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Jason Gross
University of Nebraska-Lincoln

Chris G. Henry
University of Nebraska at Lincoln, chenry1@unl.edu

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Jason Gross and Chris Henry
University of Nebraska-Lincoln

Abstract. Vegetative Treatment Systems have historically been a practice for the treatment and utilization of open lot livestock wastes. Use of these systems has been rejuvenated in recent years. A "sprinkler" vegetative treatment area (VTA) has been designed and developed as a proof of concept for addressing challenges experienced with small and medium Animal Feeding Operations. The focus of this paper is to report on the design, economics, challenges and the lessons learned on the development of this system. Cost data shows the cost of a "sprinkler" VTS to range between $31 to $63/head, compared to $51 to $170/head for a conventional holding pond system.

Keywords. Vegetative Treatment Systems, Vegetative Treatment Areas, CAFO, AFO, open lot runoff control

Introduction

A Vegetative Treatment System (VTS) is defined as a runoff control system to collect and manage the runoff from a production area using vegetation and soils. The vegetative treatment area (VTA) is the treatment, storage, and utilization area for the liquid runoff from the open lots. The VTS is the whole system which includes the diversions, gutters, sediment basins, outlet structures, transfer systems, and the VTA.

Several significant challenges experienced by the authors exist when designing waste control systems for small livestock operations; the following can be specific to open lots:

1. Limited space available for a waste control facility (typically).
2. Existing production area is down gradient of potential VTA.
3. In Nebraska, as many other Great Plains states, waste control facilities are subject to freezing temperatures and frost (frost depth is between 3 (1 m) to 4.5 ft (1.4 m) in Nebraska). If mechanical devices, specifically pumps and inlet screens, are to be used they must be able to operate near freezing temperatures and tolerate minor ice accumulations.
4. Small operations cannot leverage the "economies of scale," resources are typically limited and smaller operations must be able to compete on the same cost per head unit as larger operations.
5. System must be easy to maintain.

The objective of this paper is to describe the development, design, and construction of a "sprinkler" VTS in Nebraska as a proof of concept. The "sprinkler" VTS is an economic concept and the approach used to develop the system, the components used, and recommendations are provided for others who may wish to design a similar system.

Overview of Operation

A "sprinkler" VTS was designed for a 40 cow/calf pairs and 40 feeder calves backgrounding operation in southwest Nebraska. The operation consisted of a small corral and feeding pens near the house on the edge of a large canyon. The location experiences approximately 18 inches (45cm) of rain and 42 inches (106 cm) of evaporation per year. The soils at the site are typical of a silt loam with a water holding capacity of 0.18 inch (4.7 mm) of water per inch of soil inch. Figure 1 shows a plan of the design; a suitable location down-gradient was not available for VTA because of the canyon below the operation. The soils in the area were not deemed suitable for the construction of a clay liner. However, the soils do have a moderate intake rate and water holding capacity, which were deemed suitable for a VTA. There were no groundwater issues since static water table is over 190 feet (58 m) deep with no perched aquifer. Given the constraints, the authors developed a "sprinkler" VTS concept design as an alternative to conventional containment.

The design incorporated the follow. A diversion, designed in accordance with NRCS standards, was placed up-gradient of the open lots to exclude contributing drainage. Next, a sediment basin was placed down-gradient of the open lots just north of the tree line. The basin is the temporary storage element of the VTS. The basin was designed to fully contain the 25 year 24 hour storm including runoff and direct rainfall, plus freeboard (0.5 ft (15 cm) was used in this design, but 1 ft (30 cm) is recommended by the authors). The bottom width of the basin was designed to be large enough to allow loaders and scrapers to easily clean out the solids, but shouldn't be so large that the runoff will slow sufficiently to reach the outlet. Bottom channels were designed to slope to the outlet (or pump inlet). This slope needs to encourage good drainage and minimal erosion of the channel. At the lowest point in the sediment basin there is an outlet structure/pump inlet with a buried underground line to a dry well concrete pump station. A 2.5 inch (6 cm) mainline pipe with 2 inch (5 cm) spur lines convey runoff to six solid set sprinklers located between two terraces which serves as a preventive measure to limit runoff from leaving the VTA.

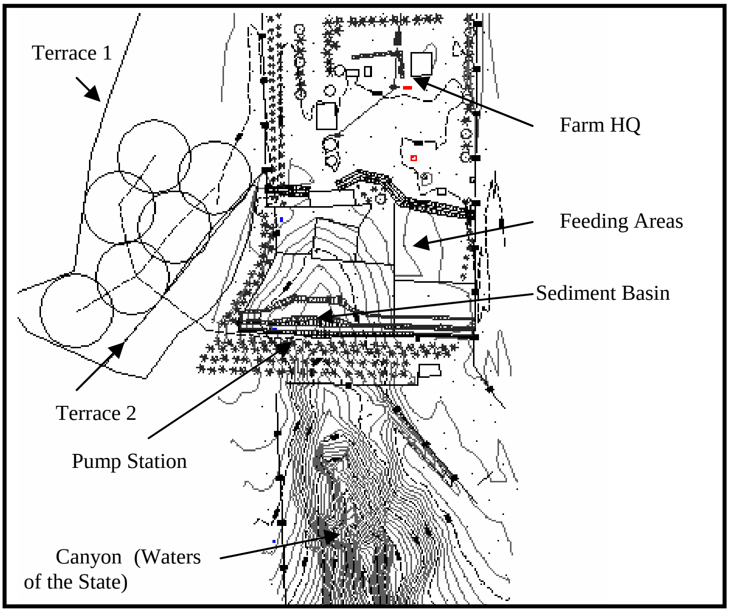

Figure 1. Plan View of "sprinkler" VTA Design

Vegetative Treatment Area Design

A VTA is an engineered system for treating waste water from open lot feedlots. It is designed to store the runoff water from the open lot in the crops root zone and to utilize the nutrients though the crop. The crop is then harvested and fed back to the livestock or used as bedding.

The Vegetative Treatment Area design followed three rules:

1. The VTA should utilize with a perennial crop the nitrogen yield of the open lot runoff without generating runoff.
2. The VTA should receive the runoff water and store it in the water holding capacity of the soil in the crop's root zone without runoff.
3. The runoff must be distributed uniformly across the VTA.

Average perennial crop yield for this site was estimated from the local area dry land grass hay and alfalfa production. VTA size was determined using the nutrient load in the average annual runoff and the average annual nutrient uptake for the perennial crops. In Nebraska, a typical VTA to feedlot ratio is about 1:1 or 1.5:1. In this design, only 50% of the available water holding capacity (AWHC) was used as available storage in the root zone (assuming the root zone was the average root depth of the species selected for the VTA). The other 50% was assumed to be already utilized by previous runoff events. Ideally, a daily time step model would provide assurance that this assumption is valid, and it is the opinion of the authors that tools such as SPAW (Soil Plant Air Water) with some modifications are suitable for these criteria. SPAW has been used by the authors on more recent projects, but was not available when this system was designed (Gustafson, et. al., 2007).

The design was not based on uniform application as would be typical for an irrigation system. In the “sprinkler” VTA design, the sprinklers were spaced with very little overlap. Sprinklers were selected that had relatively good uniformity individually and that could withstand the abrasive nature of effluent irrigation (in this case brass was used, but some plastic impacts are suitable). In addition to minimizing cost, the authors believe that since this was a nutrient distribution system, not an irrigation system, application uniformity was less important and did not justify additional cost. Furthermore, it was expected that the system would operate much less often than a similar irrigation system.

Preferred vegetation for a VTA is a perennial crop or grass. A mixture of cool season grasses will have the longest growing season and utilize the maximum nutrients; however, the competition between the grass species will yield to the more successful species, in most cases the cool season species. These mixtures need to match the climate conditions of the area. In dryer climates, a more drought tolerant grass, such as intermediate wheatgrass, could be used. In wetter areas, the mix could be predominantly smooth or meadow brome or orchard grass. Warm season grasses could also be used but should be planted in the VTA but should not be intermixed with cool season species. During the summer months the runoff water could be applied to the warm season grasses while the cool seasons are dormant, and vice versa. However, the VTA will always need a cool season grass component for the early spring and late summer rains. In this system, intermittent wheatgrass was used. The slope of the VTA is nearly level and situated between two terraces to eliminate any contributing runoff from entering the VTA. .

Distribution System

Pump stations for conveyance from sediment basins to holding ponds for CAFO permitted operations typically cost upwards of $15,000 per unit (USDA, 2004). Adaptation of known pump station configurations was not deemed to be cost effective. Therefore several iterations of pump stations configurations for a smaller size yielded the pump station shown in Figure 3. The pump station uses a three hp Berkley cast iron pump (LTH 3 HP), which is readily serviceable in Nebraska, and costs around $1,295. The pump station is set 8 feet (2.4 m) below ground to minimize freezing conditions, and consists of a pre-cast concrete septic tank, readily accessible and very cost effective housing ($460 for a five by seven by eight foot septic tank). Pipe connections from the inlet, shut off valves, and low pressure cut-off, are shown in Figure 3. The pump has unions on either side of it; this allows it to be disconnected and removed for service. The pump is supplied with a 30 amp overhead service which cost $1,075 to install. A cross section of the pump (showing the pressure relief, is shown later in Figure 7)

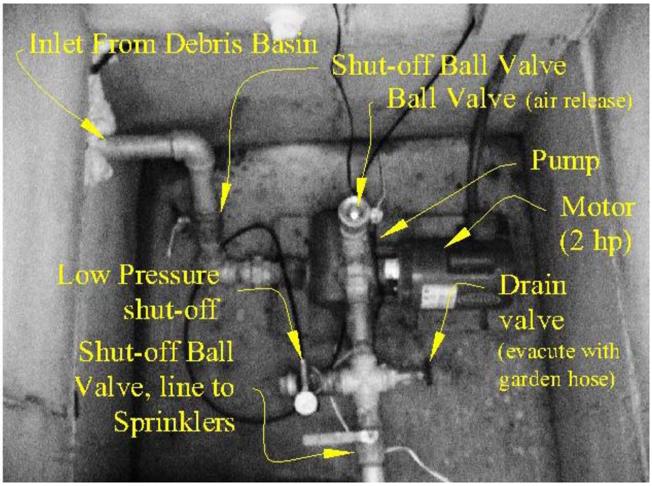

Figure 3. Pump Connections for a Dry Well Pump Station

Runoff is conveyed from the pump station to a series of six, three foot risers (shown in Figure 4) with 3/16 inch (5.8 mm) nozzle (30H Rainbird) impact sprinklers. An air/vacuum relief (AVP-1 Waterman) was provided at the end of each spur and a 70 psi (4.8 bar) pressure relief valve was installed in the mainline. If needed, the system is easily drained using a garden hose connected in the pump station.

The system was designed to match the infiltration capacity of the soils with the number of risers, flow rate of each sprinkler, pressure, and flow rate required. A pump was then selected that met the pressure and flow requirement. One significant challenge faced by the authors was finding pumps to accommodate the high pressure and low flow requirement for this type of system. Typical requirements range from 100 – 150 feet (30-45 m) of head at 30-90 gpm (114-341 L/min). With this configuration, a self priming pump is not required, significantly reducing the cost for the pumping unit and allowing for a wider pump selection range. A spreadsheet is available from the authors to aid in the iterative design process for sizing pumps, sprinkler selection, pipe, and VTA area (Henry and Gross, 2004).

Figure 4. Sprinkler Riser Installation

Basin Outlet Structure or Pump Inlet Design

The basin outlets for the “sprinkler” VTS need to function in all weather and solid accumulation conditions. The minimum outlet size was determined by pump flow rate. The outlet strainer was designed to be oversized to accommodate 50 % plugging and still provide adequate flow for the pump. The pump inlet developed for this project is shown in Figure 5 and Figure 6. The screen was made from aluminum at a local machine shop for $250 and has handles for easy removal for cleaning (can be seen in Figure 6). Pickets made from recycled plastic are used to slow the velocity of runoff into the outlet and settle the largest particles before reaching the aluminum screen. Conceptually, the screen prevents particles too large to pass through the sprinkler from passing through the outlet structure. The concrete pad was sloped to drain to the inlet pipe. The total cost of the outlet structure with the inlet pipe was $910. The total system cost is shown in Table 1.

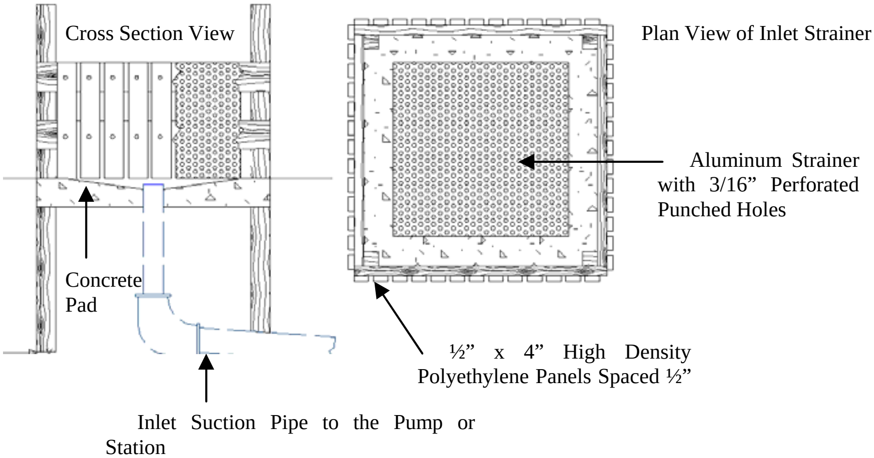

Figure 5. Plan and Cross Section View of the Inlet Strainer Drawing

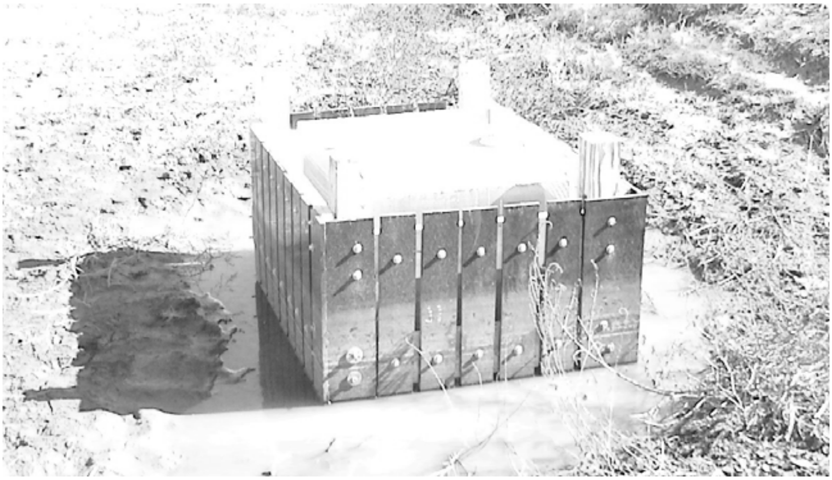

Figure 6. Inlet Strainer after Installation

Design Considerations

Pump/pressure systems that use a sprinkler application system need to be sized to deliver the flow and pressure required for the sprinklers. A recommendation for future “sprinkler” VTS includes the addition of a high quality filtration system, as a precautionary measure, to ensure the runoff water will not contain particles capable of plugging the sprinkler nozzles as shown in Figure 7. It is the experience of the authors, that on some occasions, especially after a several precipitation events in series, the last fraction of runoff to be pumped is of a “milkshake” consistency. This condition may require the removal of the strainer, so that the basin can be emptied completely. The inlet strainer needs to provide the necessary flow into the pump even if it is partially plugged so the pump doesn’t damage itself with cavitations.

This filter would be placed on the pressure side of the pump as an inline pressure filter. Several manufactures provide many sizes and options for these filters. In facilities with heavy trash, these filters can have an attachment that senses pressure loss and automatically flushes the filter. In most cases the filters can function without the automatic cleanout features. These filters will be installed on the pressure line above ground near the pump. A pressure relief valve and air / vacuum relief valves needs to be installed in between the filter and pump. After a pump cycle, the producer can drain the line and the filter to protect the system against frost damage. The filter of the pump needs to be sized just slightly smaller than the nozzle size of the sprinkler.

Sprinkler systems will work well in rolling hills and in sandy areas that have a high water table, low AWHC, or a high intake rate. Sprinkler systems can include solid sets, tow lines, side rolls, or pivots. The authors used and recommend following the guidelines set by the NRCS National Engineering Handbook Section 15, Chapter 11 on Sprinkler Irrigation Design for a "sprinkler" VTA system. "Sprinkler" VTA design is similar to a conventional irrigation system, but there are some challenges. The sprinkler system needs to apply water to meet the infiltration rate of the soil, even in wet conditions. It may be difficult to apply water through a pivot or tow line that can match the soils infiltration rate and also the desired flow rate for proper detention time for the sediment basin. Often times, the design will require a faster application rate than a pivot, tow line, or side roll can provide for the minimum sized VTA. Longer pumping times and multiple application sets may be required or use of an over sized VTA and sprinkler system. The authors have evaluated the use of other irrigation system types; however, the solid set offers many advantages. They are low maintenance, permanent, and lower cost than most other mechanical irrigation systems. Another challenge that mechanical systems must overcome are saturated soil conditions; movement irrigation systems can rarely operate in wet conditions, and is why the authors discourage the use of movement type irrigation systems unless they are adapted or proven for use in wet soil conditions. However, portable irrigation systems may be acceptable. Portable irrigation systems are systems that can be moved manually between irrigations. They must however, be able to distribute the design storm volume within a reasonable amount of time (24-96 hours) after the runoff event. Storage of runoff longer than 96 hours makes it difficult to classify a debris basin as temporary storage rather than long term storage. Long term storage structures should have liners to limit seepage. There are other practical issues that the designer must overcome with a portable system, such as total time and ability of the operator to move sets in a timely manner in order to empty the debris basin, which make the design and application of portable systems more challenging.

When locating the VTA for an open lot, the design should consider the seasonal high water table or any impervious soil layer in the determined root zone. In areas that may be sensitive to high water tables, a geological investigation may be necessary. A VTA's designed root zone needs to be a minimum of 5 feet (1.5 m) above the seasonal high water table. This will help minimize any ground water impacts from accidental leaching of the nutrients below the roots of the crop. A geological investigation can also help determine any impervious layers in the desired root zone. The storage capacity of the soil cannot extend below an impervious layer. Also, the infiltration rate of the slowest soil layer will be the designed infiltration rate when designing the application schedule. Potential problems can be eliminated by doing a quality geological investigation during the planning phase of a project.

The pump and station can be installed in many different combinations. They all need to be frost protected and easy to operate and maintain. It is preferred to use electric motors with shut down protection, but in some cases it is not practical to provide electrical service to the location where pump station must be sited. Another alternative being investigated and piloted by the authors is the use of a permanently mounted diesel power unit and pump. These systems also need an engine and pump emergency shut down for protection from plugs or empty basins. The station needs to be installed so the pump and pipelines are mounted below the frost line. Precast concrete septic tanks that are stackable work well and are easy to find and are more economical than steel culverts. Dry well pumps will have the inlet pipe from the sediment basin and strainer connected directly to a centrifugal electric pump mounted on the bottom of the pump station. These dry wells are the least expensive to install for electric motor pumps. They are easy to startup and maintain. The station will need adequate ventilation to reduce humidity. Wet wells will have the pump mounted in the water in the station or have a suction line from the water to the pump. A vertical turbine pump will be simple to install and winterize but are typically more expensive. However, vertical turbine pumps have the best efficiency and less power requirements than a centrifugal pump. A top mounted centrifugal pump with a suction line in a wet well station will have the most horsepower requirement and the most maintenance.

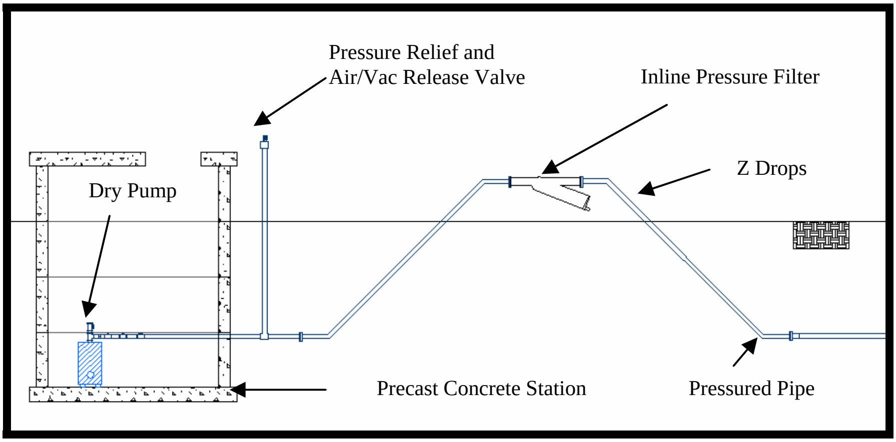

Figure 7. Cross Section of Dry Pump Station with an Inline Pressure Filter

Economics

A great deal of work went into reducing the cost of this system so that it would be competitive and economical for smaller producers. A breakdown of the costs is shown in Table 1. Table 2 compares the cost of this system to a conventional system and to gravity VTS systems designed on other small livestock operations on a per animal unit basis, developed, and constructed by the authors. While the cost appears very high for this project, the system only services a 1 acre (0.4 ha) lot, and the authors believe that the system, could service up to a 3-4 acre (1.2 to 1.6 ha) lot with the only additional appreciable cost of additional risers for the larger VTA needed. As can be seen in Table 1, the largest costs are the pipe installation and electrical hook-up. As can be seen in Table 2, the construction cost is higher than a gravity system, but comparable to a holding pond. If a 50% cost share were available, it is expected by the authors that this system would be affordable to smaller producers. The costs below do not include engineering costs, which are expected to be about 10-25% of the construction cost. Table 2 was developed from 2006 cost data from the Nebraska NRCS, for a hypothetical conventional system (data was extrapolated from several 800 head facilities) for a 1 acre (0.4 ha) 150 head lot (assumes 300 head per sq ft or 30 hd per sq m stocking density) and to 2004 and 2005 cost data from the authors from three gravity VTS systems recently installed. Actual cost data for the “sprinkler” VTS installed was extrapolated for a 3 acre (1.2 ha) lot by adding additional riser and pipe costs.

As can be seen from Table 2, while not as cost effective as a gravity VTS, it is actually less expensive compared to a conventional holding pond that would use in-situ material for a soil liner. In addition, it would be very cost effective, almost 35% of the cost if it could be used at a facility that had sensitive geology and which would require a synthetic liner and if the pond could not be located down-gradient of the production area. A hidden cost is the cost of land application equipment for the holding pond systems, as pumps and irrigation system is not included in this analysis and would be an additional expense for the operator.

Table 1. Construction cost of a “Sprinkler” VTS

Component	Description	Cost
VTA	Terraces & Sed Basin installed	$885
Pipe Installation and plumbing	Inlet, outlet, sprinkler, materials and labor	$3,710
Pump	Berkley B Series	$1,295
Pump station	Pre-cast concrete installed	$829
Electrical	Labor and parts to connect to farm service and wire pump and well.	$2,450
Inlet Structure	Pickets, concrete, labor	$280
Total		$9,449

Table 2. Cost Data of System Relative to Alternatives

System	Cost per AU (head)	Explanation
"sprinkler" VTS (1 acre or 0.4 ha) [1]	$63	From Table 1
"sprinkler" VTS (3 X larger) [1]	$31	Estimated from 1 acre VTS to be $14,000 total, 450 head
Gravity VTS[1]	$17-$30	Gravity sloped VTS, for all components
Conventional Holding Pond with in-situ liner material [2*]	$51	$7,652 for 1 ac (150 head)
Conventional Holding Pond with in-situ liner material [2*] (3X larger)	$44	$19,500 for 3 acre lot (450 head)
Conventional Holding Pond with in-situ liner material and Pump Station [2*]	$151	$15,000 for a lift station, typically required and installed
Conventional Holding Pond System with synthetic liner [2*]	$70	$0.45-$0.5 per sq ft for HDPE (High Density Polyethylene) Assumes pond is 100' by 140' by 9' Additional
Conventional Holding Pond with synthetic liner and Pump Station[2*]	$170	

All cost estimates assume a stocking density of 300 head per sq ft (30 head per sq m), or 150 head per acre (150 head per 0.4 ha) unless otherwise specified as 3X, which would be for a 3 acre (1.2 ha) lot and 450 head. VTA to lot area assumed to be 1:1 in all cases.

[1] Source: Authors Cost Data from 3 recent projects (Henry and Gross, 2007)

[2] Source: Ayala and Reedy, 2007, derived from cost data.

*Does not include land application transfer or equipment costs.

Conclusions

This paper discusses the development and design of a "sprinkler" VTS constructed in southwest Nebraska. They have the advantage of functioning safely in environments that are unsuitable for gravity or flood irrigated VTA technology. The Sprinkler VTA is conceptually, a runoff control system comprised of an over-sized sediment basin, an outlet structure capable of withdrawing liquid from the bottom of a basin, a frost protected dry well pumping station, conveyance piping, and impact sprinkler risers for distribution of runoff water to a dedicated Vegetative Treatment Area.

Several design challenges were faced in the design of this system, how to protect operate the system in near freezing temperatures, extraction of the runoff without solid particles that could cause nozzle plugging of the impact sprinklers, and how to construct it economically. A low cost dry well pump station and intake structure (outlet structure) was developed. Other challenges include acquiring pumps that meet system requirements. The long term maintenance and performance of the system will be evaluated over the next three years.

The economics of the system are competitive, with conventional holding pond systems and in some situations could be ¼ the cost. The cost of the "sprinkler" VTS covered in this paper was around $62 per head, compared to $51-$170 for a conventional system of the same size. More work is needed, to further reduce the cost and the long term maintenance and the operational success is not well known. If proven to be successful, "sprinkler" VTS's will be a very viable, practical and cost effective solution for managing runoff from open lots that cannot use a gravity VTA system.

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