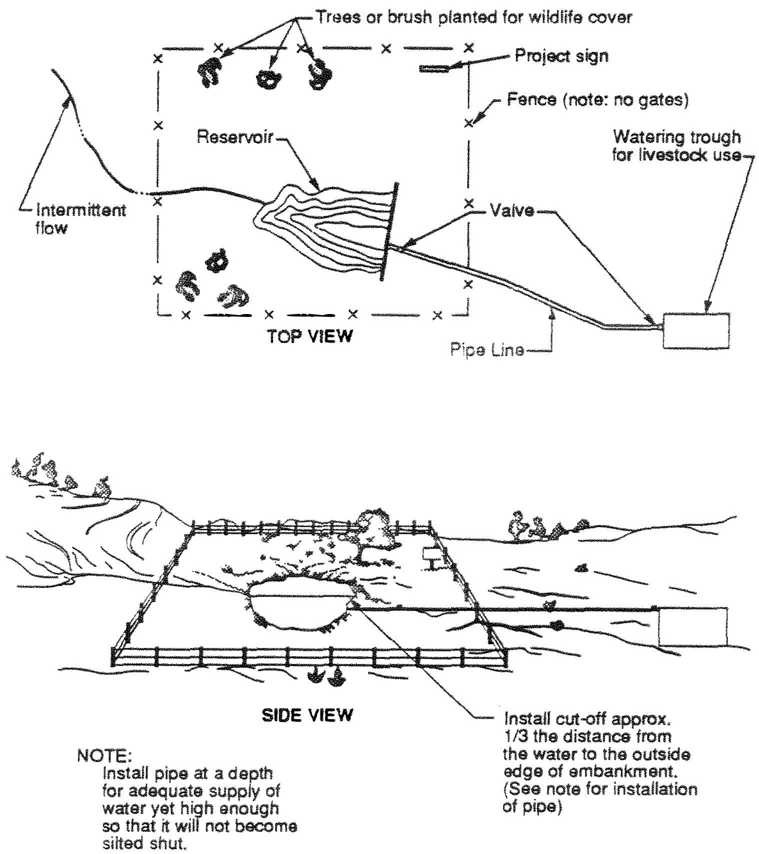
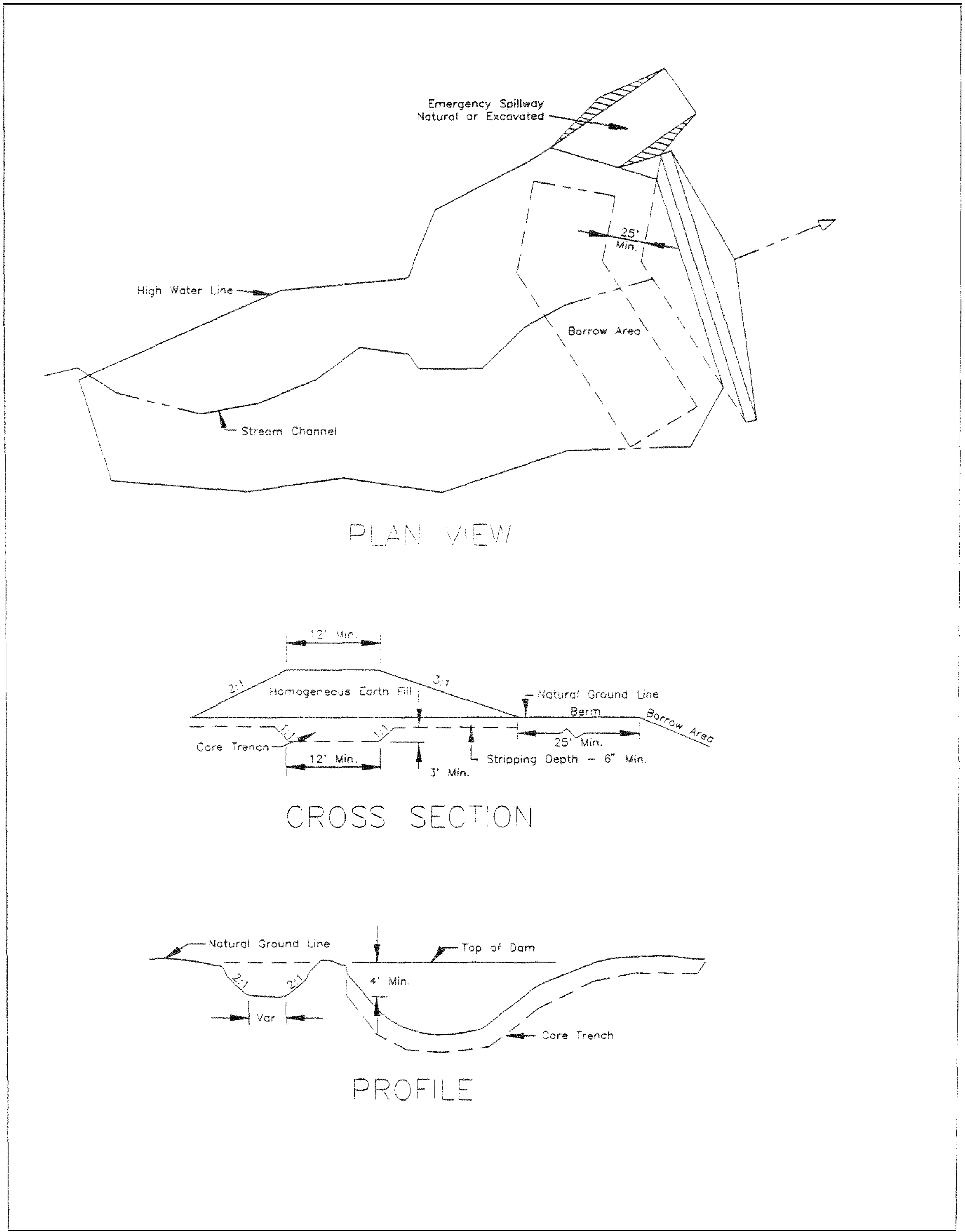
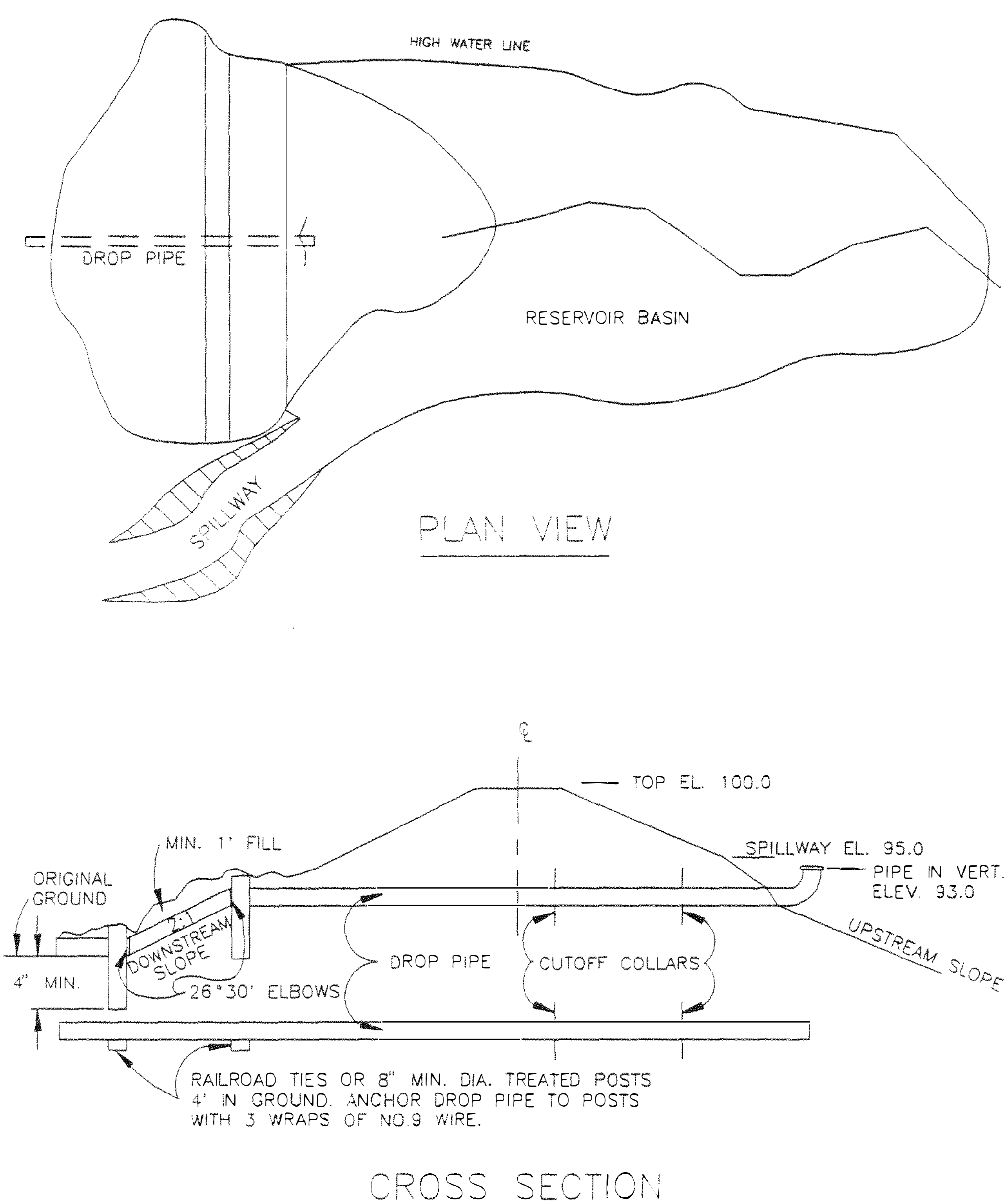
Small Reservoir and Trough



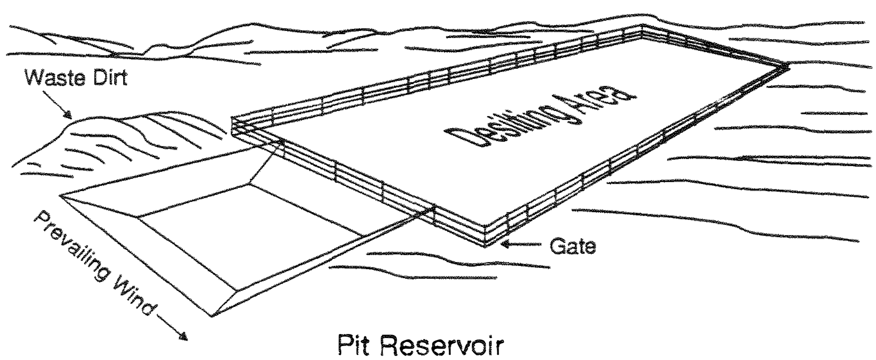
Stockwater Reservoir



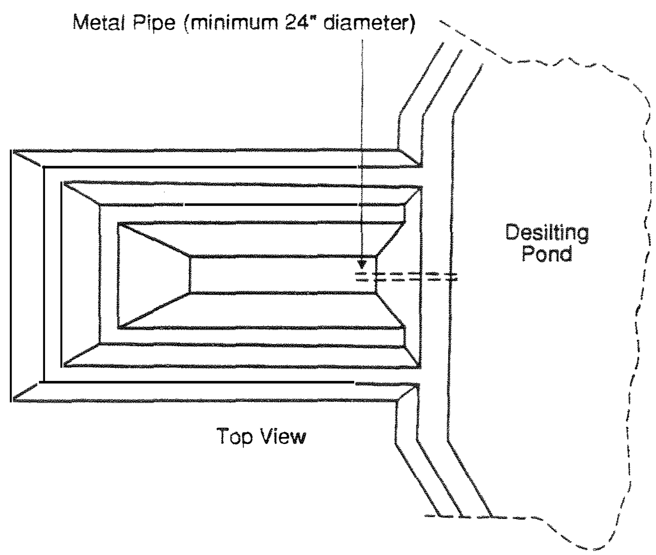
Drop Pipe for Small Dams



Pit Reservoir/Charco Pit



Pit Reservoir



Pit Reservoir/Charco Pit

H-1741-2 - WATER DEVELOPMENTS

Chapter VI

Chapter VI - Catchments

A. Introduction.

Catchments and Guzzlers are the names applied to precipitation harvesting, storage and distribution systems used primarily to supply drinking water for livestock and wildlife on rangelands. Water harvesting systems were developed in ancient times to irrigate crops and provide culinary water. Even today, in many areas of the world, water is collected from roofs of buildings and stored in cisterns for domestic needs. Other names applied to these systems include "trick tanks," "rain traps," "water harvesters," and "gallinaceous guzzlers."

Water catchments as well as other types of water developments (i.e., springs and wells) are an essential component of any management plan to maximize the control and distribution of ungulates over a geographic area. Therefore, the availability, reliability, and safe presentation of that water is critical to meet the Bureau's multiple-use objectives (see Manual Section 4412.21F). This is particularly true regarding many wildlife species where, unlike livestock, they cannot be moved to new pastures if water resources are depleted. Once wildlife species "key-in" on a particular water source and become dependent upon it, that water becomes critical to their well being. A sudden loss of relied upon waters during lambing, fawning, or calving may have a dramatic impact on the survivability of those offspring. It is, therefore, critical that water developments be designed to provide for the needs of wildlife even during those periods of nonuse by the primary beneficiary.

To implement this policy, it is necessary that the coordinator of proposed water developments closely coordinate and cooperate with other resource specialists, State and Federal agencies, and affected public land users. The design and location of new water developments should meet multiple-use objectives. Where two or more activity plans identify the need for water in the same general location and the respective plans objectives can be met without creating resource conflicts, multiple funding of a single water development should be considered.

Livestock water developments should incorporate mitigative measures for wildlife. At the minimum, escape ramps must be installed on all troughs to ensure that wildlife can escape and to protect water quality. Where the water development has the potential to benefit wildlife or wild horses and burros (where identified under a herd management plan), appropriate design modifications must be made to ensure that water is safely available when needed.

Catchments can be designed to provide multiple-use considerations with little added costs. Typically designed livestock catchments provide one or more troughs for livestock and wildlife use. However, because catchments have limited water supplies, they can go dry during high use periods or during droughts. In addition, livestock operators often turn off troughs while collecting or moving livestock. To satisfy wildlife considerations, sufficient water should be left in the water storage facility after livestock move-out to meet wildlife needs. If a reserve cannot be built into the storage facility, then separate storage facilities should be added to the project for wildlife. In cases where troughs are turned off, separate ground-level troughs should be piped off and enclosed with an appropriate protective fence to ensure that wildlife water is available. The primary beneficiary of the project is responsible for ensuring that the design of the water development meets Bureau multiple-use objectives and policies.

In this Handbook, all types of precipitation harvesters will be referred to as "catchments."

Most precipitation harvesting systems consist of four major components that function as a:

1. Watershed (natural or artificial), apron or catchment area.
2. Storage Facility (tanks, pits, basins, and bags).
3. Distribution System (pipelines, valves and troughs).
4. Fences for facility protection and safety.

Note: Storage facilities are discussed in Chapter 9.

Catchments are most often used where other sources of reliable water cannot be developed, or are uneconomical or both, and usually where animal water requirements are small. Catchments can be constructed in a wide variation of shapes, sizes and design. Design will depend on the water requirements, precipitation amounts, precipitation forms and seasonal variation, terrain, soil characteristics, and available construction materials. Consideration must be given to many environmental factors including weather, safety, construction and maintenance costs, simplicity of operation and visual environmental impact.

B. Advantages, Disadvantages, and Limitations.

Catchments can be an effective management tool to control the distribution and dispersion of both livestock and many wildlife species, such as desert bighorn sheep, antelope, mule deer, and elk. In fact, catchments are frequently used to enhance wildlife populations by providing water in otherwise excellent habitat where water is the only habitat component lacking. This is particularly true in the southwest where catchments have been used as the primary management action for reestablishing desert bighorn sheep in historic habitat.

Cost per gallon of water harvested, when compared to other developments, is usually high. Likewise, maintenance costs of catchments are usually higher than with springs, reservoirs, and pipelines. Failure to maintain catchments on a regular basis will result in premature failure. The design and cost analysis phases of project planning should be completed in detail to avoid costly mistakes. Multiple subactivity funding of large catchments may be the best way to distribute costs proportionately to benefitting subactivities.

C. Design and Installation.

1. Site Selection.

Site selection is a crucial step in the catchment development process. It affects engineering design, cost, performance, operation and maintenance of the system. All potential sites within the water short area need to be carefully studied. A multidiscipline approach enlisting several individuals in the initial planning and design phase is recommended. Proper consideration of multiple resource needs will ensure the best engineering design. Poorly located catchments will result in poor returns on investments and may contribute little towards meeting resource management objectives.

The following factors need to be carefully considered when searching for the best catchment site.

a. Selection of Development Opportunity. Review all opportunities to develop water from permanent and seasonal sources before deciding on catchment construction as the preferred development alternative. Carefully review the feasibility (including cost) of developing water through construction of wells, reservoirs, pipelines, and springs.

b. Forage and Cover. Carefully evaluate the animal forage and cover needs in the area to be serviced by the catchment.

c. Management Considerations. Catchments should be located where water could enhance intensive grazing systems, improve wildlife habitat, and provide management flexibility, yet not create additional conflicts for forage resources. Proper location of the catchment can furnish stock water to more than one pasture through piping and fencing and provide benefits to wildlife, wild horses, and burros.

d. Soils and Rock Conditions. Soils, and surface and subsurface rock conditions affect engineering design, construction, and maintenance costs.

e. Topography. Slopes and aspects need careful evaluation in site selection to minimize construction costs and the adverse effects of weather. Slopes between 3-15 percent are normally required for successful site location. Catchment apron-to-storage tank distances can be reduced if the slope steepens immediately below the apron. This results in shorter collection pipe distances, reducing construction costs.

f. Vegetation. Sprouting shrubs and rhizomatous grasses are often difficult to kill and can destroy certain apron materials within a few years. Effort should be made to avoid these areas or control these plant species before construction.

g. Access. Consideration must be given to access by vehicles or specialized equipment required for construction and maintenance. The catchment must also be located in terrain that is easily accessible to livestock and wildlife.

h. Precipitation. Precipitation patterns and the location of snow accumulation areas should be identified to ensure maximum production from the watershed apron. Localized rain shadows and areas of high wind should be avoided. Snow fences adjacent to or across the apron can increase runoff into the storage facility. Laminar netting made from high density polyethylene is available for economical construction of snow fences. This type of snow fence is a practical alternative to the old fashioned wood slat fence.

i. Potential Expansion of System. All systems should be located on slopes or terrain that will allow future expansion of the apron, storage facility, and water distribution system.

2. Sizing Catchment Apron and Storage Facility.

Sizing calculations must be done to provide accurate cost estimates and ensure successful system performance. Poor design will result in failure of the system during dry season or waste of construction dollars if the project is overbuilt.

A water balance study needs to be completed before project design. Proper sizing of the apron and storage facility must be factored into the design format. Sizing calculations should consider the following:

a. Consumptive animal water requirements by season and grazing periods.

b. Monthly precipitation quantities.

c. Monthly recharge of the storage facility.

d. Frequency of short-term droughts. Design must provide for reliable water during droughts especially for wildlife where other water sources are not available.

e. Water surface evaporation from storage facilities.

f. Runoff efficiency of apron materials.

g. Increasing water yield from snow melt through catchment apron location or construction of snow drift fences.

h. Apron size and water yield calculations. Approximate size of catchment apron and water yield can be calculated with the following equations:

CATCHMENT APRON SIZE

$$A = 0.2 \frac{u}{p}$$

A = Catchment apron area in square yards.
U = Annual water use (requirements) in gallons.
P = Average annual precipitation in inches.

CATCHMENT APRON WATER YIELD (TOTAL GALLONS)

$$R = 5.5\ P\ A\ E$$

R = Runoff in gallons.
P = Precipitation in inches.
A = Catchment apron in square yards.
E = Catchment efficiency.

CATCHMENT APRON WATER YIELD (GALLON/INCH OF PRECIPITATION)

$$\frac{\text{Surface Area (sq. ft.) of Apron}}{12} \times 7.4 = \text{gals/inch of precipitation}$$

NOTE: It is important that the collection pipe or trough located at the base of the catchment apron is large enough to transport the volume of water collected from the apron to the storage facility. Undersizing will result in spillage loss during intense rainfall events. Use hydrograph and probable rainfall events as aids to design size of pipe.

3. Catchment Designs.

a. Rock Watershed Aprons.

(1) Description. Natural rock watershed can be a sloping broad area of tightly consolidated rock often referred to as "slick rock" or small rock covered drainages. Water storage can be developed with masonry dams in rock depressions, and pot holes in the drainage channel providing siltation can be minimized. The storage can also be developed adjacent to or below the drainage by installation of a storage tank or the excavation of rock from the drainage to form an adit or cave area that reduces evaporation loss. This type of storage has been successfully developed for desert bighorn sheep in the Southwest.

(2) Advantages. Collection of runoff from a rock watershed is sometimes less costly when compared to artificial apron coverings. Depending on the size of the watershed and physical characteristics, many natural aprons produce sizable flows of good quality water.

(3) Disadvantages. Location of rock watersheds are sometimes in rough terrain away from water deficient forage areas. Rock watersheds vary in efficiency depending upon physical characteristics. Rock watersheds normally yield less than 60 percent of rainfall. Access is sometimes poor, which increases construction costs. Flood debris and sediment yields can damage the structure or reduce storage capacity of the holding tank. Cost of special design structures and maintenance to handle debris and sediment may offset any cost advantages of rock watershed aprons.

(4) Special Design Considerations. The adverse impact of flash flood debris can be reduced with the installation of rock gabion dam deflectors or debris basins constructed above storage facilities. In the Southwest, most of the flash flood debris is transported in the initial head of the flow. Silt and debris stream loads are considerably lower as flood waters subside.

b. Compacted Clay Aprons.

(1) Description. Aprons can be constructed from soils containing a high percentage of clay. Apron slopes should range from 4-5 percent on an even grade without depression that could trap water and prevent good drainage. The shape of an apron should resemble an open fan to hold down the length of the water run. The apron needs to be compacted when soil moisture is optimum. Compaction can be done with a drum roller or rubber tired vehicle. The apron should be treated with soil sterilant to prevent vegetative growth.

(2) Advantage. Minimizes the cost of apron construction.

(3) Disadvantages. Compacted clay aprons normally provide less than 50 percent watershed efficiency. Apron is susceptible to erosion. Erosion generates sediment that degrades water quality and decreases storage capacities of facilities. The apron will function best during frost-free periods and requires compaction on a regular basis when soil moisture is optimum. Apron runoff efficiencies are poor from snow melt and gentle rainfall. Susceptible to erosion damage from high intensity storms and vegetative growth.

(4) Special Design Consideration. Only soils high in clay content should be considered for these aprons. Erosion will probably require construction of a silt trap to reduce the flow of material into the storage facility. Apron compaction by rubber-tired vehicles should be accomplished by driving up and down (parallel) with the slope. Small rills, that could entrap runoff, often develop if vehicle compaction is accomplished by driving across the slope.

c. Wax Aprons.

(1) Description. Catchment aprons are treated with refined paraffin wax with a low melting point of 125-128 degree F. Aprons must be constructed with even grades at a constant slope of 4-5 percent. The aprons must be sprayed with soil sterilant and compacted with a drum roller or rubber-tired vehicle when soil moisture is available. The wax can be purchased in small blocks and melted to a liquid form and sprayed over the apron surface when day-time temperatures exceed 80 degree F and soil surface is warm. Wax should be applied at 2-21 lbs. per square yard. The wax does not form a continuous pavement cover but coats individual soil particles penetrating soil surface 1/4-1/2 inch deep. Wax application is done with special equipment, such as roofing, tar kettles, asphalt crack sprayers or boot trucks used to spray seal coats of oil on asphalt surfaces. Treatments have achieved their best success on sandy-gravelly silt loam soils low in expanding montmorillonite clays. Watershed efficiency after initial treatment averages 90 percent and declines with time approximately 50 percent before retreatment is recommended. Wax treatment of catchment aprons has been successful only at low elevations where ambient temperatures exceed 100 degree F in the summer, and frost action on the soil surfaces is minimal. A silt trap should be built to minimize siltation in the storage facility.

(2) Advantages. Wax can be applied by a two-person crew. Cost compared to other apron materials is low to moderate. Water quality is good.

(3) Disadvantages. Wax aprons require specialized equipment. They are only applicable to soils low in clay and low elevation sites with warm temperatures and moderate climates. Aprons are very susceptible to erosion by high intensity storms. Runoff efficiency is lowest during the winter. Wax aprons are susceptible to damage by frost heaving. To maintain good runoff efficiency, the apron should be compacted yearly when soil moisture is good. Annual maintenance is required to remove vegetation that reinvades the apron. Retreatment is normally required every 5-10 years. These aprons are recommended only for southwestern rangelands.

(4) Special Design Considerations.

(a) Slope. Apron slopes ranging 4-5 percent to reduce erosion hazard is recommended.

(b) Soil Characteristics. The soil must be low in expanding montmorillonite clay particles. Successful applications have been on soils containing less than 20 percent clay. Apparently, the wax does not penetrate and coat the small, tightly compacted clay soil particles as well as lighter silt and coarse grained, sandy soils. A soil scientist should be used to determine soil types.

(c) Apron Shape. Use an open fan shape to shorten water runs, reducing erosion potential.

(d) Silt Trap. Installation is required to reduce sediment accumulation in the storage facility. Open top concrete silt traps with baffle plates to slow velocity of flow have been successful. They are easily cleaned with a square-nosed shovel.

(e) Aspect. Wax aprons are located best on south-southwest slopes for maximum soil surface heating, improving the repellency of the wax coating of soil particles.

(f) Soil Sterilization. Soils used as the catchment apron should be sterilized to prevent regrowth of perennial and annual vegetation. The type of chemical used must be approved for use on public lands. The selected soil sterilant should be leached into the soil profile where it will be immobilized and not contaminate runoff water.

d. Sodium Salt Aprons.

(1) Description. Aprons are treated with a high rate of granulated or crushed rock salt. Salt is mixed into the top 2-3 inches of soil at the rate of 5 tons/acre, wetted and compacted. The sodium molecules disperse the clay which plugs soil pores which reduces infiltration and increases runoff. The sodium is held in the clay and the water produced is good quality. Information is not available to evaluate long-term performance of salt treated aprons.

(2) Advantages. Initial construction cost is low. No special or unique equipment is required for application. Sodium salt aprons provide good water quality. Salt in soil restricts vegetative growth on apron.

(3) Disadvantages. Apron treatment opportunities are restricted to soil high in clay content. Aprons are susceptible to erosion damage from intense storms and frost heaving. Performance is similar to wax aprons.

(4) Special Design Considerations. Soils must be high in expanding montmorillonite clays and should contain coarse materials necessary for the formation of erosion pavement to reduce erosion. Sodium salt is not effective with soils high in kaolinetic clays.

(5) Special Restrictions. The use of sodium salt aprons would not be politically or technically justifiable in the Colorado River Basin because of the BLM commitment under the Colorado River Basin Salinity Control Act.

Soils should be analyzed by a soil scientist. The same special design characteristics described for wax aprons apply for salt aprons.

e. Asphalt - Geotextile and Fiberglass Aprons.

(1) Description. Asphalt in various forms has been applied as a cover to aprons for several years with varying degrees of success. Asphalt-concrete, a road surface mixture of asphalt, sand, and gravel, is usually successful for short time periods before severe deterioration starts to occur through cracking and weathering of the asphalt surface. Installation and maintenance costs of hot or cold mixes are high and not recommended for apron surfaces. Asphalt emulsions containing latex additives to prevent cracking have been applied directly to soil surfaces with road surfacing equipment. Experience has shown that the latex may extend the life of the apron, but normally within 3 years, deterioration occurs rapidly by the breakup of the surface. Infiltration of moisture through the cracked surface encourages frost heaving and plant growth leading to further deterioration.

Asphalt emulsions have been used successfully when applied to geotextile fabrics made of polyester fibers and fiberglass mats which help prevent deterioration through cracking of the surface. Asphalt-clay emulsions are water soluble and are applied to the fabrics with buckets and floor brooms or directly with specialized pumps and spray guns.

(2) Advantages. Asphalt, geotextile or fiberglass, aprons are not as susceptible to erosion as soil treated aprons. They have a wider range of application to variable slopes. Recommended slopes range from 3-15 percent. They are not as susceptible to damage by frost, snow, and ice as are soil treated aprons. Maintenance costs (if properly installed) are low to moderate. No silt-trap is required. Water yield is excellent.

(3) Disadvantages. Generally speaking, asphalt aprons are messy to install. Material costs are moderately high and installation requires a considerable amount of labor. The aprons are very susceptible to damage from wind and vegetation growth. Water quality is fair as the asphalt slowly erodes from the surface and washes into the storage tank. Geotextile fabrics shrink 2-3 percent and have a tendency to separate the lap joints unless special precautions are taken during construction. Some damage has been observed in the Southwest near apron berms caused by ravens, ants, and burrowing animals.

(4) Special Design Considerations. The apron must be prepared carefully with a fabric anchor trench excavated around the apron exterior border. The apron needs to be raked clean of all stones or rocks that may eventually cut through the fabric. Two applications of asphalt emulsion are desired for longer life.

The apron should be sprayed with approved soil sterilant and/or soil surface deeply excavated to remove hard-to-kill plants (sprouting shrubs and rhizomatous grasses). The apron mat must be spiked down to the soil surface along lap joints to prevent separation caused by slight shrinkage. To compensate for the 2-3 percent shrinkage of polyester fabric, the matting must be loosely layed over the apron surface leaving numerous small wrinkles. These wrinkles will disappear after about 12 months as the material shrinks. Fiberglass matting does not shrink. The geotextile fabric must be sprayed with detergent water before the application of the asphalt to increase penetration. To prevent wind damage, numerous weights should be placed randomly across the apron. Used vehicle rubber tires and flat rocks have been used successfully to prevent apron lifting and tearing by high winds.

f. Metal Aprons.

(1) Description. Metal aprons provide excellent watershed efficiency. Aprons have been constructed out of galvanized steel, sheet metal, aluminum, and corrugated metal roofing materials. The most commonly used material has been galvanized corrugated metal roofing. Metal thickness normally ranges from 18-29 gage.

Dimensions of roofing sheets provide 24 inch wide covering and range in length from 6-16 feet. Roofing sheets can be placed in direct contact with the soil surface or secured to wood or metal support understructures. A rain gutter or wide collection trough at the toe of the apron is installed to conduct the runoff to the storage facility.

(2) Advantages. Metal provides an excellent watershed with long life and low maintenance providing it is properly installed. Slopes are not critical and can be variable along ground surfaces, provided adequate drainage is maintained.

(3) Disadvantages: Installation costs are normally high. Galvanized surfaces are resistant to corrosion but deteriorate slowly when in contact with the soil surface unless treated with an asphalt emulsion. Newly installed galvanized surfaces reflect sunlight and can be seen at great distances unless painted. Reflectiveness of the galvanized surface is reduced in time as the material is dulled through weathering. Metal aprons improperly secured or constructed above ground are susceptible to wind damage, especially those of lighter gage metal. It is recommended that metal covering aprons be constructed of no lighter than 26 gage material.

(4) Special Design Considerations: The collection trough at the bottom of the apron must be designed to handle the volume of runoff from intense rainstorms. Malfunction of the collection trough has occurred in cold climates when snow and ice builds up in the trough blocking the runoff.

The apron support structure should be adequate to prevent wind damage. Where termites are a problem, all lumber in contact with the ground should be treated with a preservative. Designs requiring C-channel steel studs or "I" beams are economical and have a long life.

g. Butyl Rubber Apron.

(1) Description. Butyl materials have been widely used for catchment aprons and storage in the past 20 years. The rubber is easily installed and has good runoff qualities. This material is somewhat resistant to deterioration by ultraviolet light and other weathering processes but has not performed well on rangelands. Most developments show severe deterioration within 4-6 years after installation.

(2) Advantages. Installation costs are low compared to other catchments because units can be purchased partially in a prefabricated condition. Prefabricated aprons and storage bags are easily installed with unskilled labor. Very little site preparation is required. They are easily transported by 4-wheel drive vehicles or helicopter to remote sites.

(3) Disadvantages: A common problem associated with butyl catchments is that snow and water accumulate on top of the storage bag causing it to remain in a collapsed state, preventing it from filling. One solution to this problem is to insert an air-filled pillow inside the bag. The most significant problem relates to butyl deterioration brought about through weathering and the damage caused by ants, rodents, and other wildlife. Holes in the butyl lead to further deterioration from wind and plant invasion on the aprons. Butyl as an apron covering is not recommended. The butyl bags, if protected from direct sunlight and harmful effects of insects and animals, could be used successfully as water storages.

h. Concrete and Shotcrete Aprons.

(1) Description. Concrete, a very common material, has been used successfully as a catchment apron covering, especially for small wildlife catchments. Concrete is a very durable material providing it is properly mixed with proper proportions of clean sand, coarse aggregate, cement and water. Concrete apron pads should also be placed with wire fabric or other steel reinforcing rebar to provide strength and prevent excessive cracking. Aprons are strong, and it is not necessary to construct protection fences to guard against mechanical damage. Concrete readily shows the effects of weathering if the mix has been done with contaminated materials available near work site or with dirty water. If worked excessively with a trowel during finishing, spalding and surface cracking usually occur. Good vehicular access to the work site, location to materials, mixing equipment, batch plants or transit mixer (ready-mix) are critical items to consider when evaluating design alternatives.

Shotcrete is a relatively new process of placing concrete. Shotcrete is applied by spraying concrete from a nozzle. The cement, sand, and/or aggregate can be sprayed as a wet premixed material or a dry mixture where water is introduced into the mixture at the nozzle. The materials are projected at high velocity onto a surface with air pressure which gives it considerable strength. Shotcrete is more commonly used to stabilize rocky slopes and embankments against erosion, tunnel linings, swimming pools, foundation repairs, and restoration of old rusted out steel storage tanks. Although not known to be used as an apron material for catchments, there is no reason to believe that it would not perform well if properly applied.

(2) Advantages. Concrete is very durable and if properly mixed and placed with skilled labor, is maintenance free.

Shotcrete has the advantage of easy, quick application on uneven surfaces. It is very strong and easily colored to blend in with the landscape. It can be applied with a limited amount of forming. Because shotcrete is so versatile, it could be used to build the apron and the storage tank during the same construction phase. For more information, see the Storage Facility Section of this Handbook.

(3) Disadvantages. Concrete can be a costly material to use if vehicular access to worksite is poor or materials must be hauled over long distances to remote worksites. Specialized mixing equipment and semi-skilled laborers are required to do a good job. Installation usually requires a large number of workers.

Shotcrete applications would be limited to worksites with good road access. It is necessary for the trucks transporting the shotcrete pumping equipment and the mix materials to have good access to the worksite.

The cost of shotcrete is relatively high and depending on the thickness and worksite access, costs approximately $10-$20 per square yard for a catchment apron. However, this may be a practical construction alternative if the storage tank could be completed at the same time the apron is placed.

i. Fiberglass Parabolic Tank and Apron.

(1) Description. This type of catchment has been designed for wildlife by several companies and can be ordered as an unassembled catchment unit. In appearance, the unit resembles the popular conception of flying saucers and is often referred to as such. The unit comes in a variety of sizes with the larger unit consisting of a 16-foot diameter shallow circular storage tank with a domed roof that acts as the catchment apron and evaporation control. Big game animals can drink through a slot in the roof cover or the water can be piped to a trough. Storage capacity varies from several hundred gallons to 2,100-gallons. The 2,100 gallon unit requires 17 inches of precipitation to fill the storage tank to capacity.

(2) Advantages. The unit is simple to construct and can be installed without the use of specialized or heavy equipment. It provides for evaporation control and distribution of water to big game without pipelines, float valves, and drinking troughs. The unit can be transported to remote sites by helicopter or 4-wheel drive trucks. Maintenance costs are very low. Small holes are easily patched.

(3) Disadvantages. The dome-shaped roof that acts as the catchment apron is too small for the storage facility where annual precipitation is less than 17 inches or the water requirement of big game animals exceeds water harvested. The dome-shaped roof apron is not conducive to snow accumulation, especially in windy areas which would reduce runoff when snow melts. Numerous seams must be carefully sealed during installation to ensure that no leakage occurs.

(4) Special Design Considerations. Rock free soil to 20 inch depth on 0-3 percent slopes is required for hand labor installation.

j. Inverted Umbrella Catchment.

(1) Description. This type of catchment has been designed for wildlife but can also be used as a supplemental livestock water if large enough. The catchment consists of a steel tank with bolt-on steel "wings" for water collection that resemble an inverted umbrella. Typically, the tank and wings consists of 20-gage corrugated galvanized steel and can vary in size considerably. The most commonly used design consists of an 8-foot tall by 8-foot diameter tank with an attached 16-foot diameter collection area. This design provides 2,700 gallons of storage and 201 square feet of collection area.

(2) Advantages. The unit is simple to construct and can be flown into remote sites. Because most of the tank is enclosed, evaporation is insignificant. The materials are long lasting; thus, the catchment is expected to have 20 plus years of useful life. The unit can be built in a variety of terrain with the only requirement being the ability to clear a flat surface approximately 8-feet in diameter.

(3) Disadvantages. The "wings" are susceptible to being uplifted by strong winds and may result in damage to the wings or entire unit. The amount of surface collection area is limited; therefore, the reliability of the catchment may be poor during dry periods. The entire unit is above ground and can be obtrusive to the visual scene depending on the location. Because of the high profile, it may become an easy target for vandals.

(4) Special Design Considerations. The unit should be located in sheltered areas protected from high winds that may damage the structure.

k. Other Catchment Apron Materials.

Several other types of catchment apron coverings have been used with varying degrees of success on rangelands. They include the following:

(1) Gravel covered plastic sheeting or hypalon.

(2) Corrugated fiberglass roofing panels.

(3) Asphalt shingled roofs.

(4) Thick rubber-nylon reinforced landing mats and conveyor belts from military surplus or other inexpensive sources.

(5) Soil cements, silicones, or other petroleum soil treatments.

Some of these materials are worthy of consideration if they can be obtained at very little cost and are inexpensive to install. However, they are not recommended as normal construction materials to be purchased in open market situations.

D. Literature Cited.

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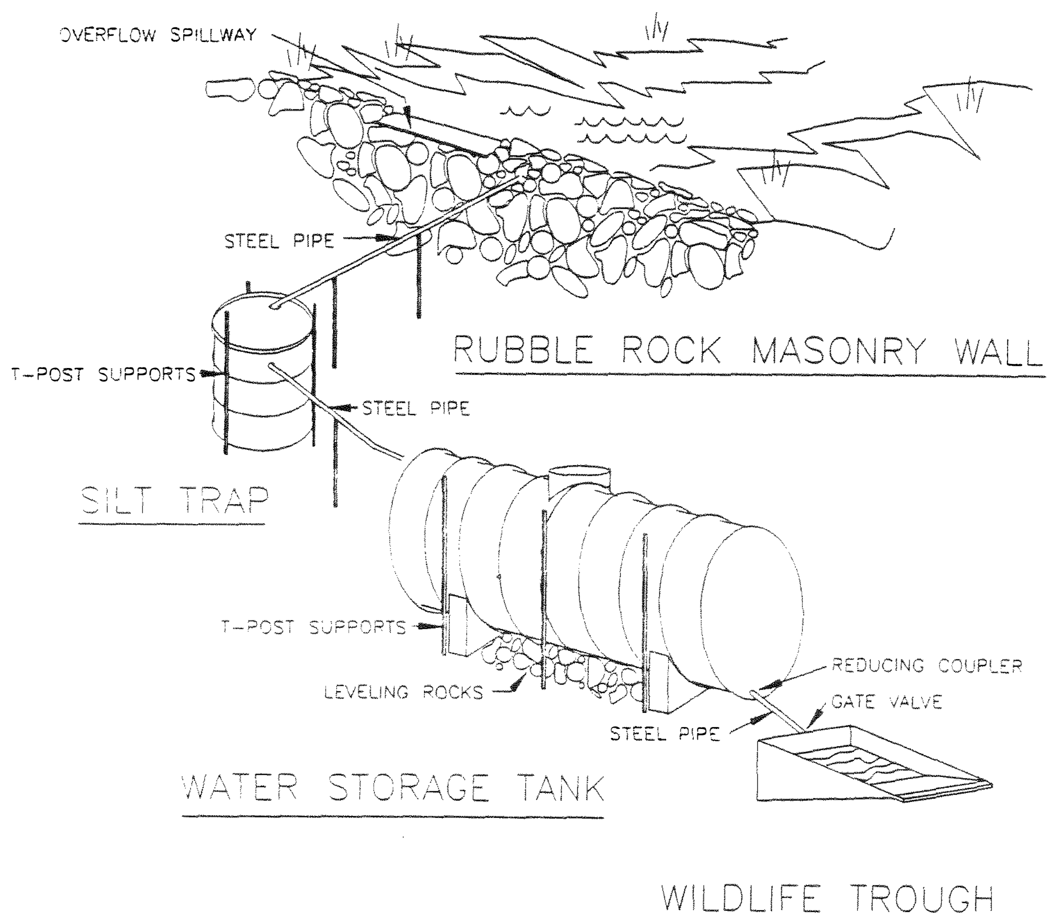
Catchment Apron Construction and Maintenance Summary Table

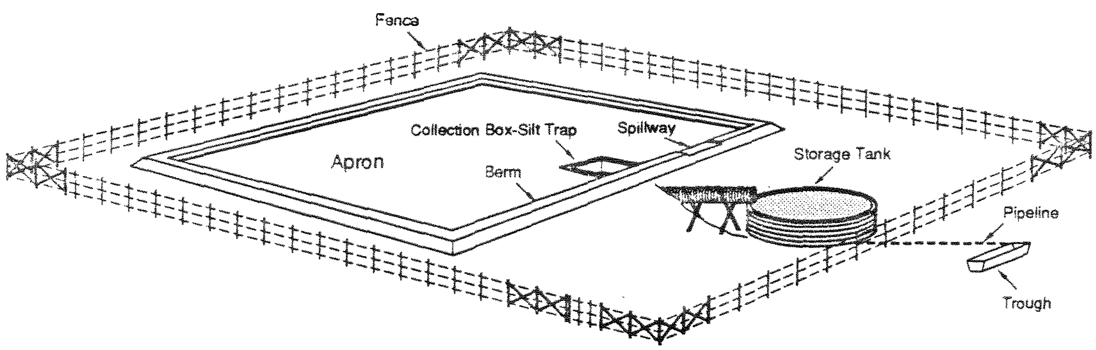
Apron Surface	Site Conditions Slope (%)	Site Conditions Surface	Costs[1] Construction Materials $/Yd²	Maintenance Labor-Equipment	Runoff Requirement	Expected Efficiency (%)	Life (Yrs)
Asphalt-Geotext. or Fiberglass	3-15	Rock Free Soil Sterilant	$ 2.50	High	Low	95	20
Paraffin Wax & Sodium Salt	4-5	Selected Soils Smooth, Compacted Soil Sterilant	$ 1.50	Low	Mod.	75	5-10
Butyl Rubber	3-15	Rock Free	$ 8.00 - 10.00	Low	Mod.-High	95	4-7
Metal Roofing	3-15	Variable	$ 5.00 - 10.00	High	Low	98	20+
Concrete incl. Shotcrete Cement	3-15	Variable	$15.00 - 20.00	Mod.	Low	70	20
Clay Soils	4-5	Smooth, Compacted Soil Sterilant	--	Low	High	50	--
Rock	Var.	Rough	--	Low	Low	60	--
Fiberglass Saucer (Wildlife)	0-3	Rock Free Soil	$3,000 Total Cost for 2100 gal. Unit	Low	Very Low	98	20+
Inverted Umbrella (Wildlife)	0	Variable	$2,000 Total Cost for 2700 gal.Unit	Low	Low	98	20+

[1] Approximate on-site costs not including site preparation. Cost based on 1985 prices for materials.

Rock Apron Wildlife Catchment

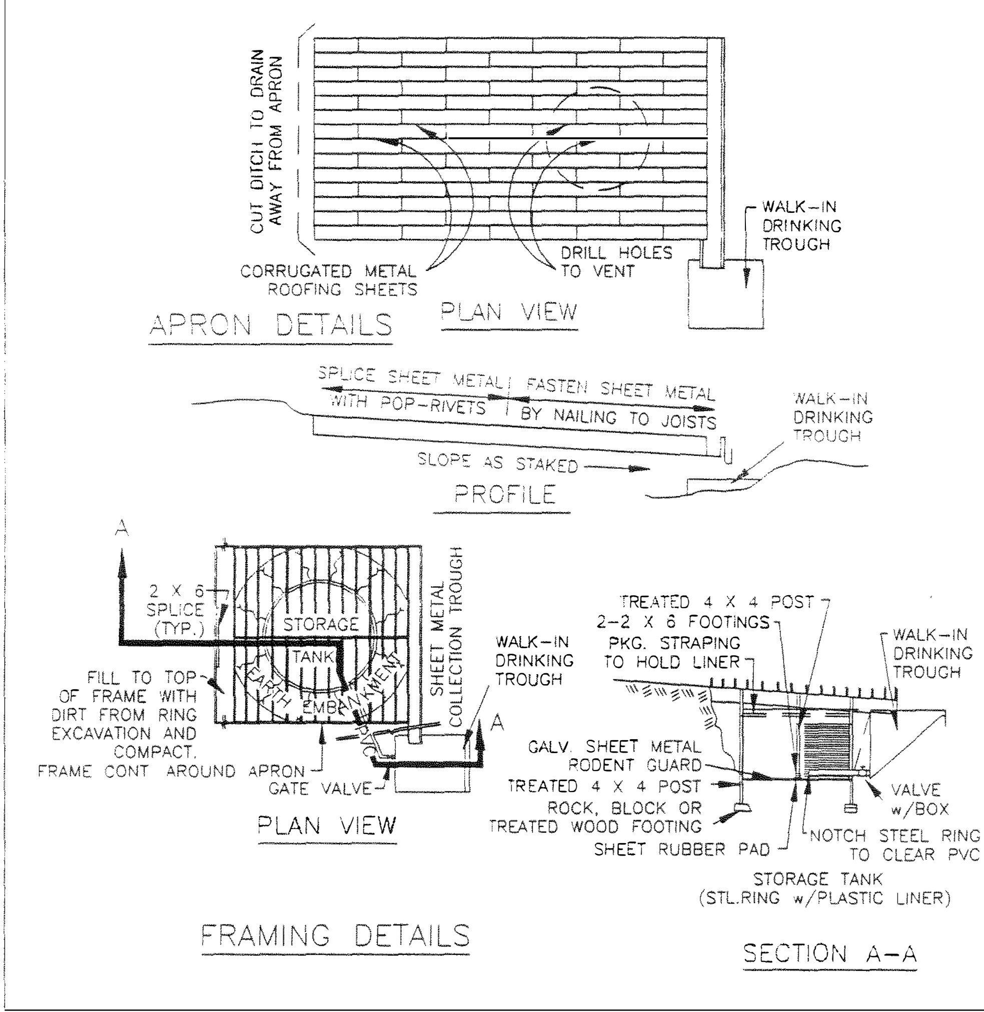


Typical Water Catchment Layout



Chapter VI

Typical Plastic Lined Ring Tank Catchment



Chapter VII

Chapter VII - Wells

A. Introduction.

A well is an engineered hydraulic structure that, when properly designed and constructed, allows efficient removal of ground water from a water-bearing formation. The design of a well should involve careful consideration of material selected based on water quality and geologic conditions. Of equal importance is the selection of proper techniques in drilling, construction, and developing wells to take maximum advantage of hydrogeologic conditions. Consider power availability (wind, electric, solar, etc.) depth to water, yield, screening needs, storage, locations of use points, season, pipeline distribution, cost of distribution system, and flow controls.

Water wells are generally drilled in one of two types of aquifers: water table aquifers, and artesian water aquifers. Water table aquifers are generally open to atmospheric pressure; therefore, when drilling into this type of aquifer, the static water level remains at the depth water was encountered, even after proper development of the well. When drilling penetrates an artesian aquifer, water rises in the borehole due to hydraulic pressure. If the pressure is high enough (i.e., the potentiometric level of the aquifer is above ground surface at the well site), water will flow freely from the well without being pumped. The occurrence of artesian wells results from aquifers being confined by an impervious material and the recharge area being higher in elevation than the point in the aquifer where the well is drilled.

Occasionally, wells are drilled into a third type of aquifer known as a perched water table. This is generally a low-producing aquifer due to small recharge and storage areas. Wells in this aquifer type are often drilled with horizontal drilling equipment. See Illustration VII-1 for a comparison of the aquifer types. Wells are generally considered as a source of water where springs or surface water supplies are inadequate or unreliable, and they can offer long-term or short-term solutions to water requirements.

A well-site examination should be made to evaluate the possibility of obtaining water. The well-site examination provides information for estimating well depth, yield availability, pumping depth, and aquifer material type, and for recommending the drilling method most suitable for the geologic conditions at the site with the least amount of risk. This information is then used in designing the well and pumping system and preparing the bid draft.

B. Well-Site Investigation Request.

Identification of areas where water is needed should be made early in the planning process. These areas are evaluated during the well-site investigation to determine the feasibility of drilling a successful well at a specific site. The proposed areas for drilling should be identified on Form 7230-4, Well-Site or Spring Examination Request (see Illustration VII-11). Well-site examination must be performed by qualified BLM geologists or hydrologists from a Resource Area, District, or State Office, or the Service Center. The use of contracted services to evaluate well sites is acceptable if the contractor meets certain qualification standards. The contracting of water dowsers or "water witches" to select drilling locations should not be authorized.

In preparing the well-site examination request, it is important that the resource specialist supply as much of the information as possible on the form. If additional information is needed on nearby water sources, the District or State Office hydrologist should be consulted. This completed form provides information necessary for an accurate assessment of ground water conditions. For example, the form provides information to the person doing the investigation on three known sources of water in the vicinity of the proposed well-site. This information is extremely useful during the well-site investigation.

When considering a proposed location of a well, the requesting resource specialist should make some preliminary assumptions concerning items such as season of use, water distribution plans, access to the drilling site, and future water supply needs. These items should be noted in the request for well-site investigation, and retained as part of the permanent record of the well.

C. Applications.

Water wells are especially applicable in several of the following situations:

- When a water supply is needed year around.
- When a specific watering site is needed.
- When a greater yield is required than is available from springs or catchments.
- When cost, political, geologic or climatic conditions preclude use of lengthy pipeline systems.
- When high water requirements dictate the need for centrally located water sources for grazing management.

Several other site-specific situations may exist where water wells are the preferred application.

D. Advantages And Disadvantages.

1. Advantages.

The advantages of a well can be realized only when the well is properly designed and constructed, and the appropriate pumping and delivery systems have been installed.

Wells are very reliable as year-around sources of water. In cold climates, a system can usually be designed to deliver water without freezing.

Water yield of wells can be adjusted as water requirements dictate. For example, the pumping rate can be increased up to the maximum designed capacity of the specific well.

Storage is relatively inexpensive, as the aquifer and the well bore can be used for storage, eliminating the need for costly surface storage systems. In winter-use systems in cold climates, this is an important advantage.

The life of a properly designed and constructed well is often 20 years or more. Although the initial expenditures are great, this results in a very cost-effective alternative of water development. (Some maintenance on the well may be required to achieve maximum longevity.)

Geologic conditions often allow for flexibility in well location. Therefore, the well can be drilled at the point of need for the water supply.

Records collected during drilling of the well often yield information about subsurface geologic conditions and ground water flow valuable to geologists, hydrologists, and engineers.

A properly designed and constructed well can be practically maintenance free.

2. Disadvantages.

Surface appurtenances (windmills, pump jacks, and other pumping systems) are expensive, are often complex, and require regular maintenance.

Maintenance can be difficult if accurate records were not kept during initial design and construction of the well.

Local water quality may not meet standards for human or livestock consumption.

There is always the risk of a dry hole.

E. Formation Types.

The location of a well-site may be in a consolidated or an unconsolidated formation. There are advantages and disadvantages of drilling wells in each of the formation types, as shown in Table VII-1. Many times, the well must be located on a specific site, and options for selection of the formation to be drilled in are not possible. If possible, when selecting potential sites for water wells consideration should be made of consolidated versus unconsolidated materials as possible water sources. Areas of particular concern are pollution, initial cost versus projected maintenance, local availability of drilling technology, and weather patterns.

TABLE VII-1

Formation Type	Advantages	Disadvantages
Consolidated	Not subject to effect of cycles of subnormal rainfall. Generally require little maintenance. Do not normally require well screen.	Are usually deeper. Yields may vary within same formation. Mineral content may increase with depth. Water temperature increases with depth. Subject to pollution from distant and local sources.
Unconsolidated	Usually not deep. Relatively low cost. Water generally low in mineral content. Water has lower temperature.	May be more affected by dry cycles. Will need to be screened. May require gravel pack. Will usually require more maintenance. Requires more developing time. May be subject to local sources of pollution.

F. Well Design Considerations.

The design of wells in unconsolidated and consolidated formations can be very different. In unconsolidated formations, the entire borehole is cased. Blank casing (non-perforated) is placed from the surface to the intake casing, and well screen or another type of intake casing is placed in the aquifer according to the well design. A drillable plug can be placed in the bottom of the intake casing to prevent fine sand or silt from entering the completed well. Intake casing can be installed without placing a gravel pack (artificial filter material) around it if the natural aquifer material is suitable to properly develop. Gravel packs are used when the natural aquifer material is extremely fine sand (smaller than .008 inch), when the sand has uniform, fine grains, when large diameter wells are drilled (reverse rotary drilling method), in semi-consolidated sandstones where weak and flaking conditions may exist, or when the aquifer is artesian and the intake casing size is reduced below the upper casing. Development considerations are nearly the same for gravel pack or natural filter designs. To allow placement of a gravel pack, the borehole must usually be drilled at a larger diameter than if no gravel pack was used. See Illustration VII-2 for examples of well designs.

The design of wells in consolidated formations can vary from casing in the entire borehole to only having a surface casing.

The determination of when and where upper and intake casing must be used in a well in consolidated formations can be made as the well is drilled. If the borehole is stable from the surface to the bottom, including through the aquifer, only a surface casing must be installed. Other conditions may exist in the borehole that will require additional casing to be set. An aquifer may be encountered that has poor quality water. Casing and the use of grout or packers may be used to keep the low quality water from entering the well. Aquifer materials may be consolidated but have a cementing agent that erodes or dissolves as water is removed from the well. As this happens, a well screen may be needed to keep the solids from entering the well and passing through the pump. Also, there may be overburden or zones between consolidated materials that can cave into the borehole without an upper casing for support. It is usually easier to case the entire borehole past the zones where problems exist than to case only certain zones or formations.

G. Well Construction.

Well construction involves up to five different operations:

- Drilling the borehole.
- Installing the upper casing.
- Installing intake casing and gravel packs.
- Sealing the surface.
- Developing the well.

Chapter VII

1. Drilling Methods.

The more common drilling methods used for construction of private or commercial wells are also suitable for use in drilling wells for BLM applications. These methods include:

- Cable tool or percussion drilling.

- Direct rotary drilling.

- Reverse rotary drilling.

Advantages and disadvantages of these methods are listed in Table 2, Page VII-19. The selection of the most suitable drilling method for a particular job requires an understanding of geologic conditions and limitations and capabilities of drill rigs.

a. Cable Tool Drilling.

Cable tool rigs (also called percussion or spudder rigs) drill holes by lifting and dropping a drill string consisting of a drill bit and drill stem, into the borehole. In consolidated formations, the material is crushed by the weight of the drill string, while in unconsolidated formations, the material is mostly just loosened. The crushed or loosened material is mixed with water or a drilling fluid. When the slurry is so thick that it retards the action of the bit and drill stem, it is removed from the borehole by lowering a bailer or sand pump into the hole to remove the cuttings. If sufficient natural moisture is not present to make the slurry with the cuttings, water will need to be added to the borehole as drilling progresses. In cable tool drilling, casing is normally driven as the borehole is drilled. Drilling in consolidated formations, which is often very slow, requires only surface casing be set. To drive the casing, drive clamps are attached to the drill string, which provides the driving weight, and the string is lowered repeatedly on top of the casing, driving it into the hole. A set of drilling jars are usually placed in the drill string and function mainly to "hammer" the drill bit and string from the borehole if the drill string gets stuck. The jars can also be used to assist in pulling casing from wells that will not be completed. See Illustration VII-3 for a detail of a cable tool rig and accessories used in drilling.

b. Direct Mud Rotary Drilling.

Direct rotary drilling provides a relatively rapid drilling method and the capability of searching greater depths. A wide variety of rotary rigs are available to match drilling needs with formations to be penetrated. Rotary drilling rigs operate by using a hollow drill pipe to turn a drill bit. As the bit turns, it loosens or crushes the formation. A drilling fluid is circulated through the drill pipe and bit into the borehole, using a pump (see Illustration VII-5). The fluid carries the cuttings to the surface, cleaning the bore hole, and flows into a portable or dug mud pit. The cuttings settle out of the drilling fluid and the fluid is recirculated through the pump and drill pipe.

Drilling fluid in a borehole can penetrate the aquifer and deposit solids that may be difficult to remove during well development. Mud rotary drilling should be selected only when enough information is known about the aquifer to prevent damages that will result in loss of well yield. The selection and control of the drilling fluid is very important. Commercial bentonite and organic polymers are available from many manufacturers and the type used should be compatible with drilling conditions. As these conditions change, additives can be used to alter properties of the fluid, such as weight and viscosity. The fluid must have properties that allow it to keep the borehole open after drilling is completed, to allow logging of the hole and installation of casing.

Bit selection, rotation speed, and pressure exerted on the bit by the drill pipe and drill rig are critical in all rotary drilling. Proper material selection and technique assure minimum wear on equipment as well as good vertical borehole alignment. See Illustration VII-5 for a drawing of mud rotary drilling method.

c. Direct Air Rotary Drilling.

Air rotary drilling is very similar to mud rotary except that air is used to carry the cuttings from the hole instead of a liquid slurry. As the bit loosens or crushes the formation, an air compressor forces air through the drill pipe and bit and carries the cuttings up the annulus at a high velocity. Water can be injected into the system with a high pressure, low volume pump to reduce the dust and improve the efficiency of cuttings removal from the borehole. Additives can be injected with the water to produce a foamy discharge which further enhances the removal of cuttings by reducing open area in porous formations to reduce air loss, and filling the air space in the annulus between the drill pipe and the borehole sides. In semiconsolidated formations, the foam can often keep the borehole open long enough to set casing.

In unconsolidated formations, the efficiency of air rotary drilling can be enhanced by using a casing driver to drive casing as drilling progresses. The procedure is to drill several feet, pull the drill string back into the casing, drive the casing to the point where drilling stopped, then drill out through the bottom of the casing and repeat the sequence. Generally, a heavier-walled casing is needed to withstand the hammering of the driver, as well as a drive shoe welded to the bottom of the casing. See Illustration VII-4 for a drawing of the air rotary drilling method.

d. Direct Air Rotary Drilling With Down-The-Hole Hammer.

This drilling method combines rotary and percussion drilling methods. Air, water, and foaming additives can be used, as with direct air rotary drilling. The main difference from direct air rotary is the bit type and the use of a hammer drill located between the bit and the drill pipe. The bit is flat on the bottom with carbide inserts, and as it is rotated slowly, the hammering action pulverizes the formations. The cuttings are then removed with air. Drilling in hard materials is very rapid compared to drilling with other methods. When drilling in unconsolidated materials, such as boulders, a casing driver can be used very effectively since the drilling action or the hammering action of the casing driver can crush boulders as drilling and driving progress. The use of foaming additives and casing drivers, combined with the capabilities of the down-the-hole hammer and casing drivers, make this drilling method very versatile. It is increasingly more popular with many drillers in a wide variety of formations that, until recently, could not be drilled with air-rotary rigs.

e. Reverse Rotary Drilling.

Drilling with this method is similar to direct mud rotary, except the flow of drilling fluid is reversed. Clean water or a mud slurry flows into the annulus, keeping the borehole full to prevent caving. The cuttings pass through the bit and are pulled up the drill pipe by a centrifugal pump as they are loosened (this method is used for drilling in semiconsolidated and unconsolidated formations). Although large diameter wells can be drilled with this method, depth is a limitation, and large amounts of drilling fluid are needed. When rocks too large to enter the drill pipe through the ports in the bit are encountered, they must be removed with boulder catchers, forced into the borehole wall, or crushed with a roller cone bit. Reverse rotary drilling is generally used for drilling large diameter holes, up to 5-feet in diameter, which makes it popular for drilling high capacity wells that will receive a gravel pack around the intake casing. See Illustration VII-6 for a drawing of the reverse rotary drilling method.

With the use of air assist drilling, a compressor injects air into the drill pipe near the bit, cuttings and drilling fluid are carried to the surface with air. This increases the depth to which reverse rotary drilling is effective.

f. Additional Drilling Methods.

There are several other drilling methods, most of which are less suited to BLM applications. A few of these are mentioned below.

(1) Bucket Augering - Can be done to depths of 250 feet if the materials penetrated have a high amount of clay to keep the hole open. Rocks can create problems and must be removed as in the reverse rotary method.

(2) Driven Wells - Are installed in unconsolidated formations free of cobbles and large rocks. Well points are driven by hand with drivers similar to fence post pounders, or with weights up to several hundred pounds. Depths of driven wells are usually less than 50 feet deep.

(3) Jet Drilling - Uses a high velocity stream of water and a chisel-shaped bit lowered through the formation with a pipe string. The string is raised and lowered as with percussion drilling and the water under pressure helps loosen the formation and carry the cuttings from the hole. Drilling depths vary depending on formation, hole diameter, and pump capacity and pressure.

2. Selection and Installation of Upper Casing.

The upper casing serves several functions. During drilling, as well as after well construction, the upper casing prevents the wellbore from caving. In many formations, caving may not be a problem, and the upper casing is not needed. However, State laws or Bureau specifications dictate the minimum amount of casing that must be placed in every well drilled, for protection of shallow ground water. The upper casing also serves as a barrier to keep poor quality water from entering the completed well. If a free-flowing artesian well is developed, the upper casing, combined with the intake casing, serves to carry the water from the confined aquifer to the surface of the ground without losing water to the unconfined aquifer or (dry) upper strata above the confining materials.

The diameter of the upper casing should be selected based on the water pumping system to be used. Generally, the diameter of a completed well should be at least 2 inches larger than the pump. Most pumping systems in BLM wells are 3 to 4 inches in diameter, so a minimum 6-inch diameter well casing should be specified. This also allows adequate room for proper well development, as discussed in this Chapter. For a pumping system larger than 4 inches in diameter, see Table 3, page VII-20 for a recommendation of minimum casing diameters for various sizes of pumps. Free-flowing artesian wells can be constructed with smaller diameter casing without sacrificing production greatly. Initial planning includes maintenance considerations and possibly increased yield requirements. Therefore, it should be recognized that drill pipe and fittings necessary to redevelop wells (as well as develop initially) are often 4 to 5 inches in diameter. Constructing wells, whether free-flowing or pumped, with a minimum of 6-inch diameter casing will allow future deepening of existing wells, lining existing wells with plastic or metal casing for maintenance purposes, and telescoping a wider range of well-screen diameters during initial construction or maintenance.

A wide range of materials are available for casing or lining wells. Selection of casing material should be based on water quality, well depth, cost, and the geologic strata being penetrated. Water quality considerations can be made based on water sampling and testing of adjacent wells or test wells drilled near the location of proposed well sites. Casing material can then be selected depending on the characteristics of the water.

Well depth and water quality determine the wall thickness and collapse strength needs of the casing. Installation of casing with some of the recently developed casing drivers may require that casings have a heavier wall thickness than that needed for wells with open hole drilling.

Polyvinylchloride (PVC) and fiberglass well casings can be used, provided their limitations are noted and adhered to. Usually these limitations are collapse strength, heat resistance associated with grouting, and the depths to which they can be set, due to formation pressures.

Cost of the casing materials available can vary greatly, so proper selection of the material most suitable for a particular application is important. An evaluation of factors affecting needed materials must be completed to prevent costly overdesign of the well. The BLM's Branch of Engineering Services at the Service Center can supply necessary specifications and requirements based on projected well design criteria.

3. Installation of Intake Casing and Gravel Packs.

The intake casing is placed in the aquifer to allow water to pass through while keeping the aquifer material from entering the well. The intake casing can be one of several types available, such as wire wrap screen, shutter screen, bridge slot pipe, or milled slot pipe. In cases where the drilling is in a consolidated formation, leaving the aquifer open may be acceptable. Using a wire wrap screen is the most desirable, since the size of the openings can be designed to allow efficient water removal from the aquifer while retaining the majority of the aquifer material outside of the intake casing. This increases the stability of the borehole, since one can control the amount of aquifer or gravel pack material removed from around the casing during well development and pumping. Wire wrap screen provides for maximum efficiency when developing a well, by jetting the aquifer through the screen, since the percent open area of well screen is very high when compared to other types of intake casing. With a high percent open area per unit of length of the screen, the entrance velocity of the water passing through the screen can be kept low, even in thin aquifers. This design consideration will help control incrustation and corrosion of the intake casing. A V-wire wrapped screen should always be used unless there is some overriding justification for another design. See Illustration VII-7 for comparisons of intake casing designs.

Selection of material for the intake casing should receive the same considerations as the upper casing, including depth, cost, geologic strata characteristics, and water quality (for corrosion/incrustation resistance). The design of the intake casing is critical to the life, production, and efficiency of a well. A particle size analysis should be conducted on the samples taken from the portions of the aquifer that are to be screened. Using this information and results from aquifer production tests, the optimum slot size and amount of screen needed for maximum productivity of the well can be determined.

When a well screen is needed and the formation characteristics indicate that a gravel pack is necessary, the filter material gradation used in the gravel pack must be determined based on a particle size analysis (sieve analysis) of the formation samples (the well design consideration section discusses when gravel packs are necessary). The gravel pack material is placed around a well screen that is centered in the borehole with the use of casing centralizers.

This gives a uniform thickness of filter material around the well screen that nearly stops the travel of fine aquifer material into the well. The thickness of the gravel pack should range from 2 inches minimum to 8 inches maximum. A thickness of less than 2 inches cannot be accurately placed, and a thickness greater than 8 inches will not allow proper development of the water-bearing formation.

4. Seals.

Grout seals are placed in the well annulus around the permanent surface casing or the pump chamber casing to provide a sanitary seal. The seal should be of sufficient thickness and of proper design to prevent surface water or other contaminants from entering the well bore.

Bentonite or cement grout is generally used for the seal material. If properly installed, the seal will form a bond between the casing and well bore. Minimum thickness for surface seals vary between States so the respective State water regulating agency should be consulted for individual requirements. The method of emplacing the grout seal is usually determined by the driller. Each driller has a preferred method depending on the kind of drilling rig being used and the geology of the drilling location.

A surface seal should always be used, even when not required by a State water regulatory agency.

5. Well Development.

Well development is the process where fine soil materials are removed in and around the screen allowing water to flow more freely. This process is accomplished by surging water or air through the well screen and into the surrounding material. The well development process:

- Removes materials that have built up in the openings of the screen during the well drilling and casing installation processes.

- Removes fine material from the sides of the borehole that resulted from the drilling procedure, e.g., drilling mud.

- Increases the hydraulic conductivity of adjacent geologic materials and the filter pack by removing fine materials.

- Stabilizes the fine materials that remain in the vicinity of the well and retards their movement into the well.

The benefits of well development are increased yields, reduced pumping of fines which can damage pumps, and decreased corrosion and encrustation which lower intake velocity at the well screen. The result of the development process is a layer of coarse particles adjacent to the screen. The percentage of finer particles increases with distance away from the well. Well development is necessary in any well because clogging can occur regardless of the drilling method used or the formation being penetrated.

Wells can be developed by natural ground water flow or by artificial means. Before developing a well, the well should be bailed or circulated with water or air to remove sand that has accumulated during construction. Bailing or circulating also ensures that water will flow into the well. Development procedures can last from about two hours to several days depending on well depth and formation properties.

Natural development of wells is accomplished by alternately pumping and allowing the well to recover. This method does not cause much of a surging action and is relatively ineffective in alleviating particle bridging and in removing fines. There are several additional methods that can be used in well development. They are:

- Over pumping. This method develops aquifers by pumping at high rates and assumes that the system will be stable at normal pumping rates. A larger capacity pump should be used than the pump that will be used for water delivery. When the pump is stopped, backwash helps overcome bridging of particles. While this method is the simplest and quickest, it is also the least effective.

- Surge blocking. In this method, a surge block or surge plunger is pushed in and pulled out of the well in a plunger-like fashion. The plunger can be solid or valved. Valved plungers allow action on the downstroke and strong action on the upstroke, but care must be taken on the upstroke because screens can collapse. This method is the most common and is a highly effective method of development.

- Jetting. In jetting, a device with two or more nozzles is pushed into the well screen and water or air is jetted through the screen openings. The water reverses direction returning through the screen and carries fines into the well for removal. Pumping the well while jetting with water helps flow reversal and fine particle removal, and provides water for jetting. This is one of the most effective development methods.

- Compressed air surging. This method is a combination of air jetting and pumping with water. Air is gently pumped into the well and water is pumped out of the well to start the circulation. The airline is then closed off and pushed down into the screen area while air pressures build to 100 to 150 pounds per square inch. An air blast is then released, surging through the system. This cycle is repeated several times.

Several other methods exist that are less common for general applications of well development, and should be considered if the above methods do not seem effective in a particular well.

The methods previously discussed can be aided with the use of dispersing agents and acids. Dispersing agents (such as polyphosphates) act as deflocculants and disperse clay. Mild acids can be used to dissolve limestone and open crevices.

If organic polymers are used as a drilling fluid, chlorine should be added to the system when drilling is complete to break down the drilling solution and allow more complete development as well as removal of the drilling fluid.

H. Other Considerations.

1. Sanitation of Wells.

Long-term sanitary protection of wells begins with well design. The selection of well casing materials for various water and soil characteristics is important, as discussed in the sections on upper and intake casings and well screen selection. Proper placement of a grout seal prevents entrance of contaminants from surface water.

Most bacteria and viruses in the well environment are nonpathogenic. Disinfecting a well will destroy organisms that can be introduced into a well system during installation of the pump or the pipeline system or during maintenance of the pumping system. Therefore, disinfection of drilling equipment before construction and disinfection of the well following construction or any repair is necessary. Use of a chlorine solution is the most effective way to disinfect or sterilize wells, pumps, pipeline systems, or storage tanks. Chlorine is an oxidizing disinfectant that kills bacteria on contact. The chlorine concentration must be sufficient to ensure that a free chlorine residual remains in the well and pipeline system several hours after treatment begins.

Before chlorination, the well, pump, pipeline and storage tank should be cleaned of grease, soil sediment etc., which may protect bacteria from the effects of chlorine. The concentration of the chlorine solution should be high enough that when mixed with the water in the pipeline storage system, wellbore, and area directly outside of the intake casing, the solution will remain between 50 and 200 miligrams per liter.

This concentration should remain in the system for at least 4 hours to assure complete disinfection. If it falls below 50 parts per liter, the treatment should be repeated until it maintains the concentration. As the last step of the disinfection process, it is very important that all traces of chlorine be purged from the well system before placing it into service. Certain by-products of the chlorination process may be hazardous to human health or harmful to stock.

After the disinfection process, water quality should be checked by analyzing the water for consistency with State drinking water standards. This will also give valuable baseline ground water quality data for that well location. These tests must be performed by a water quality lab recommended by the State Office hydrologist. Samples must be collected according to prescribed procedures so that any bacteria are preserved, and the sample is truly representative of conditions in the well. The test is not expensive; some county health departments will provide this analysis without charge. The results will determine if the water is suitable for consumption.

The primary purpose of a water analysis is to determine the suitability of water for a proposed use. Sampling water for quality, whether in test, monitor or production wells, should occur only after Ph, electrical conductivity, and temperature of the water being pumped from the well have stabilized. The sample can then be tested for these quality standards applicable to a proposed use, whether domestic, agricultural, or industrial. For information on water quality, see Manual 7240, Water Quality.

2. Test Wells.

In many situations, it may be helpful to drill a test well before drilling a production well. In areas where little is known of the subsurface geologic conditions, a well-site investigation may indicate that there is high risk associated with completing a successful well. A test well can be drilled at less cost than a production well and will provide valuable information necessary to decide if a production well can be completed in that location and if the water yield and quality will be acceptable, given the intended use of that well.

A test well also yields information useful in designing a well. Samples of the formations penetrated (including aquifer materials) during test hole drilling can be evaluated before drilling a production well, and the most efficient design for that site can be projected. Materials for this optimum design can be selected, purchased, and available for installation when the production well is constructed.

3. Well Logs.

As a well is being drilled, samples of the materials penetrated should be collected at regular intervals (every 5 or 10 feet and at each apparent change in formation). The samples should be placed in sample bags, marked to indicate well name, depth of sample, and date, and preserved as long as the engineer or hydrologist feels it is necessary. The driller is required by BLM and most States to submit a driller's log showing his analysis of formations penetrated, thickness of formations, aquifer locations, and miscellaneous information relative to the drilling of the well. Once a hole is drilled, geophysical data can be collected and plotted on graphs to show thickness of zones, classification of formation types, water quality, and relative porosity of zones. This can be valuable information in designing a well, and should be used in conjunction with the driller's log and well samples collected during drilling to place well screens and gravel packs. Several types of logging procedures exist; however, a limited discussion of geophysical logging follows.

Resistivity logs, usually called electric logs, give a detailed picture of the character and thickness of the various strata at the well site and an indication of the water quality by measuring the apparent resistivity of materials surrounding the well bore. These relative values are plotted against depth, so the optimum location(s) for setting a well screen can be projected by using the logging results. Cuttings collected during drilling should be used to determine opening sizes for the well screen based on a sieve analysis. Electric logging offers several advantages in well design, such as locating the top and bottom of each formation, differentiating clean sand strata from silty sand and from sand strata with clay lens and determining relative water quality. Resistivity logging can only be done in uncased boreholes that are filled with fluid.

Spontaneous potential (SP) logs are usually run in conjunction with resistivity logs. Spontaneous potential are naturally occurring electrical potentials (voltages) that result from chemical and physical changes at the contacts between different types of subsurface geologic materials, and between the drilling fluid and the formation in a borehole. A probe is lowered into an uncased borehole filled with drilling fluid, and another probe is grounded at the surface near the well, usually in the mud pit. The probes are connected to terminals on a millivolt meter that measures variations in spontaneous potentials as the probe in the borehole is lowered past different formations. These measurements are plotted against depth to provide the SP log.

The results of the SP and resistivity logs are usually plotted on the same graph since they both reflect values plotted against depth. When comparing the two curves, accurate estimates can be made on location and thickness of various geologic formations, water quality, and production potential of an aquifer.

Gamma, Gamma-Gamma, and Neutron logs can be run in wells that are cased or uncased. They use either naturally occurring or introduced radiation sources to measure various relative values in the formation penetrated by a borehole, such as bulk density, permeability, and moisture content. These types of logs may be important if there are no records available for a well or wells in an area where information about subsurface geology is needed, or if an existing well is going to be maintained or replaced.

Geophysical logging can be a valuable tool for designing wells, estimating water quality, and collecting important subsurface geologic information. Use of logging should be encouraged in water well drilling, especially when quantity and quality required at a site are critical.

4. Well Maintenance.

Well maintenance is an attempt to restore a well to its most efficient condition by various treatments, including reconstruction. Well maintenance should be prescribed after deciding that the decrease in water delivery is not a mechanical problem with the pumping or delivery systems. Effective well maintenance begins with a collection of all available records for a well showing geologic conditions, water quality, pumping performance, and specific capacity (yield per unit of draw down). Wells should be pump tested when completed, so records of initial production are available for comparisons when maintenance is needed. After reviewing the records available for a well and comparing this information with its present performance, most problems can be diagnosed and the method of maintenance prescribed. If initial construction and design were poor, the solution may be to drill a new well.

Major problems in wells can vary with the types of aquifer and drilling method used during initial construction. Table 4 lists prevalent well problems that occur in various types of aquifers.

Diagnosis of well problems can be done more effectively if proper records of pumping performance are kept. People using wells should be encouraged to monitor, record, and date information such as static water level, pumping level, pumping rate, total hours used per day or week, maintenance of pumping system, and sand content in water samples. This information can be used to help solve production problems when they develop.

5. Recordkeeping

Records of all water developments should be maintained permanently, even when a dry hole is drilled. Information that should be retained is: (1) Well Site or Spring Examination Request (Form 7230-4), (2) Well Log (Form 7230-2), (3) Water Well Drilling Record (Form 7230-1), (4) Well Site Investigation Field Form (Form 7230-3), and (5) Project Inspector's Logbook. A well-site field card is available to record information obtained from rancher's on their wells or on wells visited during a field inventory. See Illustration VII-8-12 for examples of these forms.

Upon completion of drilling, copies of the well records (drillers log and well completion report) should be sent to the Service Center Ground Water Hydrologist.

Table 2 - Relative Performance of Different Drilling Methods in Various Types of Geologic Formations

Type of Formation	Cable Tool	Direct Rotary (with fluids)	Direct Rotary (with air)	Direct Rotary (Down-the-hole air hammer)	Direct Rotary (Drill-through casing hammer)	Reverse Rotary (with fluids)	Reverse Rotary (Dual Wall)	Hydraulic Percussion	Jetting	Driven	Auger
Dune sand	2	5	Not recommended	Not recommended	6	5*	6	5	5	3	1
Loose sand and gravel	2	5	Not recommended	Not recommended	6	5*	6	5	5	3	1
Quicksand	2	5	Not recommended	Not recommended	6	5*	6	5	5	Not recommended	1
Loose boulders in alluvial fans or glacial drift	3-2	2-1	Not recommended	Not recommended	5	2-1	4	1	1	Not recommended	1
Clay and silt	3	5	Not recommended	Not recommended	5	5	5	3	3	Not recommended	3
Firm shale	5	5	Not recommended	Not recommended	5	5	5	3	Not recommended	Not recommended	2
Sticky shale	3	5	Not recommended	Not recommended	5	3	5	3	Not recommended	Not recommended	2
Brittle shale	5	5	Not recommended	Not recommended	5	5	5	3	Not recommended	Not recommended	Not applicable
Sandstone—poorly cemented	3	4	Not recommended	Not recommended	Not applicable	4	5	4	Not recommended	Not recommended	Not applicable
Sandstone—well cemented	3	3	5	Not recommended	Not applicable	3	5	3	Not recommended	Not recommended	Not applicable
Chert nodules	5	3	3	Not recommended	Not applicable	3	3	5	Not recommended	Not recommended	Not applicable
Limestone	5	5	5	6	Not applicable	5	5	5	Not recommended	Not recommended	Not applicable
Limestone with chert nodules	5	3	5	6	Not applicable	3	3	5	Not recommended	Not recommended	Not applicable
Limestone with small cracks or fractures	5	3	5	6	Not applicable	2	5	5	Not recommended	Not recommended	Not applicable
Limestone, cavernous	5	3-1	2	5	Not applicable	1	5	1	Not recommended	Not recommended	Not applicable
Dolomite	5	5	5	6	Not applicable	5	5	5	Not recommended	Not recommended	Not applicable
Basalts, thin layers in sedimentary rocks	5	3	5	6	Not applicable	3	5	5	Not recommended	Not recommended	Not applicable
Basalts—thick layers	3	3	4	5	Not applicable	3	4	3	Not recommended	Not recommended	Not applicable
Basalts—highly fractured (lost circulation zones)	3	1	3	3	Not applicable	1	4	1	Not recommended	Not recommended	Not applicable
Metamorphic rocks	3	3	4	5	Not applicable	3	4	3	Not recommended	Not recommended	Not applicable
Granite	3	3	5	5	Not applicable	3	4	3	Not recommended	Not recommended	Not applicable

*Assuming sufficient hydrostatic pressure is available to contain active sand (under high confining pressures)

Rate of Penetration:
1 Impossible
2 Difficult
3 Slow
4 Medium
5 Rapid
6 Very rapid

Table 3 - Recommended Well Diameter for Various Pumping Rates

Anticipated Well Yield		Nominal Size of Pump Bowls		Optimum Size of Well Casing†		Smallest Size of Well Casing†	
gpm	m^3/day	in	mm	in	mm	in	mm
Less than 100	Less than 545	4	102	6 ID	152 ID	5 ID	127 ID
75 to 175	409 to 954	5	127	8 ID	203 ID	6 ID	152 ID
150 to 350	818 to 1,910	6	152	10 ID	254 ID	8 ID	203 ID
300 to 700	1,640 to 3,820	8	203	12 ID	305 ID	10 ID	254 ID

Table 4 - Most Prevalent Well Problems Occuring in Various Types of Aquifers and the Typical Maintenance Frequency Required

Aquifer Type	Most Prevalent Well Problems*	Major Maintenance Frequency Requirement (Municipal)
Alluvial	Silt, clay, sand intrusion; iron precipitation; incrustation of screens; biologic fouling; limited recharge; casing failure	2-5 years
Sandstone	Fissure plugging; casing failure; sand production; corrosion	6-10 years
Limestone	Fissure plugging by clay, silt, and carbonate scale	6-12 years
Basaltic lavas	Fissure and vesicle plugging by clay and silt; some scale deposition	6-12 years
Interbedded sandstone and shale	Low initial yields; plugging of aquifer by clay and silt; fissure plugging; limited recharge; casing failure	4-7 years
Metamorphic	Low initial yield; fissure plugging by silt and clay; mineralization of fissures	12-15 years
Consolidated sedimentary	Fissure plugging by iron and other minerals; low to medium initial yield	6-8 years
Semiconsolidated and consolidated sedimentary	Clay, silt, sand intrusion; incrustation of screens in sand and gravel wells; fissure plugging of limestone aquifers in the interbedded sand, gravel, marl, clay, silt formations; biologic fouling; iron precipitation	5-8 years

*Excluding pumps and declining water tables.

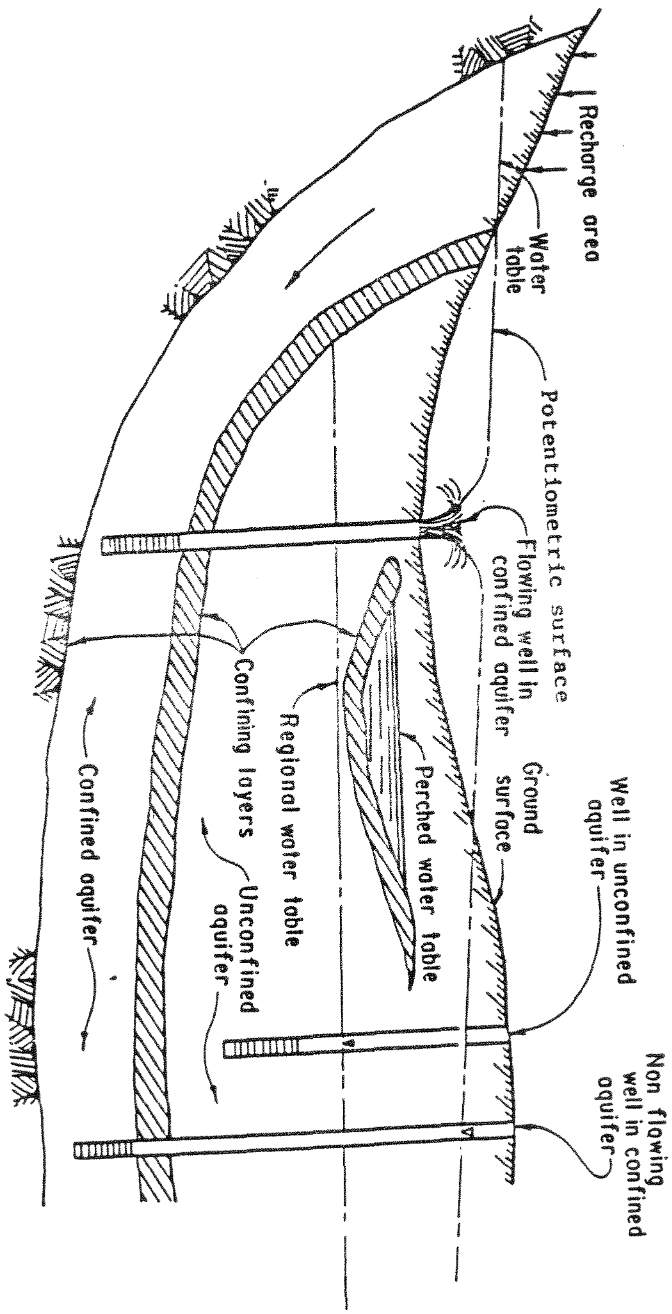
Estimates of major maintenance frequencies are based on the following assumptions:
1. Wells are being pumped continuously at the highest sustained rate they are capable of producing.
2. Major maintenance is required when the sustained yield decreases to 75 percent of the initial yield.
3. Major maintenance is considered to represent a cost expenditure of approximately 10 percent of the total current replacement cost. Minor maintenance is excluded.
4. Wells are designed in accordance with current practices, not necessarily in accordance with best available technology.

(After Gass et al.)

H-1741-2 - WATER DEVELOPMENTS

Chapter VII

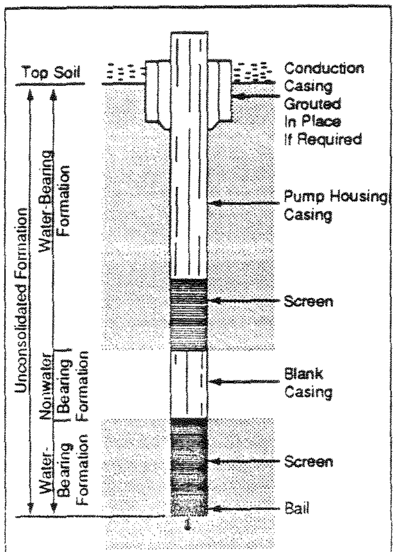
Hydrogeologic System and Aquifer Types



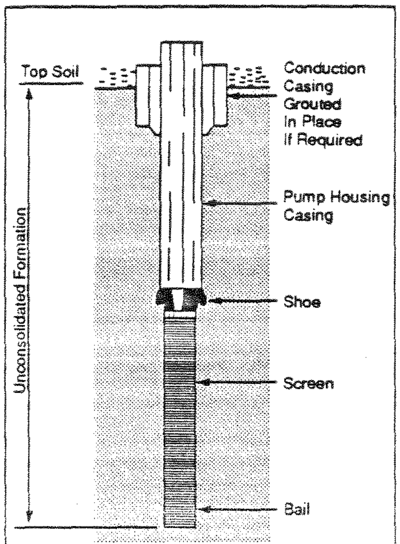
H-1741-2 - WATER DEVELOPMENTS

Chapter VII

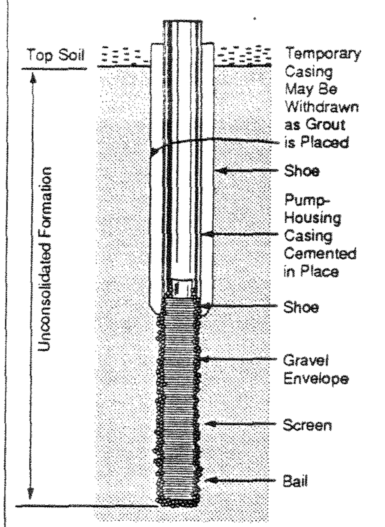
Well Design Examples



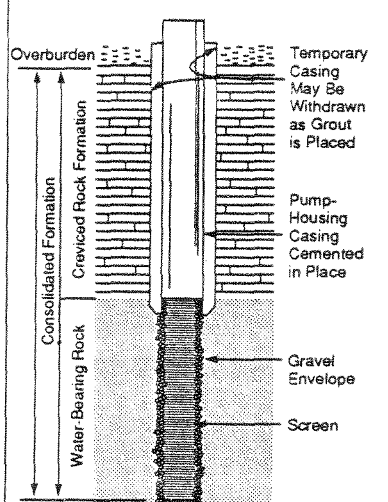
Casing and screen placed in open hole without forcing. Blank casing in nonwater-bearing formation optional.



Driven casing in unconsolidated formation constructed by advancing the casing by driving or jacking.



Gravel envelope terminated above screen using telescoped screen and cemented pump casing.

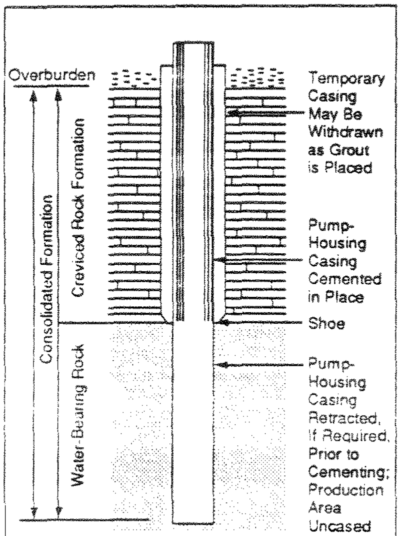


Well with grouted pump-housing casing; screen and gravel packed; used when formation yields water with turbidity unless filtered through gravel pack; conductor casing installed through overburden.

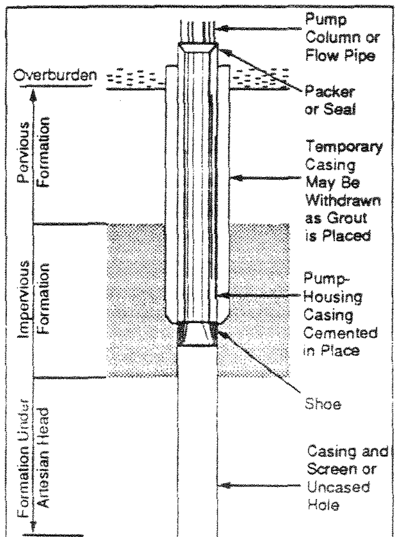
H-1741-2 - WATER DEVELOPMENTS

Chapter VII

Well Design Examples



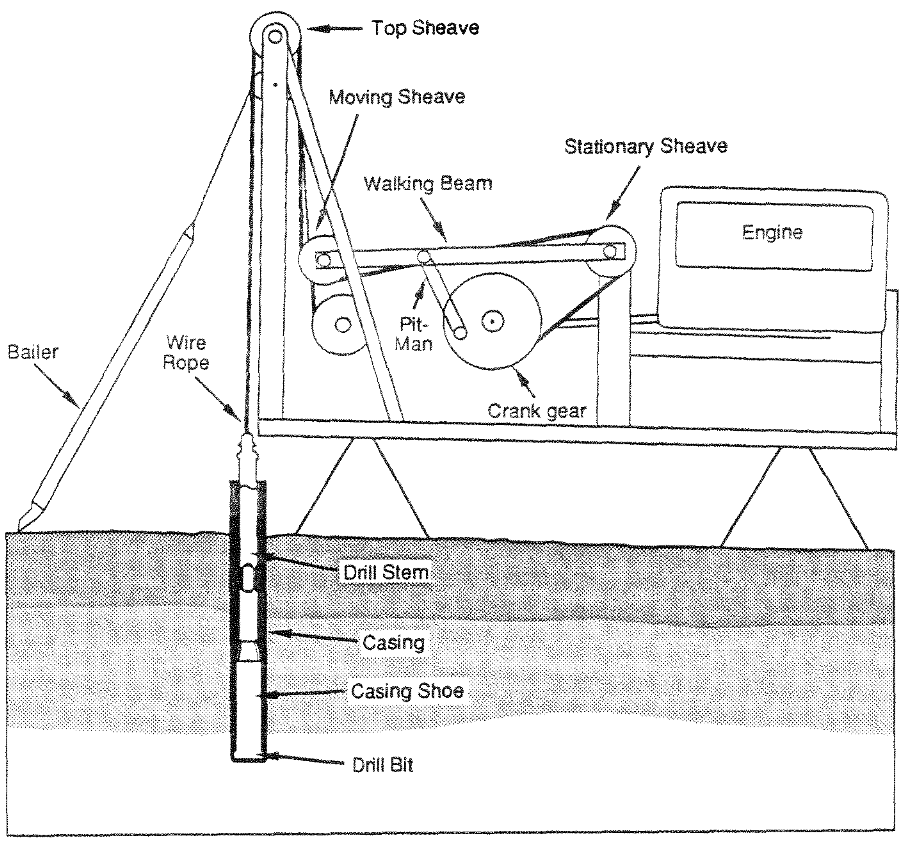
Well with grouted pump housing and production formation unscreened; used in consolidated formations where production is derived from crevices, fractures, and solution openings.



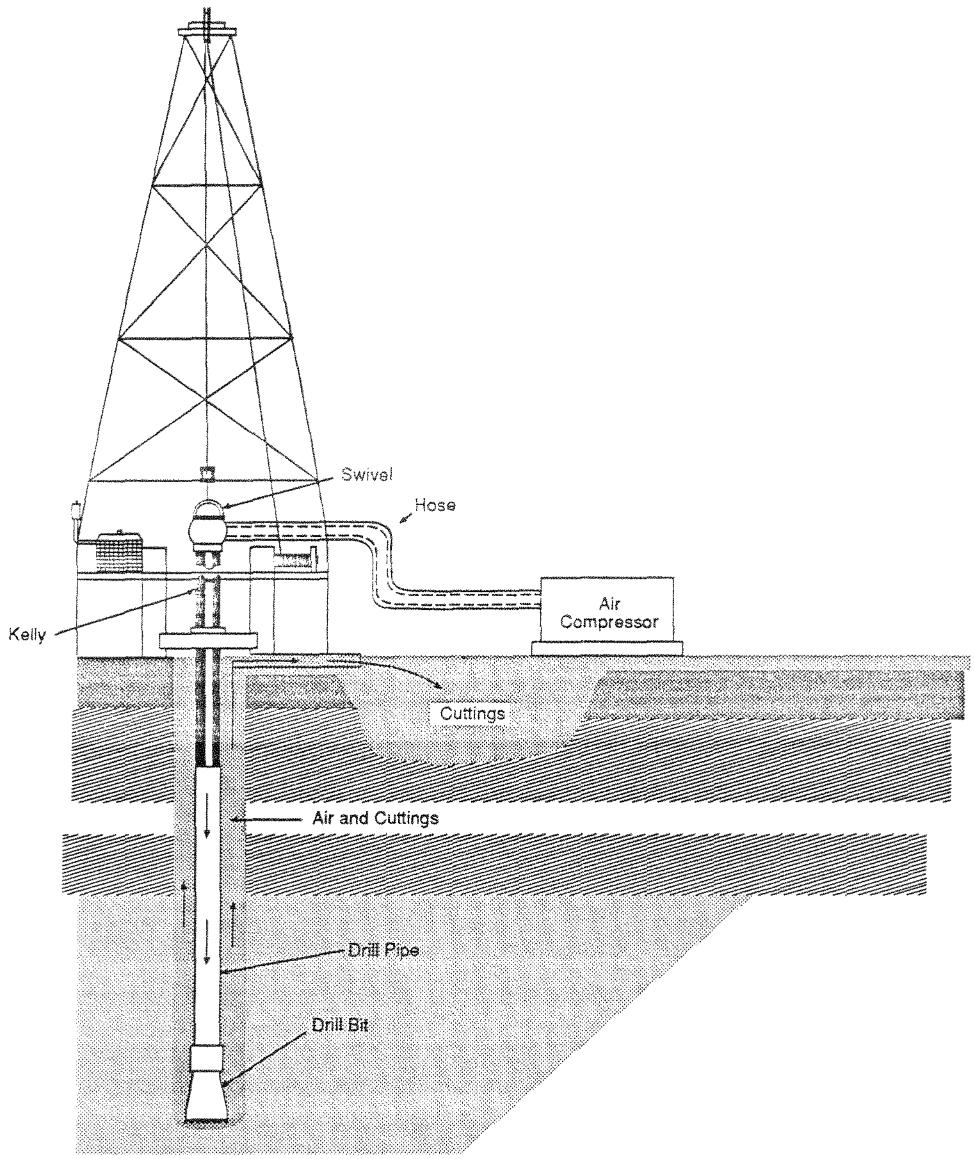
Pump-housing casing grouted in place into impervious formation when artesian conditions exist providing control of artesian flow and prevention of loss into overlying pervious formations.

Chapter VII

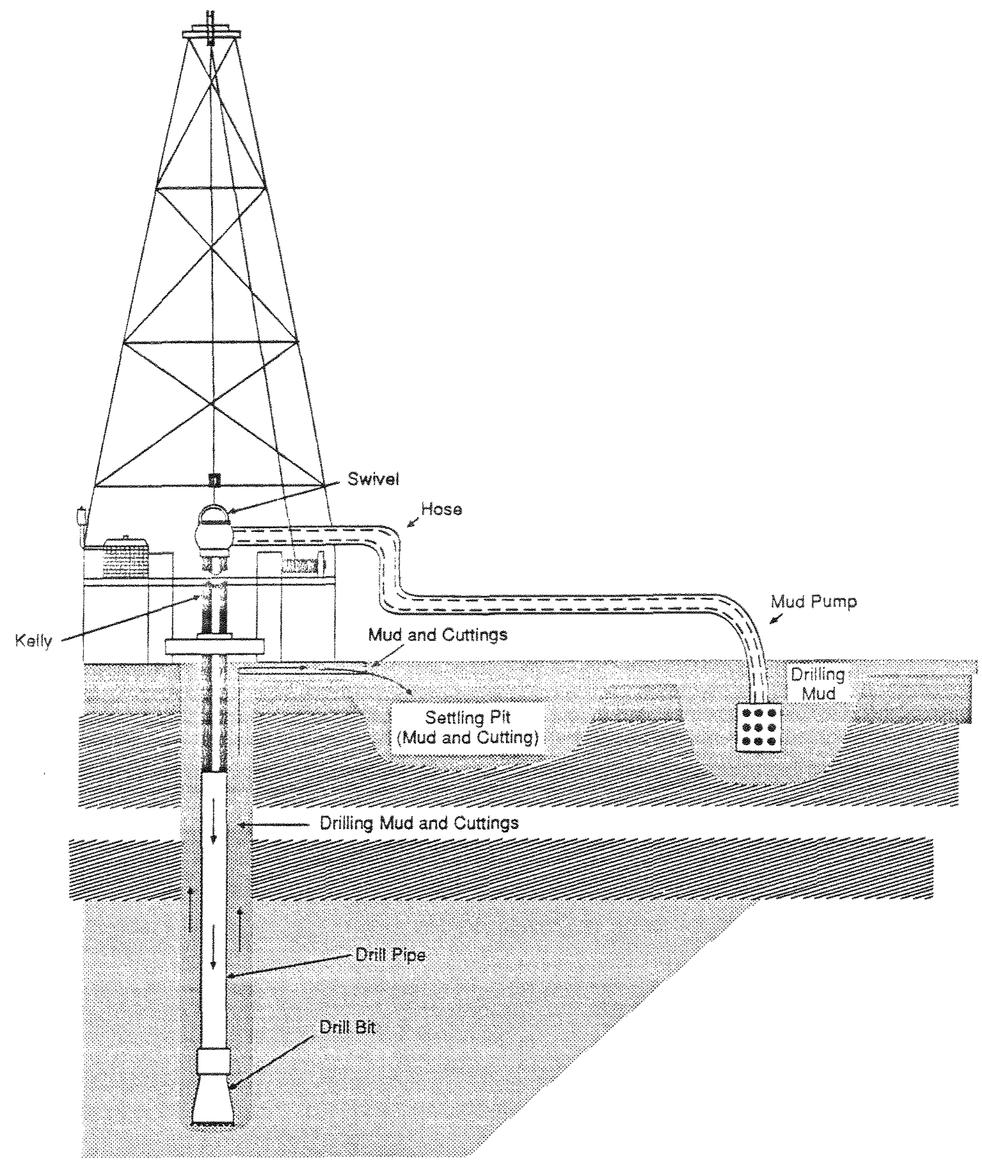
Dtail of Cable Tool Rig



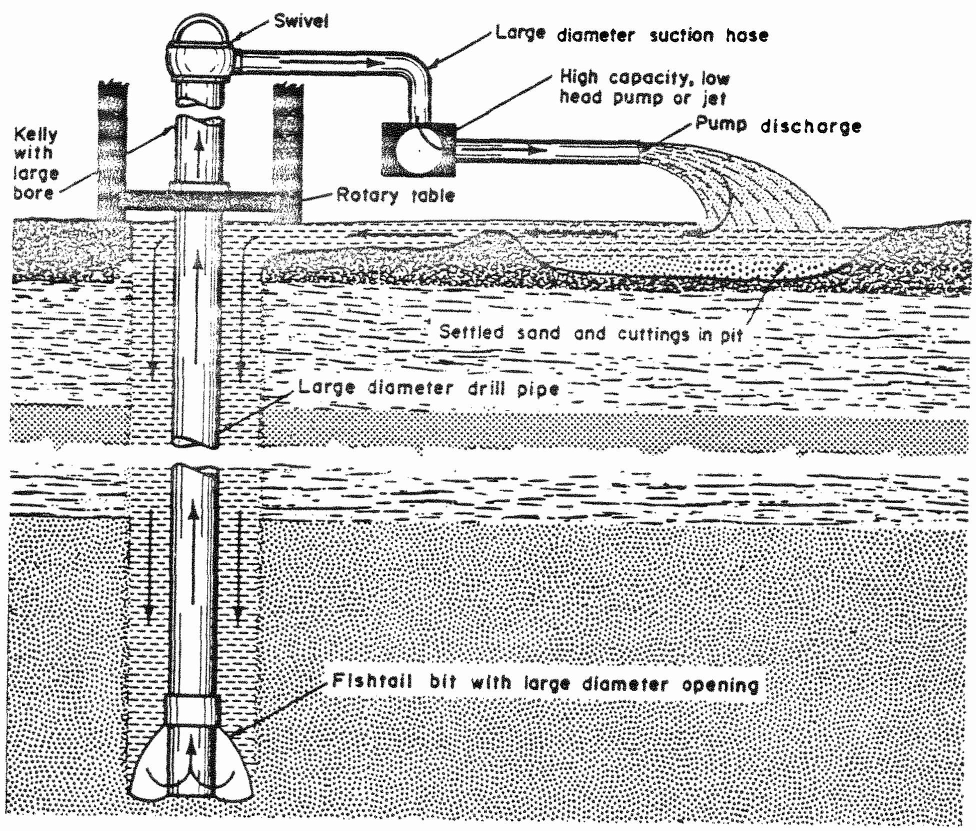
Air Rotary Drilling Method



Mud Rotary Drilling Method



Reverse Rotary Drilling Method



Types of Intake Casing

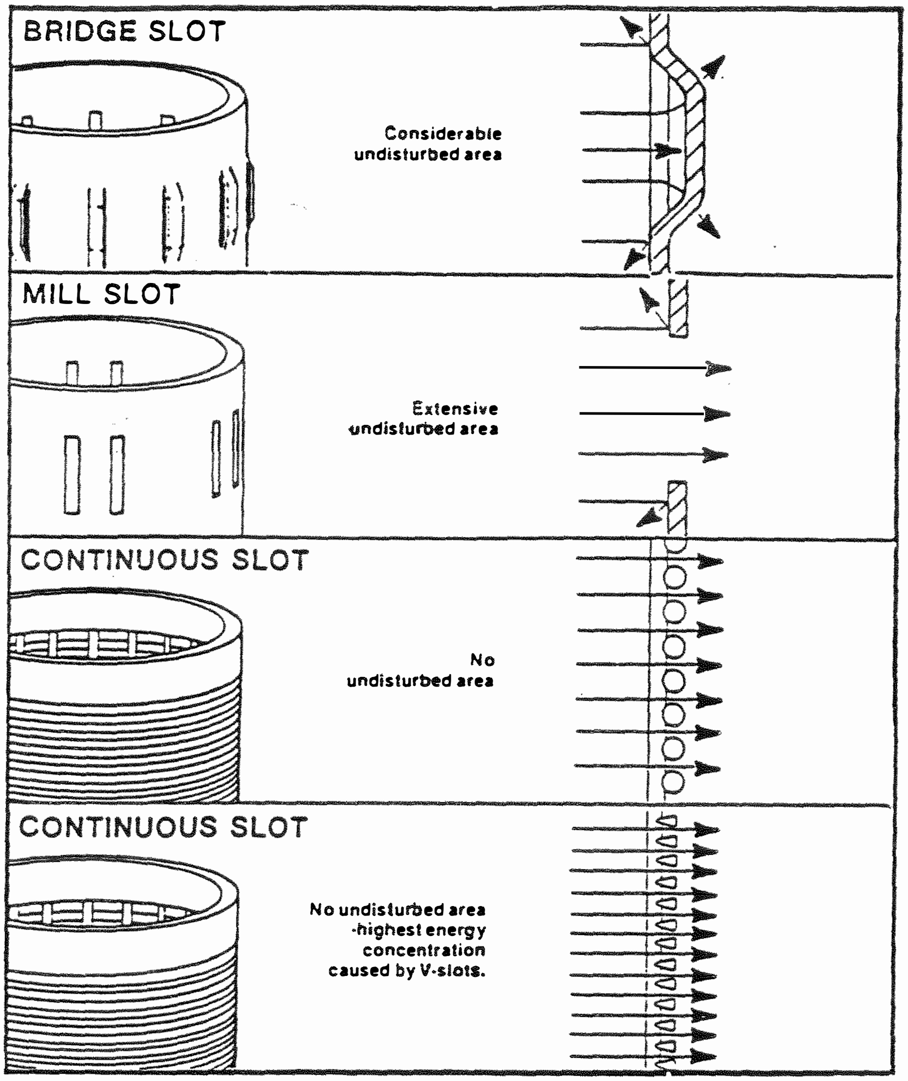


Illustration 8

Form 7230-2, To Be Used by Driller When Drilling a Well on Public Land

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

WELL LOG

Improvement Number	Improvement Name	T. N S	R. E W
Well Name		Sec. ¼ ¼ ¼	
		State	County
Date Drilled		District	Resource Area

DEPTH (Feet)		CUTTINGS SAMPLE NUMBER	DESCRIPTION OF MATERIALS DRILLED			WATER YIELD (gpm)	REMARKS (Quality of water, ease of drilling, caving, loss of drilling fluid, etc.)
FROM	TO		TYPE OF ROCK	COLOR	OTHER CHARACTERISTICS (Grain size, hardness, etc.)		

(Instructions on reverse)

Form 7230-2 (July 1988) (formerly 7420-2)

Form 7230-2a, Well Log Continuation Sheet

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

WELL LOG CONTINUATION SHEET

Improvement Number	Improvement Name
Well Name	
Date Drilled	

DEPTH *(Feet)*		CUTTINGS SAMPLE NUMBER	DESCRIPTION OF MATERIALS DRILLED			WATER YIELD *(gpm)*	REMARKS *(Quality of water, ease of drilling, caving, loss of drilling fluid, etc.)*
FROM	TO		TYPE OF ROCK	COLOR	OTHER CHARACTERISTICS *(Grain size, hardness, etc.)*		

(Continue on reverse)

Form 7230-2a (July 1988)

Chapter VII
Form 7230-3, Used to Compile Well-Site Field Investigation Information

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

WELL-SITE EVALUATION FIELD FORM

Site Name ______________ Planned use ______________

State ______________ County ______________ District ______________

Resource Area ______________

Examined by ______________ Date ______________

Location: T. ______ N/S , R. ______ E/W., Sec. ____, ____¼ ____¼ ____¼

Description and topography: ______________

____

____

____

Altitude ______ altm./topo. Map ______________

Geology (Structure, stratigraphy, lithology, and water-bearing properties)

____

____

____

____

____

____

____

____

____

Inferred aquifer (s): ______________

____

Hydrogeology (Wells, springs, streams, plant indicators, estimated hydraulic gradient, etc.) ______________

____

____

____

____

____

____

____

____

____

____

State ______ T. ______ N/S, R. ______ E/W, sec. ______ AMS Map (1°×2°) ______

Form 7230-3
(June 1982)

Chapter VII

Form 7230-3, Used to Compile Well-Site Field Investigation Information

	Estimated		Actual	
Drilling depth				
Depth to water level				
Yield	gpm pump	gpm flow	gpm pump	gpm flow
Quality				
Specific capacity				
Pumping lift at gpm				

Drilling and Casing Recommendations: This site (is) (is not) in an area where the depth, thickness, and other characteristics of the aquifer are accurately known and a flowing well (is) (is not) anticipated.

Evaluation:

Form 7230-1, Water Well Drilling Record

Form 7230-1
(July 1988)
(formerly 7420-1)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

WATER WELL DRILLING RECORD

T. N S	R. E W
Sec. ¼ ¼ ¼	
State	County
District	Resource Area
Date	

1. Improvement Number
2. Improvement Name
3. Name of Site

4. Map Coverage — Name — Scale

5. Driller (*name*) — Address (*include zip code*)

6. Type of drilling rig used (*Cable Tool, Air Rotary, Downhole Hammer, etc.*)
7. Date well started — Date Completed

8. Altitude of land surface (*ft*) — Determined by ☐ Altimeter ☐ Topographic Map

9. Total depth (*ft below*) ☐ Land Surface ☐ Top of casing
10. Static water level (*ft below*) ☐ Land surface ☐ Top of casing

11. Aquifer(s) and depths (*Rock Type and Name of Formation*)

12. Shut-in pressure (*flowing, well, psi*) — Determined by

13. Yield (*gpm*) — after (hrs) — ☐ Pumping ☐ Bailing ☐ Flowing

14. Drawdown
- feet — after (*hrs*) — discharging at (*gpm*)
- feet — after (*hrs*) — discharging at (*gpm*)

15. Quality of water — Electrical Conductivity µmhos/cm — Taste — Odor — Temperature (°F)

16. Casing
- Distance top ☐ above ☐ below land surface (*ft*)
- Type — Diam. (*in*) I.D./O.D. — Weight (lb./ft.) — Depth (*ft*) to (*ft*)
- Type — Diam. (*in*) I.D./O.D. — Weight (lb./ft.) — Depth (*ft*) to (*ft*)

17. Perforations/Well Screen
- Type — Slot Size — Cut Size
- Formation and Spacing — Depth (*ft*) to (*ft*)
- Formation and Spacing — Depth (*ft*) to (*ft*)

18. Pump
- Type — Rated Capacity (*gpm*) — Horsepower
- Manufacturer and Model
- Phase ☐ Single ☐ 3-Phase — Date Installed
- Depth of Pump

19. Windmill
- Manufacturer and Model — Date Installed
- Mill Diam. — Cylinder Size: (Dia)______ (Length)______ — Sucker Rod Stroke
- Sucker Rod Length — Depth of Cylinder

20. Information obtained from (*name*) — Date

(*Remarks and Instructions on reverse*)

Chapter VIII

Chapter VIII - Water Delivery Systems

A. Introduction.

1. Pipelines.

Pipeline systems are commonly used throughout the BLM to transport water to points of use. Pipelines can be made of several materials and can vary in capacity, depending on the requirements and the design. Pipelines connect sources of water, storage facilities, and points of use, such as water troughs. They are operated and controlled by valves.

2. Application.

Pipelines are long term solutions to water supply problems. Properly designed pipelines can be the most economical way to move water over moderate to long distances for more than 1 to 2 years. Pipelines can be designed for automatic or manual operation and require minimal maintenance if designed and installed correctly. Depending on what materials are used in construction, pipelines can last many decades. When buried, the pipeline is relatively vandalproof. If future expansion is considered when the pipeline is designed, it is easy to add capacity or extend the pipeline for additional facilities.

B. Design Considerations.

1. General.

The planner and designer should consider several factors for the construction of a pipeline. First, planners should consider how pipelines function.

2. Types and Function.

There are two basic types of pipeline systems. One system is driven by the force of gravity, as water flows to a lower elevation. The other system uses pumps to force the water through the pipeline. Pumps add energy to the water, allowing it to flow faster, farther, and to higher elevations.

3. Routing.

The route of the pipeline should be selected to minimize interference with other facilities, terrain obstacles such as cliffs or marshes, rock outcrops, and extremes in elevation that may cause excessive pressures in the pipe. The route should minimize the length of the pipeline while minimizing interferences with the above problems.

4. Calculating Required Flows.

Pipe flows are usually measured in gallons per minute (GPM) when calculating the hydraulics of the system. Total system requirements may be calculated in GPM or gallons per day (GPD). To design the pipeline, the total amount of water required at all use points along the line must be known. The source of water and any storage facilities should be considered since they influence capacity and required flows. If the demand can be accommodated by a small but continuous flow, such as with a storage tank, then a smaller diameter pipe can be used. If the demand must be met intermittently using large flows, such as where a pump operates only intermittently, then a larger diameter pipe is required.

5. Pipeline Hydraulics.

Pipelines function according to laws of hydraulics. Moving water from one point to another requires energy. In a gravity system, water moves from a point of higher potential energy to a point of lower potential energy. The difference in potential energy between the two points is the energy available to overcome friction in the pipe and provide pressure at the outlet. Each 2.31 feet of elevation is equivalent to one psi of pressure. As the water moves through the pipe, its flow is slowed by friction with the pipe walls. Since this frictional force is proportional to the speed of the water, the faster the water flows through the pipe, the more energy that is required to push the water through the pipe. Also, the longer the pipeline, the more frictional force that is generated. Therefore, it takes more energy to move a given volume of water through a smaller, longer pipe than through a larger, shorter pipe. A very long, relatively small pipeline system may deliver only a trickle of water at the delivery point if sufficient energy is not available to move the water through the system.

In a pumped system, the pump adds the energy. The added energy increases the pressure at the pump. This additional pressure is in the form of kinetic energy. As the water flows through the pipe, the energy is used to overcome pipe friction energy losses for longer pipe runs, and to allow the water to flow to higher elevations, converting kinetic energy into potential energy.

In any water system, excessive water velocities or pressures must be avoided. These can lead to bursted pipes and inoperative systems. The safety factor designed into pipelines may accommodate occasional overpressures, but the system must be designed to avoid these situations in all anticipated operating modes.

6. Seasonal or Intermittent Usage.

The pipeline will burst if exposed to subfreezing temperatures which will cause the water to freeze and expand in the pipe. Likewise, if the water is allowed to become too hot in a pipeline, it may burst the pipe. Therefore, the planner and designer must anticipate these situations in designing the pipeline. The most common way to protect the pipe from temperature extremes it to bury it in the ground. In climates that experience prolonged subfreezing weather, the pipe must be buried deeply enough to avoid the cold. An alternative to deep burial is:

- Draining the pipeline if it has been designed and installed to drain to the drainpoints without leaving sections of the line full of water and if the operating personnel drain the line before it freezes.

C. Pumping Systems.

1. Introduction.

Pumps are used to either move water from a source into a pipeline system or to add energy to the pipeline system so the water can move over higher elevations or move longer distances. In either case, a pump transforms mechanical energy to an increase in pressure in the system. This pressure allows the water to flow further and in greater volumes. The mechanical energy comes from direct conversion such as from a windmill or from electrical power where a motor converts the power to mechanical motion.

Life-Cycle Costs: The maintenance and operating cost requirements of the pumping system should be determined and analyzed in conjunction with the overall cost of the project. The life-cycle cost of any system should be the figure used in evaluating competing designs of pumping systems. After the planned life of the project is determined, annual operating and maintenance costs can be calculated as well as periodic component replacement. These costs can be factored back to present values and used for comparison between systems.

Designs should be selected that minimize maintenance and have standard, locally available components, such as motors or bearings.

2. Types of Pumps.

a. Centrifugal Pump. A pump which has an impellor or series of impellors that spin and force water into a smaller space, thereby increasing its pressure.

TABLE VIII-1

The following table gives general applications of well pumps.

Type of Well	Type of Pump	Normal Capacity Range (Gallons Per Hour)	Practical Suction Lift* (Feet)	Max. Practical Pumping Depth (Feet)	Usual Discharge Pressure Range (PSI)	Remarks
Shallow Well	Shallow Well Jet (Jet on Pump)	200-1500	20-25	25	20-40 30-50	1. Simple in construction 2. Easy to service 3. Can be used with 1" & larger wells 4. Less efficient hydraulics
Shallow Well	Piston or Reciprocating	200-800	20-25	25	20-40 30-50 40-60	1. Adaptable to low capacity & high head 2. Handles air without losing prime 3. No longer widely used 4. Can be used with 1" & larger wells
Shallow Well	Straight Centrifugal (Single & Multi Stage)	500-2000	15-20	20	20-40 30-50	1. Suitable for high capacities 2. Efficient hydraulics 3. Can be used with 1" & larger wells 4. Simple & easy to service
Deep Well	Deep Well Jet (Single & Multi Stage) (Jet in Well)	200-600	15-20 Feet Below Jet	200	20-40 30-50 40-60	1. Simple in construction & operation 2. No moving parts in well 3. Less efficient hydraulics 4. Can be installed in 2" & 3" wells 5. Can be located away from well
Deep Well	Submersible	200-3000	Pump & Motor Submerged	600	30-50 40-60 50-70	1. Suitable for deep settings 2. Adaptable to frost proof installations 3. Efficient hydraulics 4. Available in wide range of heads & capacities 5. Only available for 3" or larger wells
Deep Well	Piston or Reciprocating	200-800	20-25	150	20-40 30-50 40-60	1. Suitable for deep settings 2. Adaptable to frost proof installations 3. Efficient hydraulics

*Practical suction at sea level. Reduce 1 foot for each 1000 feet above sea level.

b. Submersible Pump. An electrically driven centrifugal pump that is submerged, along with a sealed motor, in the water. The motor and the pump are one unit. Power is supplied along wires to the motor. This is a very adaptable pump.

c. Turbine Pump. An electrically or internal combustion engine driven centrifugal pump where the pump is in the water and is driven by a shaft from the power source. This is usually used for high-volume pumping.

d. Jet Pump. This centrifugal pump is on the ground surface and uses a jet of high pressure water to lift water back to the pump which also pumps the water into the system.

e. Positive Displacement Pump. In this pump, a moving piston or gear system forces the water into a smaller space, increasing its pressure. This pump is used in windmills or in situations where high pressure to volume ratios are required.

f. Air Lift Pump. These pumps function by pushing compressed air down a well through a pipe set inside the casing. The air bubbles push water to the top of the well. This method can be used for test pumping a well to determine its capacity or for wells where the water would be harmful to a pump, such as a well that is not able to keep sand out of the casing. Air is supplied by an air compressor driven by an internal combustion engine, an electric motor, or a windmill.

3. Power Sources: While all pumps require mechanical energy, the energy can come from several sources.

   a. Wind Power: Windmills convert wind into mechanical or electrical energy, but the mechanical conversion is usually more efficient for pumping water. Windmills can also compress air for the air lift pump. Windmills have a high first cost but a low operating cost. Annual maintenance is required and the windmills are susceptible to storm damage and vandalism. Windmills use positive displacement pumps. The capacity is dependent on the size of the windmill, the pressure required, the available wind, and the design of the windmill. Windmills can pump water to a higher elevation when used with a stuffing box on the polished rod, and when the windmill has enough head capacity to pump to the required elevation.

   b. Water Power: Flowing streams can operate hydraulic rams which use a positive displacement pump. The hydraulic ram can pump against low to moderate heads at low volumes. The usually low volume pumps have a moderate first cost and low annual operating costs.

c. Internal Combustion Engines: Internal combustion engines, fueled by gasoline, diesel, LP gas, or natural gas, can operate pumps directly or indirectly. Turbine pumps and positive displacement pumps can be directly driven from the engine through a drive train. A pump-jack is used to convert rotating motion to vertical motion to operate a reciprocating positive displacement pump. Engines must be derated 20 percent for continuous service to provide reliable power. They must also be derated for altitudes if they are designed for sea level operation and ambient temperature according to the following tables:

TABLE VIII-2

Engine Altitude	Engine Type	
	Nonsupercharged	Supercharged
	DF-Rating Factor	
2,000	0.980	0.980
3,000	0.935	0.950
4,000	0.895	0.915
5,000	0.855	0.882
6,000	0.820	0.850
7,000	0.780	0.820
8,000	0.745	0.790
9,000	0.712	0.765
10,000	0.680	0.740
12,000	0.612	0.685
14,000	0.550	0.630
16,000	0.494	0.580

Supercharger may be mechanical or exhaust driven.

TABLE VIII-3

Ambient or Intake Air Temperature, °F	Correction Factor
90	1.000
95	0.986
100	0.974
105	0.962
110	0.950
115	0.937
120	0.925
125	0.913
130	0.900

Therefore, a nonsupercharged engine rated a 10 BHP at sea level, operating in 105°F air at 9,000 ft, in continuous operation, would be rated at: 10 (0.962) (0.712) (0.80) = 5.48 or about 5.5 hp.

The designer must specify a larger engine if the derated horsepower is insufficient for the application.

The power transmitted from the engine is further reduced by the type of drive train used. Chain drives or straight drive shafts can transmit 90-95 percent of the power while multiple geared drives may only transmit 65 percent of the power. The type of drive must be designed and rated for the power and loads it must transmit.

Internal combustion engines are commonly used to drive alternating current (AC) or direct current (DC) generators. The power output of the generator is proportional to the output of the engine. If the engine must be derated, then the generator must also be derated. Care must be taken not to overload the generator since this will shorten the life of the electrical components of internal combustion engines are commonly used to drive alternating current (AC) or direct current (DC) generators. The power output of the generator is proportional to the output of the engine. If the engine must be derated, then the generator must also be derated. Care must be taken not to overload the generator since this will shorten the life of the electrical components of the generator as well as the driven motor. Furthermore, the designer must consider the size and duration of start-up loads on the generator that usually exceed the operating loads. The engine-generator set must have sufficient short-term capacity to handle start-up loads.

The size and features required of the engine and drive train or engine-generator set determine the initial cost of the power system. Operating costs would consist of maintenance requirements and fuel and lubricants required.

d. Solar Power: Sunlight converted to direct current electrical energy can power pump motors. First costs are extremely high (unless a portable unit which can be moved to several locations is purchased) per delivered capacity, but annual operating costs are very low. A system required to operate on a 24-hour basis or over a period of time, when there is insufficient sunlight to operate the pump, needs batteries or another back-up power source. Battery back-up will substantially increase the initial cost and the annual operating cost. Battery replacement must also be anticipated based on the type of batteries purchased and the level of maintenance they receive. Operation is dependent on available sunlight and the solar panels are subject to vandalism. Direct current may be converted to alternating current with special equipment if required by the situation.

e. Electrical Utility Power: If the power requirement is near an electrical distribution system, this source may represent the lowest first cost, and substantially lower annual operating costs. However, this situation usually is not the case, and power must be brought in with poles, wire, and possibly transformers, at considerable cost. Internal combustion engine powered generators can provide the power but have relatively high operating costs. Generators can be installed at the site or be portable and used at the pump site only when required.

Electrical power runs motors which are very common pump drivers. Motors can operate on DC and either single-phase or three-phase AC. Voltages are supplied to meet motor requirements. Some direct current and all single-phase AC motors require starting controls. Motor specifications should be written for the specific requirements of the installation. In sizing the motor, future requirements, electricity costs, and motor pump efficiencies should be considered to choose the most economical motor. Some motors offer design features which offer interchangeability with other brands of motors and long service lives. These designs should be selected where the cost of replacement is far greater than the cost of the motor.

4. Pump Controls.

Controls are required for automatic operation of pumps and are used to protect manually operated systems. Controls may consist of pressure sensors, electrical switches and relays, water level sensors, timers, automatic, mechanically operated or manual valves, and low water level/recovery systems. The controls should operate from a central point and have indicators to show what the status of the system is. The designer must consider the cost of manual operation, the cost of a system failure or malfunction, and the cost of controls when planning the operation of the system.

5. Other Considerations.

Since many BLM projects have low volume requirements for water, all of these factors should be considered.

Specific requirements for great well depths or high water pressures for high or long pipeline system will mandate the use of larger, submersible pumps, as the other pump systems cannot deliver adequate pressures from deep wells for pipeline systems.

The choice of pumping system should also consider:

a. The quality of water being pumped (chemicals, sand, corrosiveness).

b. The location (vulnerability to vandalism, proximity to power or roads).

c. The environment (subject to extremes of heat or cold and freezing).

d. Intermittent versus continuous or automatic use. (This will determine what kinds of controls will be required.)

D. Water Hauling.

1. Introduction.

Hauling water to livestock and wildlife in tank trucks may be used in emergencies, may provide a temporary source of water, or may be used as a continuous practice on rangeland where no other sources of water are available.

If an adequate road system exists, large tanker trucks may be used to fill storage tanks so pipelines can continue to operate during an emergency. Water may also be hauled to water catchments during periods of low rainfall for wildlife and livestock provided there is access.

Water hauling may provide a temporary source of water for livestock and wildlife in seldom-used pastures or where it is not feasible to develop a water source.

Water may be hauled from existing sources for emergency fire control, well drilling, etc. Arrangements should be made in advance with the owner of the water source.

H-1741-2 - WATER DEVELOPMENTS

Chapter IX

Chapter IX - Storage Facilities.

A. Introduction.

Storage facilities as used herein to refer to those water-holding facilities that provide storage between the source and the point of use. Storage facilities generally consist of tanks, butyl bags, and lined pits. Tanks are constructed from steel, concrete, fiberglass, shot-crete, plastic, and wood.

Storage facilities can be a major expense component of any water distribution system. Design or selection of the type of storage facility should be carefully considered as a critical component of any water development system. The most cost-effective alternative selected will differ from one locality to another because of availability of material, construction skills, remoteness, and access to the construction site.

Commercially manufactured tanks or surplus containers secured from other sources have been successfully used for water storage facilities. Tanks can be categorized as vertical, horizontal, skid mounted, open top, closed top, or bottomless (needing a bottom), and can be galvanized, painted, or unprotected.

Storage tanks lend themselves to a wide range of applications. Low level, terminal storage tanks are favored where the supply from the source is by gravity feed, such as a spring, and high level tanks are favored where the water is being lifted to the point of storage, such as from a windmill or other pump. Tanks are normally constructed on relatively flat terrain, but can be constructed on fairly steep slopes with proper site work. Tanks should not be located on unconsolidated fill or soil that may compact and settle with time. Tanks are normally located at a higher elevation than the point of use to allow for gravity flow. Some specific applications of tanks are as follows:

1. Serves as back-up and storage to handle peak usage or even out intermittent flow from the source.

2. Serves as a back-up in case of failure or interruption of the primary supply source. Unless there are other water facilities conveniently located to serve the area or the supply source is dependable, such as a stream, it is advisable to have an intermediate holding facility as a back-up until the supply source can be repaired or restored.

3. Frequently provides an economical method of promoting better distribution of livestock and other target species to meet management objectives and provide some flexibility in season of use.

4. Used to serve several watering facilities from a central location.

5. Provides the opportunity for some economics in construction and operation of a watering system.

6. Storage tanks are used to provide a pressure break (break to atomsphere) for pipelines placed on steep slopes.

7. A covered storage tank is used where there is a need for a relatively clean supply of water at the point of use. Closed tanks help maintain water quality by preventing the growth of algae, waterbugs, and keeps trash, small animals, birds, and dirt out.

   As a rule of thumb, the recommended storage capacity for emergency supply in case of power or pump (water supply) failure should be a minimum of 3 days. Wildlife and other specific applications needs may be in excess of this requirement. See Illustration X-10 for methods of figuring tank storage capacity.

B. Design and Installation.

1. Types of Tanks.

a. Steel.

The most common material for tanks is steel. The different styles and types of steel tanks available are too numerous to mention here, but some of the most common tanks are constructed from galvanized steel with or without a bottom or top (needing a bottom or top). Other styles and types of steel tanks are oil field storage, railroad tank cars, horizontal skid mount, and surplus military containers. Some smaller tanks are mounted on trailers for portability.

(1) Advantages. Relatively easy material to work with and assemble from components. Low maintenance and under most circumstances, easily repaired. Generally, minimum site work is required.

(2) Disadvantages. Depending upon the type and style of tank, the initial cost can be relatively high compared to other storage options. Tanks assembled from components take some time to ensure water tightness. Preassembled tanks and skid mounted tanks may be difficult to transport to some locations. Vandalism may be a problem.

b. Bottomless (Steel Ring).

Several types of steel ring tanks used in combination with other materials to form the bottom have proven successful. The rings are usually ordered as unassembled steel plates that, when assembled, form a circular ring. The plates are bolted together along vertical seams. A water tight seam is made by inserting a strip gasket along the bolt line. The steel plates are generally made out of heavy gage flat steel sheeting or corrugated metal for added strength. Steel plates can be ordered to form tanks of any reasonable storage capacity, usually 2 1/2- to 12-foot heights. Grain bin type rings with vertical and horizontal seams is another commonly used type of ring.

c. Steel Ring - Concrete Bottom.

Concrete can be placed to form an excellent bottom with the advantages and disadvantages discussed under concrete tank section. Vehicular access to the construction site is normally a requirement to use concrete as a construction material. Every effort should be made to avoided having a joint in the bottom. Joints can be avoided by delivery of adequate concrete quantities to make a monolithic bottom. If a joint is necessary, a neoprene water stop should be installed during placement of the concrete.

d. Steel Ring - Plastic Liner.

Plastic liners (PVC) have been used successfully with steel rings. These tanks are built using the same principles used in above ground swimming pools. Plastic liners will deteriorate in a few years if exposed to sunlight. For durability, it is recommended that these tanks be protected from sunlight with a roof cover that also will restrict evaporation loss. Special precautions must be taken to protect the liner from punctures or holes that may result from rodents or burrowing animal activity. If properly constructed, the plastic liner steel ring tank should last over 20 years.

e. Steel Ring - Elastomeric Bottom.

Artificial rubber such as hypalon has been used recently as a bottom for steel ring tanks. Hypalon is a very durable synthetic rubber with nylon reinforcement. It is resistant to deterioration by sunlight and most petroleum based chemicals. It is relatively inexpensive, but requires special installation procedures (see drawings). For prolonged life, hypalon should be protected from sunlight. Anticipated life is over 25 years.

Steel ring tanks with plastic liners or hypalon bottoms have the advantage of providing large storage capability at remote sites where construction access is severely limited. Material economics for providing this type of storage is very good, but this could be offset by increased labor cost of assembly.

f. Wood.

A common tank material, but having limited application as a water storage facility for rangeland purposes. Most wooden tanks constructed specifically for water storage purposes are constructed from redwood, and are round vertical tanks, with either low or high profile. Wooden tanks have been used by the Bureau in the past, but are not recommended, except in special situations requiring mitigation of visual impacts.

(1) Advantages. Durable material, relatively long life, low maintenance.

(2) Disadvantages. High initial cost. Requires semiskilled labor to assemble. To ensure the maximum life expectancy, installation requires site work and a good foundation preparation. Once installed wooden tanks are not readily moved.

g. Concrete.

Concrete is a construction material, available in most communities. Concrete (for the construction of tanks) is readily adaptable to many different construction techniques and methods of placement. Concrete can be placed above ground, below ground, as shot-crete and used as concrete for bottomless galvanized steel tank, concrete lined pits, etc.

(1) Advantages. Concrete is durable, long life, low maintenance, relatively vandal proof, adaptable to many shapes, commonly understood material requiring unskilled labor, and requires a minimum of site preparation work.

(2) Disadvantages. Remote and difficult terrain may make concrete an uneconomical alternative. Concrete construction requires forming, specialized equipment and under some conditions can be labor intensive. Concrete tanks should be considered a permanent structure. Most adaptable to low profile structures or as pit liner. Concrete storage facilities commonly have an open top which results in high evaporation losses.

h. Shot-Crete.

Shot-crete is "sprayed-on" concrete. (The installation or placement technique gives this method its name.) The mortar or concrete is projected at high velocity onto a surface. Placing the material by this method gives a high density mass that is readily adaptable to many different shapes or forms, readily adheres to most surfaces, and is waterproof when coated with a sealant after curing.

Shot-crete may be applied in thicknesses ranging from 1/2 to 12 inches. Shot-crete is readily adaptable to use as a structural member or as a decorative coat over other materials. For thickness over 2 inches, an accelerating admixture is recommended to provide an immediate initial set of the concrete. Shot-crete, when properly applied, may be more economical than precast, forming, or other methods of placing concrete. Shot-crete facilities readily blend in with the environment.

There are two general mixing methods used. The dry mix process transports the cement-sand mixture by air pressure to a special nozzle where water is introduced under pressure and the ingredients are jetted from the nozzle at high velocity onto the surface to be shot-creted. The wet mix process mixes all the ingredients together, similar to mixing, regular concrete before being conveyed to the nozzle and jetted with high pressure air onto the surface to be shot-creted.

(1) Advantages. A minimum amount of forming is required; and with the proper mix ratio, the material can be placed on vertical surfaces. Although reinforcement may be desirable, many applications are just as successful without the use of reinforcement. If reinforcement is desired, steel fibers (inch long "threads of steel" mixed with the concrete) into the mix greatly increases the strength and simultaneously reduces the required thickness. The continuous placement of the shot-crete generally avoids problems of construction joints and other discontinuity in construction, which is a plus for the typical small Bureau job. The material can be placed around unusual objects or projections during construction that make this type of construction blend very well with the surrounding landscape. The final coat can be colorized to blend in with the surroundings. Most shot-crete facilities are relatively vandal proof.

Shot-crete is particularly adaptable to the following situations:

(a) Repair and restoration of old concrete.

(b) The repair or rehabilitation of deteriorating storage tanks or water holding facilities where the side walls of the old tank serve as a form for the material to adhere to.

(c) The lining of pit type storage facilities or the construction of watering facilities where it is desired to imitate rock and natural landscape formations.

For other applications of shot-crete, see Chapter VI on catchments.

(2) Disadvantage. Shot-crete takes specialized skill and equipment. Site access is important, both for the equipment and material.

i. Fiberglass.

Fiberglass reinforced plastic is a relatively new material as compared to steel and wood. Fiberglass tanks are readily available for storage applications, including water. The term fiberglass covers a wide variety of materials and applications--one of the most common is glass fiber reinforced polyester for underground petroleum storage tanks. Tanks constructed to store petroleum products are adaptable to storage of water, but the cost may be significantly higher than other alternatives. Another alternative that has proven successful is the use of prefabricated fiberglass septic tanks. Other alternatives include tanks constructed from some other material and protected with a fiberglass reinforced plastic coating.

(1) Advantages. Fiberglass tanks when used for the storage of water should provide a long lifed, low maintenance facility. Fiberglass tanks are relatively resistant to deterioration from contact with soils. Fiberglass tanks are easily repaired if the damage is not too extensive.

(2) Disadvantages. Fiberglass tanks are not readily constructed on site; therefore, the tank size and logistics of getting the tank to the site must be considered. Fiberglass tanks are subject to damage due to vandalism and rodents. Some fiberglass tanks are subject to deterioration from sunlight and should be protected; whereas other tanks continue to perform satisfactorily after long exposure to sunlight. It is not recommended that a fiberglass tank be used as a portable tank. Portable fiberglass tanks used as pumpers on fire equipment shed the fiberglass after some period of use and plug the pump screens. Depending upon the configuration of the tank, the tank may not be designed to withstand the soil weight of being totally buried. Installation of fiberglass tanks requires good bedding and compaction.

j. Polyethylene Tanks.

Polyethylene tanks made from a high molecular weight material have proven satisfactory for water storage. Typically these tanks are installed at the base of a rock ledge or cliff. Installation at these sites provides for protection from the direct sunlight and when the tank is painted to match the rock, visual impacts are significantly reduced. The manufacturer should be consulted on the life expectancy of these tanks.

(1) Advantages. Typically these tanks are in small sizes and are easily transported. Generally they are constructed like a cube, which makes them relatively easy to roll into place. The sidewalls are flexible and are not readily damaged during installation.

(2) Disadvantages. Adherence of paint to the surface to protect from sunlight and to lessen visual impacts is a problem. Storage capacity may not be adequate for the need.

k. Butyl Bags.

Butyl rubber storage tanks, commonly called bags, are often used at catchment type projects where a low profile storage system is desirable. Butyl bags have been widely used for storage, generally in conjunction with Butyl catchment aprons. For further discussion on the use of butyl, see Chapter VI on catchments.

(1) Advantages. Although the material is resistant to deterioration by sunlight and other weathering processes, it has not preformed well over time.

(2) Disadvantages. Butyl bags should be protected if at all possible, preferably by a roof. The weight of water and snow accumulation on top of the storage bag usually prevents the bag from filling as designed. A roof would help prevent the accumulation of water, snow, and other debris on the bag. Butyl materials are very susceptible to damage from ants, rodents, ravens, coyotes, and other small animals. Butyl materials are not recommended for use unless they can be protected.

l. Military Surplus.

Military bases often have available as surplus item, high quality containers that can be easily adapted for storage or watering troughs. Military bases usually have a continuing supply of shipping containers that can be used for small storage (200 to 1000 gallon capacities). These containers have been used successfully for numerous applications. Each specific use will have to be evaluated individually.

m. Surplus Oil Field Tanks.

The use of surplus oil field tanks, like military shipping containers, must be evaluated on a case by case basis.

2. Evaporation Control From Open Top Tanks.

Evaporation water loss from open tanks can be a serious problem on desert rangelands. Evaporation losses from exposed water surfaces can be as high as 7 feet in the Southwest. Controlling evaporation losses should be considered as part of the system design if the design includes an open top storage tank.

Roofs over storage tanks are a common technique to control evaporation. The roof can be extended over the sides and built with inverted pitch to act as part of the catchment apron area. Roofs can be constructed of corrugated steel and suspended from the edges.

Floating covers of low density synthetic foam rubber sheeting are an effective means of controlling evaporation from vertical walled storage facilities. However, they are also susceptible to distortion and damage by the wind. Synthetic covers are also susceptible to windthrow distortion and folding that exposes the water surface to evaporation. These covers also deteriorate in sunlight and ravens are thought to increase deterioration by tearing holes in the foam rubber.

Other evaporation control measures, such as applying chemicals that float, styrofoam blocks, and wood floats, have for the most part been used unsuccessfully. To be effective and to prevent sinking, a wood cover should be supported by some kind of float device. Float covers also allow birds safe access to water in the tanks.

C. Special Considerations.

Consideration for analyzing the most practical and economical alternatives of providing storage should include the following:

1. Terrain features and the logistics of constructing or placing the facility at the point of need.

2. Soil disturbance requirements and constraints in siting the storage facility.

3. Freezing of the storage facility, including valves and outlets, where there is a desire to provide year around water.

4. Visual impact of a storage tank next to a water facility or set on a hill or slope. It may not be desirable to draw attention to the watering facility.

5. Consideration of how close to the road the facility will be located or within sight distance of other roads.

6. On pits and reservoirs, consider if it would be undesirable to have others use the water by pumping out of the storage facility (i.e., energy development companies).

7. Avoid siting tanks where they reflect in the sun because they attract attention and encourage vandalism. Paint may be the solution to this problem. However, maintenance of the paint can become a problem.

8. If at all possible locate storage tanks, pits, etc., reasonably close to the point of use.

9. Avoid leaving ladders, etc., open hatch covers, and other temptations that can lead people to fall in or go swimming. (For tanks).

10. On pits and reservoirs, consider the need for flattening the side slopes leading to the water. Avoid steep banks as they may become traps for livestock, game animals, and humans.

11. On open top installations, provide ways for birds and small mammals to escape the deep waters.

12. The site must have physical access for construction, monitoring, and maintenance.

Chapter IX

Table 1 - Storage Facilities - Installation and Cost vs. Type of Tank

Type Tanks	Availability	Ease of Installation	Durability (Life)	Relative Cost
Common Steel Tanks:				
Galvanized Steel	Readily available	Moderate	Good	Moderate
Surplus Oil Field	Available in some areas	Moderate	Good	Moderate to inexpensive
Surplus Railroad	Available in some areas	Moderate	Good	High
Surplus Military Containers	Available in some areas	Moderate	Fair	Inexpensive
Horizontal Skid Mounted	Readily available	Easy	Good	Moderately high
Bottomless Steel Ring				
Concrete Bottom	Readily available	Average	Good	Average
Plastic Liner	Readily available	Easy	Fair	Low
Elastomeric Bottom	Readily available	Easy	Fair	Moderate
Wood				
Redwood	Generally special order	Difficult	Good	High
Concrete				
Concrete	Readily available	Moderately difficult	Good	High
Shot-Crete	Available most areas	Moderately difficult	Good	High
Other				
Fiberglass	Available most areas	Average	Poor	Moderately high
PE Tanks	Available most areas	Average	Poor	Moderately high
Butyl	Available most areas	Difficult	Poor	High

H-1741-2 - WATER DEVELOPMENTS

Chapter X

Chapter X - Water Troughs

A. Introduction.

Troughs, as used in this Handbook, are man-made shallow receptacles used to distribute water to grazing animals. Troughs are used for water storage and presentation. There are many different types of livestock water troughs in use throughout BLM today. Troughs have been made with steel, fiberglass, concrete, wood, galvanized metal, high density polyethylene (PE), and combinations of the above. The location, size, and kind of trough are very important considerations in planning a water development. Equally important is the kind(s) of grazing animal(s) and the season(s) of use within the project area.

To be effective and require minimum maintenance, water troughs should be constructed of strong materials, be well reinforced, and have adequate supports. They should be located on level, solid ground, be firmly anchored to the ground, and sealed against leakage.

Nearly every water development can be constructed using a trough for the storage and presentation of the water to the grazing animals.

B. Types of Troughs.

1. Steel.

Steel troughs are probably the type most frequently used today. They are available from several commercial outlets. They come in all sizes and shapes, or can be developed to meet special situations. Some specifications require that the steel trough be hot dipped - galvanized after construction. This will double the life of the trough particularly if lighter gauge metal is used. Popular steel and aluminum troughs that have been used in the past are military surplus shipping containers. Some of these have been in the ground for over 20 years and still appear to be in good shape.

2. Fiberglass.

Fiberglass troughs seem to stand up well if properly installed. They require a level pad and a protective, anchoring frame. They are light and can be moved into remote areas easily. Use of heavy duty fiberglass is recommended for a satisfactory life.

3. Bottomless - Steel Ring.

Galvanized bottomless troughs are round rings which require poured concrete for the bottom. They are excellent troughs if the project is not too far from a concrete source, otherwise the cost is prohibitive.

4. Concrete.

A concrete trough may be reformed and hauled to the project or formed and poured at the project site. There are not many of this type presently used in BLM. However, they can withstand crowding pressure from large grazing animals, i.e., buffalo.

5. Wood.

Wood troughs should be used only when the supply of water is constant. This is necessary to prevent excessive checking and warping. If this is done, the life of a wood trough may be as long as the average metal trough.

Freezing does little or no damage to wood troughs. Wood troughs may be used when special visual resource or other aesthetic considerations are important (wilderness study areas).

C. Size of Troughs.

There are three important considerations for determining size of trough: drinking space, volume, and height. (See Illustration X-10.)

Drinking space should be sufficient to prevent crowding by the animals while watering. Design considerations should allow for the size and behavior of the animals using the trough.

The dimensions of the trough should allow an animal to be able to fully reach the water in the trough even when the water level is low. This is particularly important when a trough is attached directly to a storage tank. This situation occurs with the fiberglass "flying saucer" catchment with some corrugated tin apron catchments where there is a ground level trough attached, that works on an equilibrium with the storage tank and when a low water level in the storage tank causes the water level in the trough to also be low.

The volume of water needed is also an important consideration in determining the size of trough (see Illustration X-10). On many water developments, particularly springs and windmills, the trough may be the only water storage available. There must be sufficient stored water during peak demands to satisfy the need. Since the recharge on many of these types of developments will not be fast enough to satisfy demand, within a reasonable period of time, storage must be provided.

For developments equipped with pumps that provide water on demand or systems with storage facilities, the amount of water stored in the trough is not so critical.

D. Location of Troughs.

Troughs should be placed in a stable/flat area with sufficient space for the animals to move around them. It is good practice to keep them away from the following areas:

1. Heavily travelled roads.

2. High visual resource management areas, recreation areas, and campgrounds.

3. Riparian zones.

4. Erosion hazards.

5. Fence corners.

6. Fence lines.

7. Areas that would create resource conflicts.

8. Animal traps.

9. Potential wildlife ambush sites.

It is BLM's policy that water be safely available for wildlife. For example, troughs should be located away from obstacles such as fences where the animal may be trapped by predators or where sudden flight behavior may cause injury if the animal runs into the obstacle. Some predators, such as bobcats, learn to hunt at waters where prey congregate. Therefore, troughs should be located away from potential ambush sites such as cliffs or rock outcrops. This is particularly true for bighorn sheep waters.

E. Special Considerations.

Most pipelines are a closed system, therefore, float valves or water meters are needed. Floats can either be put in the trough or along the line at proper level. They must be adequately protected to keep animals from breaking them. They are usually housed in a protective cover that may also be designed to serve as an escape ramp for wildlife. Escape ramps must be placed in all troughs and there are many different types. A triangular shaped expanded metal ramp that attaches to the rim of the trough will intercept a swimming bird or mammal from any direction in the trough and is used in many BLM Districts. On large circular troughs several of these may be needed.

Algae sometimes becomes a problem in troughs. If there is a problem, a commercial algaecide may be used according to its label. Periodic cleaning or shading of the trough may help.

In winter use areas, the following will help prevent water freezing in the trough:

1. Solar reflectors.

2. Propane bubbler systems.

3. Electric heaters.

4. Painting the trough black.

5. Locating on southwest exposures.

6. Wave action created from water falling into trough from inlet pipe.

Support frames around troughs are very important to stabilize the troughs and keep the grazing animals out.

BLM guidance concerning making water safely available to wildlife and other multiple use concerns is discussed in Chapter 2 of this Handbook.

The height of the trough is a very important consideration. It should match the type of animals using it. Many BLM troughs have been installed that did not take into consideration smaller animals; resulting in additional expense to modify them after installation. Twenty inches above the ground level is considered satisfactory for most grazing animals on public land.

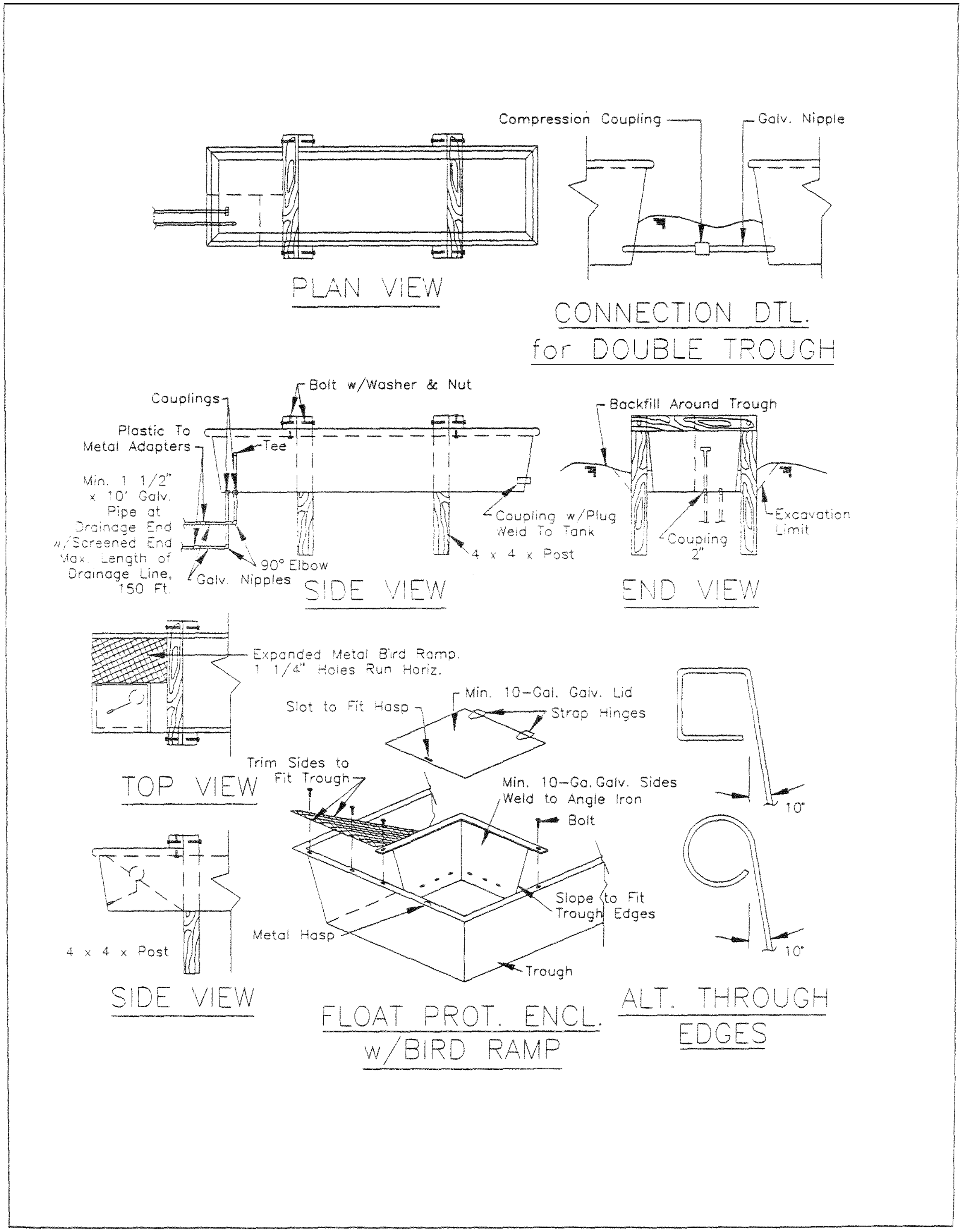
Cement pads and/or gravelling around the trough may be required to maintain the proper height of the trough. Trampling and soil compaction from the watering animals as well as water and wind erosion may cause the trough to become "pedestalled." Geotextile fabric designed for soil separation may be placed under the gravel to hold it in place.

Where separate drinking facilities are provided for wildlife, the trough should be at ground level with a built-in, walk-in ramp.

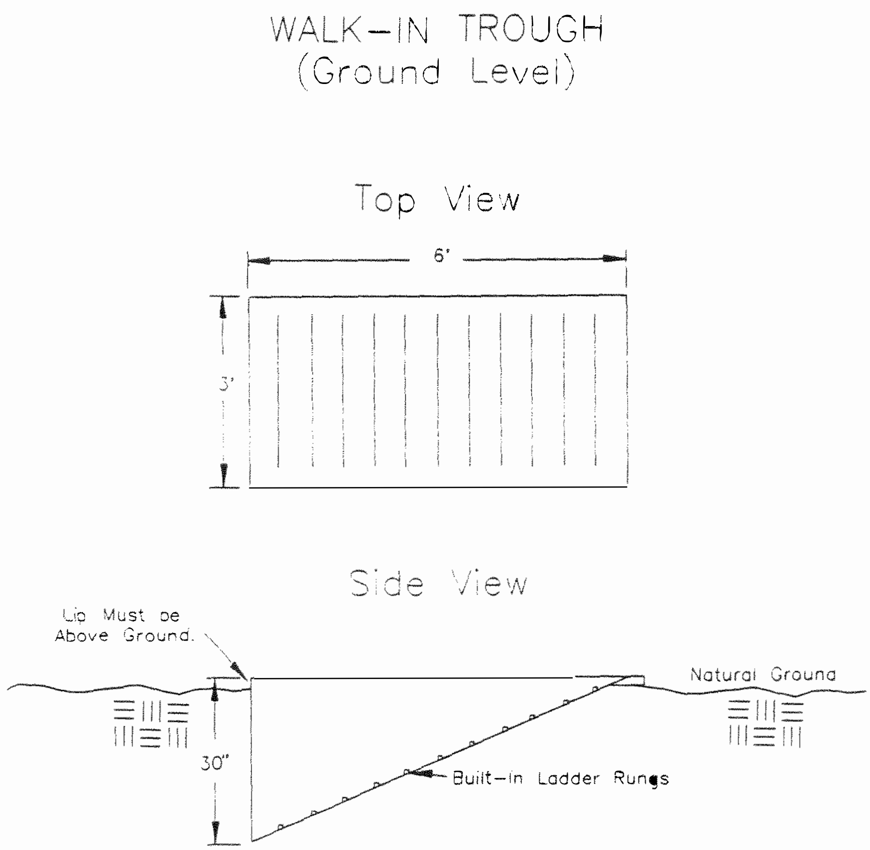
The dimensions of the trough should be sufficient to allow for the horns or antlers of bighorn sheep and mule deer to adequately clear the sides of the trough.

See Illustrations X-1 through X-10 for various trough designs, trough modifications for wildlife, instructions for the calculation of water tank capacity and a summary comparison of differing types of water developments.

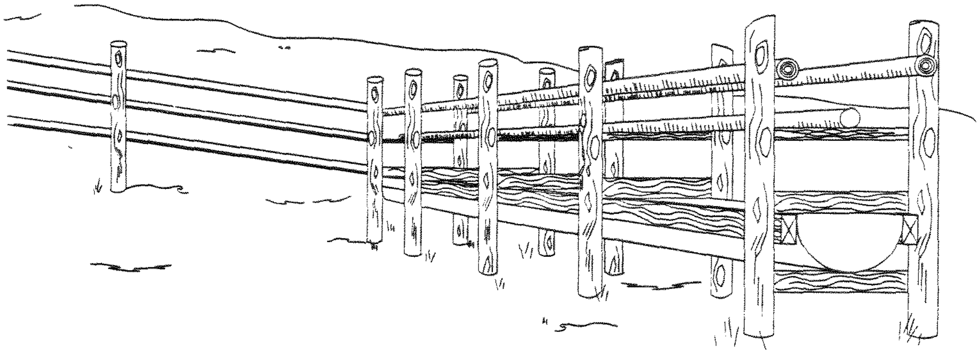
Rectangular Water Trough

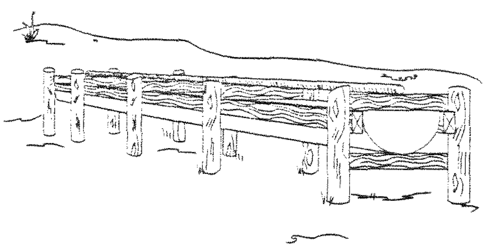


Walk-In Trough

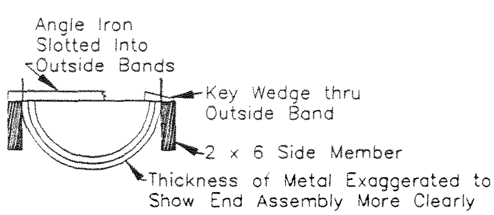


Metal Flume Trough

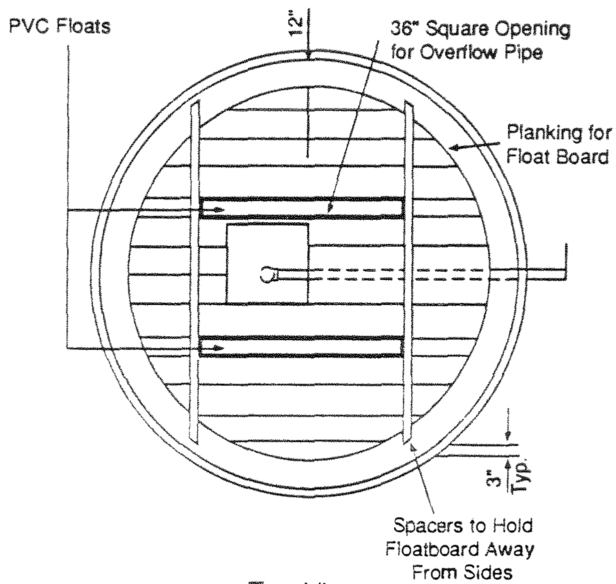




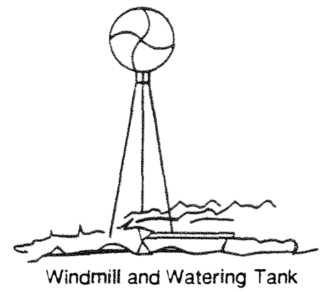
NOTE:
Brace under trough should be at ground surface for sheep but higher for cattle.

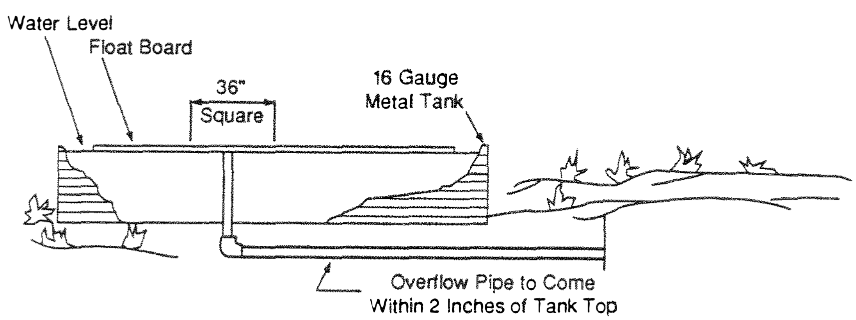


Round Water Trough with Float Board



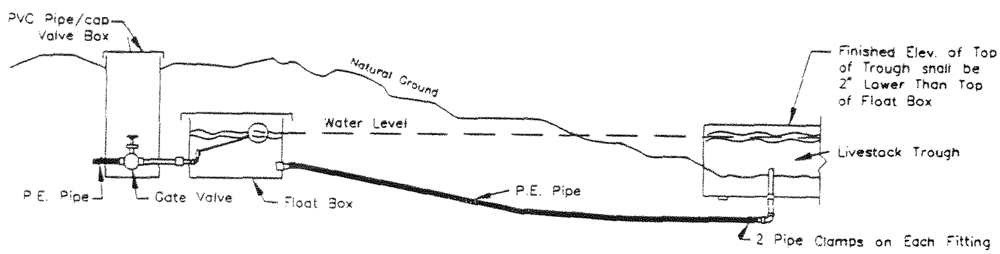
Top View

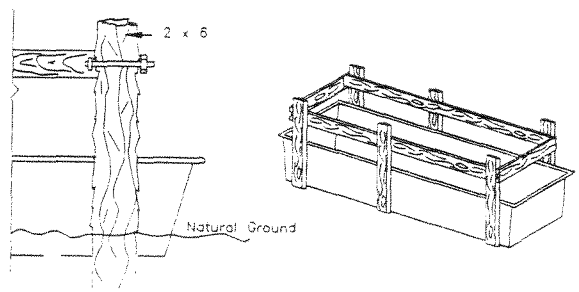




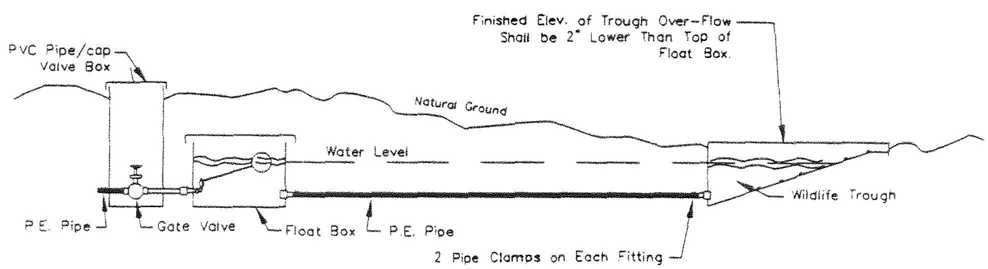
Side View

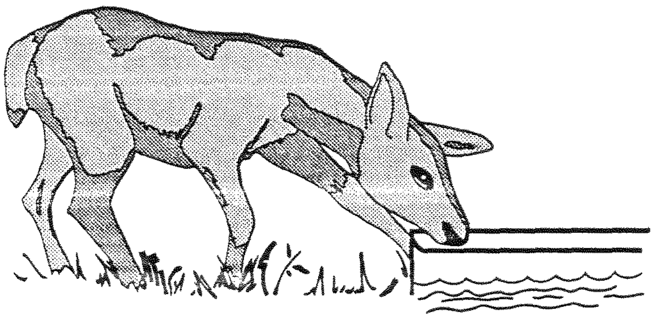
Float Box - Livestock Trough and Wildlife Trough



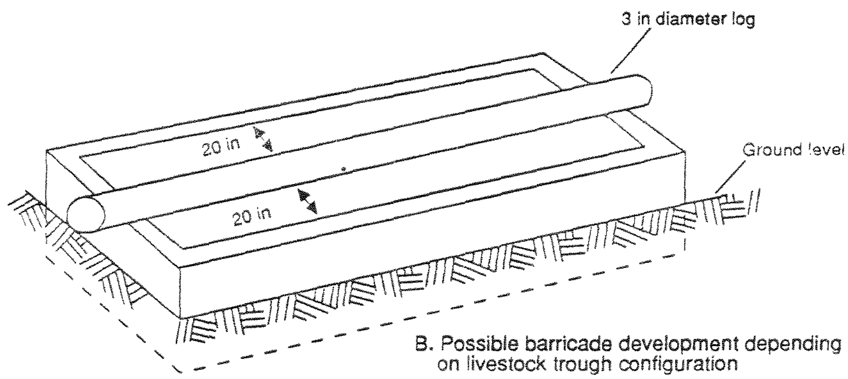


NOTE:
Bury float box below frost line.

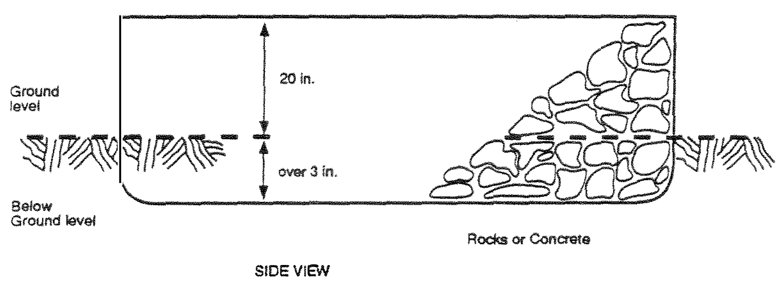




A. When trough height is 20 in or less wildlife have better access to water



B. Possible barricade development depending on livestock trough configuration

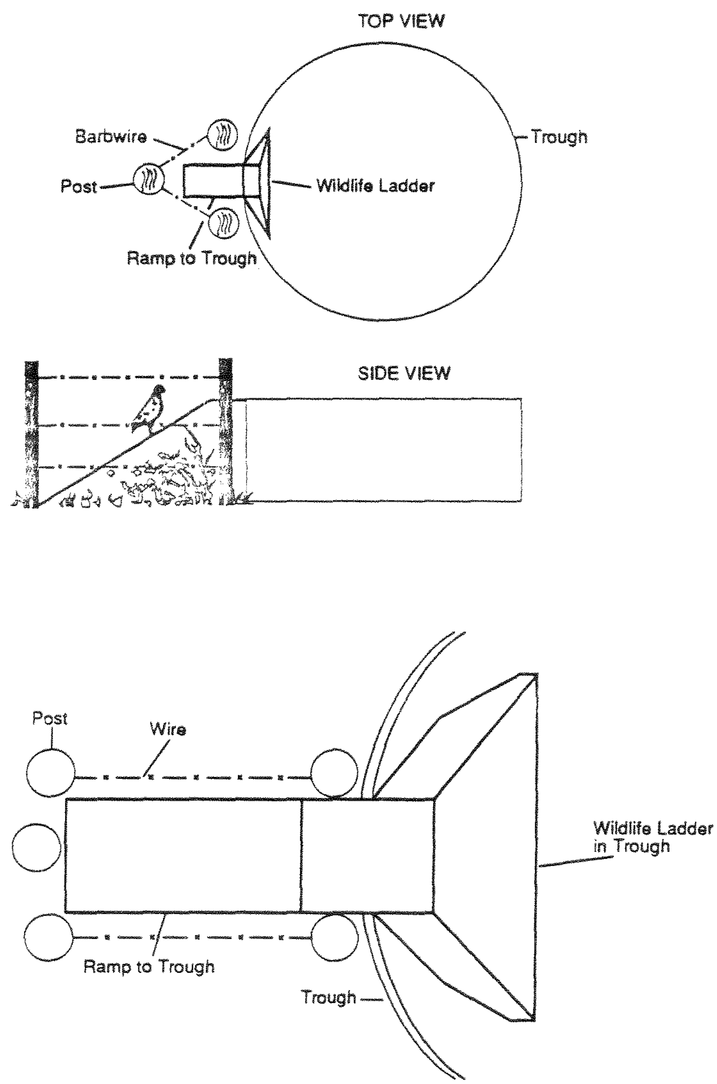


C. Placing of rocks, concrete blocks or other ramp facilities provide on escape route for wildlife where the water depth exceeds 20 inches

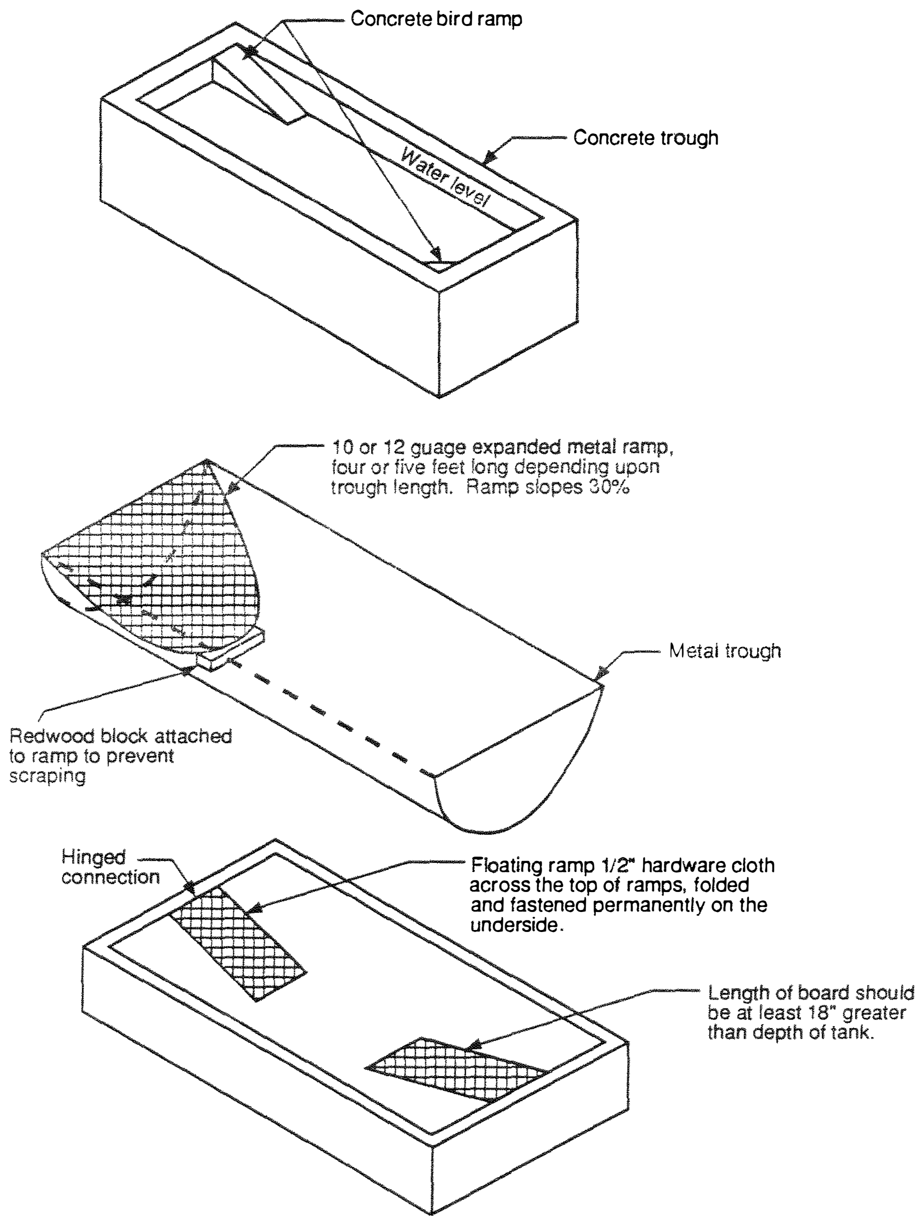
Design modifications beneficial to wildlife for water troughs constructed for domestic livestock (adapted from Wilson and Hannans 1977).

Chapter X

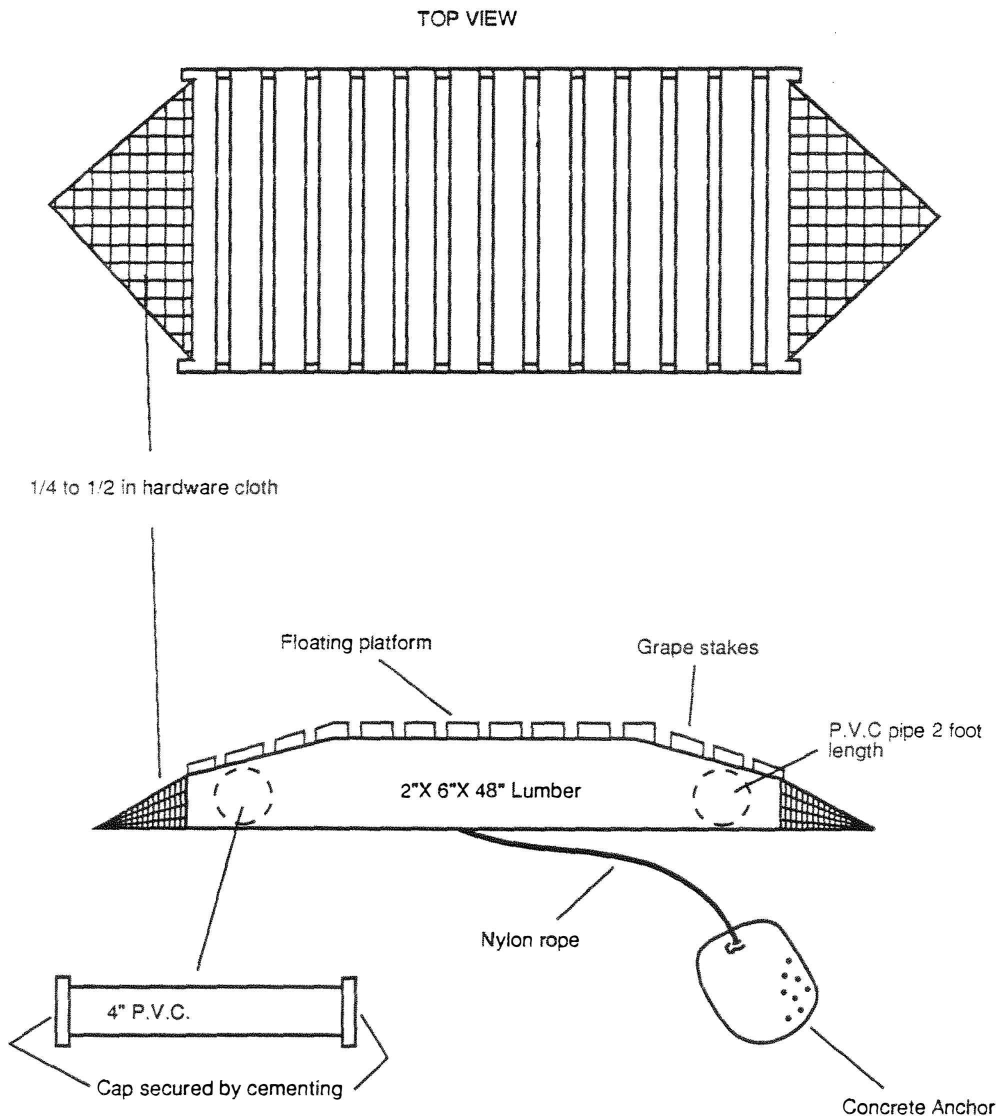
Wildlife Ladder Modifications



Water Trough Bird Ladders



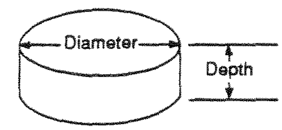
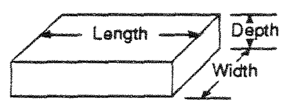
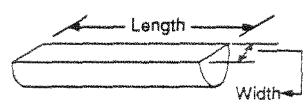
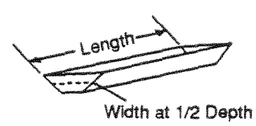
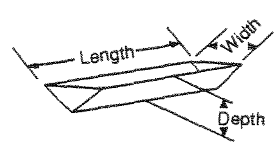
Floating Wildlife Platform



Floating wildlife platform recommended for large open water storage tanks (Wilson and Hannans 1977).

Chapter X

How to Figure the Capacity of Water Tanks

Round or Circular Tank	To find gal. capacity: diam. X diam. X depth X 5.86 = gals.	
Rectangular Tank or Trough	To find gal. capacity: Width X depth X length X 7.46 = gals.	
Curved Bottom Trough	To find gal. capacity: Width X width X length X 2.93 = gals.	
Slanting Sides Trough	To find gal. capacity: Width (meas. at 1/2 of depth) X depth X length X 7.46 = gals.	
V Sides Trough	To find gal. capacity: Width X depth X length X 3.73 = gals.	

Summary Comparison of Various Water Developments

Water Development Type	Construction Costs 1/	Dependability	Yield	Needs	Annual Maintenance Advantages	Disadvantages
Springs	Low	Good	F to G	Low to Med	Usually dependable	Annual maintenance
Wells	Med to High	Good	Good	Med	Dependable if in good aquifers	Necessary maintenance
Reservoirs and Pits	Low to Med	Fair-Good	Fair	Low	Low maintenance	Not dependable in low rainfall periods or if they lack water-holding capacity
Catchment	Med to High	Fair to Good	Fair	Low to High	More flexible on location	High maintenance
Wetland/Riparian Potholes	Low to Med	Fair	Fair	Low	Economical to develop	Potholes could be a hazard to wildlife and livestock
Delivery and Supplemental						
Pipelines	Med to High	Good 2/	-	Med	Economical way to distribute water. Save developing another source.	More maintenance to keep Operational. Must have reliable source.
Storage Tanks	Med	Good 2/	-	Low	Provides constant supply	Additional expense
Water Hauling	Low	Good	Good	Low	Distribute water in emergencies and to seldom-used pastures	Labor intensive + expensive

1/ L - Less than $3,000, M - $3,000 to $10,000, H - Greater Than $10,000

2/ Depending on Source