TECHNICAL NOTES

US DEPARTMENT OF AGRICULTURE STATE OF COLORADO NATURAL RESOURCES CONSERVATION SERVICE

ENGINEERING TECHNICAL NOTE 26 **January, 2003**

FEEDLOT RUNOFF TREATMENT SYSTEM

DESCRIPTION and PURPOSE

A feedlot runoff treatment system is a combination of practices including a sediment basin, flow distribution device, and vegetated infiltration area designed for the treatment of stormwater runoff from open livestock feedlots. A conceptual plan is shown in Figure 1. This technical note provides an additional design method for use under NRCS Conservation Practice Standard 635 - Wastewater Treatment Strip.

The purpose of this system is to collect and infiltrate stormwater runoff to prevent degradation of downstream water sources, providing an alternative to the traditional runoff storage pond. The system design addresses both nutrient and hydraulic loading within the infiltration area. The sediment basin and vegetated treatment area are utilized to collect and recycle nutrients for beneficial use.

LIMITATIONS

This system applies only to the treatment of runoff, and shall not include process wastewater such as that generated from a dairy milking center, residential septic system, manure slurry from a confined swine facility or effluent from a waste treatment lagoon. The system is not suitable where runoff from the infiltration area discharges directly to a surface water body. This system is not acceptable for any Concentrated Animal Feeding Operation as defined under either federal or state regulations. The system is limited to use on sites with adequate land area, topography, and soil characteristics such that the design criteria can be satisfied. Generally soils with a depth of less than 2 feet, slopes outside the range of 0.5 to 4%, or an intake family of 1.5 or greater are not suitable. Sites where groundwater is located within 10 feet of the ground surface should be avoided.

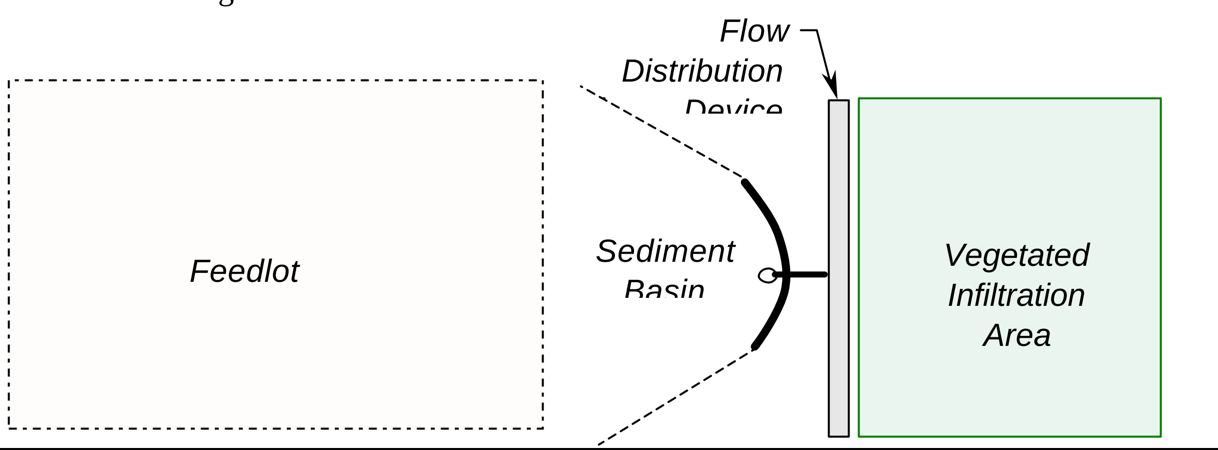

FIGURE 1. Feedlot Runoff Treatment System Schematic

OPERATIONAL CONCEPTS & ASSUMPTIONS

The feedlot runoff treatment system design and operational criteria are based on the following concepts and assumptions:

- Analysis of climate station data indicates 80% to 90% of all rainfall events are smaller in amount than the 2yr - 24 hr event. Therefore infiltrating all the runoff from a 2yr-24hr event within the vegetated treatment area, and providing a high level of treatment for larger storms, will provide an adequate level of water quality protection for runoff receiving areas downstream from Animal Feeding Operations (AFOs).
- Runoff from the feedlot can be detained in the sediment basin until most runoff from direct rainfall on the infiltration area has occurred. This reduces the opportunity for transporting contaminants off the infiltration area during runoff events smaller than the 2yr frequency design storm.
- Feedlot runoff discharged from the sediment basin is applied to the infiltration area by the flow distribution system such that the application rate does not exceed the soil's intake rate.
- The infiltration area is sized such that the annual average nitrogen loading rate does not exceed the nitrogen removal rate from harvesting the vegetation.
- Its assumed the soil moisture content in the plant root zone beneath the infiltration area prior to an event is less than 50% of total water holding capacity. Therefore limiting the design application volume (direct rainfall and lot runoff) to 50% of the soil moisture storage capacity will minimize the opportunity for leaching nutrients below the root zone.
- Extraneous runoff producing areas outside the feedlot must be excluded from the system with diversions, gutters, etc., to the extent feasible.
- Regular maintenance is required, which includes removing solids from the sediment basin and harvesting the vegetation from the infiltration area at least once per year.

DESIGN CRITERIA

Sediment Basin. The storage volume and outlet system shall be sized to:

1. Store the average annual sediment volume delivered from the feedlot area, which is estimated as 2% of the average annual runoff.
2. Provide runoff storage volume and release rate(s) that result in a minimum of 2 hours detention time for the 25yr-24hr runoff event, and adequate detention time to facilitate infiltration of the 2yr-24hr event, without uncontrolled discharge from the basin.

Pipe spillways, consisting of an inlet structure, a flow controlling orifice, and a main conduit will be used as the primary outlet device. The inlet shall consist of a perforated riser or other device designed to preclude entry of debris into the pipe spillway. Risers shall be made from rigid, relatively smooth materials. Perforations may consist of round holes (minimum 1" dia.) or rectangular slots. The minimum diameter or side dimension of any riser shall be 6 inches. The hydraulic capacity of the inlet shall be 1.2 times the required design discharge.

An orifice will be designed to control discharge as nearly as possible to provide the required design discharge. An orifice is typically fabricated from a plate fixed within the riser between the sediment basin channel and the main conduit. A single smooth circular hole centered in the plate provides the flow control. The holes are generally fabricated in 1/4-inch increments.

The main conduit shall consist of non-perforated pipe with a minimum diameter of six inches. Design hydraulic capacity shall be greater than or equal to design orifice discharge.

All pipe spillway components shall be designed to withstand dead loads from earth fill and adjacent structures and live loads due to animal and vehicle traffic. Components and fittings shall be hydraulically smooth, watertight and corrosion-resistant. Where applicable, pipe spillway components shall also be protected from damages resulting from fire and maintenance operations.

Sediment basins formed by earth embankments shall have side slopes of 3H:1V or flatter and minimum top widths of four feet. A natural or excavated emergency spillway will be provided whenever possible. Freeboard of at least 1.0 feet will be provided between 25yr storm detention volume elevation and the crest of the emergency spillway.

The designed dimensions, cross sections and clearance distances shall facilitate maintenance operations, especially sediment removal. The riser and orifice shall be accessible for sediment removal and repair.

Flow Distribution Device. The flow distribution device shall be designed to distribute the outflow from the sediment basin uniformly over the upstream end of the vegetated infiltration area in a manner that satisfies the hydraulic performance criteria for the infiltration area. The water control structure may consist of gated pipe, level weirs or other similar devices connected to the sediment basin outlet. For long infiltration areas multiple flow distribution structures will be necessary to assure adequate application uniformity. Head loss within the flow distribution device should be minimized. Closed conduits shall have a minimum diameter of six inches. The flow distribution device shall be designed to facilitate maintenance, especially sediment and debris removal.

Vegetated Infiltration Area. The infiltration area is designed using graded border irrigation principles to accomplish the following:

1. Infiltrate the sediment basin discharge resulting from a 2 year 24 hour runoff event. The infiltration area is sized such that the infiltration volume does not to exceed 50% of the available water storage capacity in the root zone beneath the infiltration area.
2. Limit flow depth to 6 inches, flow velocity to a maximum of 1.5 ft/sec, and provide a contact time of at least 2 hours for the sediment basin discharge resulting from a 25 year 24 hour storm event; and
3. Limit nitrogen loading to the rate of nitrogen removal from harvesting vegetation in the infiltration area.

Infiltration Design Element. The grass filter area shall be designed to infiltrate the sediment basin discharge resulting from the 2 year - 24 hour rainfall. The following relationship shall be used to allocate soil moisture storage:

$I_F + I_{LR} < 0.5AWC$ where:

I_F = Portion of 2yr-24hr rainfall that falls directly onto the grass filter area and is infiltrated, in inches;

I_{LR} = Volume of lot runoff discharged from the sediment basin that is infiltrated into the grass filter, expressed as an equivalent depth in inches over the grass filter area; and

AWC = Plant available water content of the soil within the root zone.

NRCS procedures may be used to determine runoff depths to compute I_F and I_{LR} using Tables A2 and A3 from Appendix A.

"Available Water Content (AWC)" refers to the amount of moisture which can be stored in the soil root zone and extracted by the plant. AWC by soil type is listed in soil survey data tables in Section II of the NRCS Field Office Technical Guide . The soil must have a minimum depth of two feet.

The intake family curves will be used to determine opportunity and application times. The minimum required application time is given by the relationship

$T_A = T_T - T_F$ where:

T_A = Minimum required application time onto the grass filter area;

T_T = Total opportunity time required for application of $I_F + I_{LR}$; and

T_F = Opportunity time required for infiltration of I_F.

To meet this requirement, the detention time of the sediment basin must equal or exceed the application time, T_A. The peak discharge from the sediment basin pipe spillway is related to the border width and length using the following border irrigation principles:

$$Q = w \times Q_u \quad \text{and} \quad Q_u = \frac{(L)(I_{LR})}{720(T_A)} \quad \text{where:}$$

w = grass filter width (ft);

Q = peak discharge from the sediment basin pipe spillway (cfs);.

Q_u = Unit flow rate through the treatment area, (cfs/ft); and

L = Flow length through the treatment area, (ft).

The parameters I_{LR} and T_A are as previously defined; 720 is a unit conversion factor.

Within the overall width (w) and length (L), the vegetated treatment area will be subdivided into border segments according to the following guideline:

Flow Direction Slope (%)	Maximum Border Width (ft)
0.5 - 1.0	50
1.1 - 2.0	40
2.1 - 4.0	30

Slopes of less than 0.5% or greater than 4.0 % are not applicable to this practice. Uniform slopes in the direction of flow are strongly recommended; however, actual slope may vary from the design slope by ± 50% as long as the slope limits are not exceeded. Each border is to be level in the direction perpendicular to the flow (no cross slope). The maximum border length is 1,200 feet. Flow re-distribution devices shall be provided for each border length increment of 300 feet. Flow distances of 300 feet or less are more conducive to uniform flow and infiltration. The minimum border ridge height shall be 0.8 feet. Grass filter and border dimensions may be adjusted slightly to facilitate maintenance and equipment operation.

Flow Design Element. The flow through the grass filter area shall conform to the following limits:

1. Flow depth less than 6 inches;
2. Flow velocity less than or equal to 1.5 ft/sec; and
3. Contact time (i.e. travel time through the filter) greater than or equal to 2 hours.

The unit discharge determined for the infiltration design element will be used to analyze the flow design. Charts and equations contained in Appendix 1 may be used for this analysis.

The outlet of the grass filter area shall be stable and the filter shall not discharge into an actively-eroding area such as a gully or into any surface water body.

Nitrogen Loading Design Element. Unless site specific data is available, the nitrogen load shall be estimated as 50 pounds per acre-inch of feedlot runoff applied to the treatment area. The amount of runoff shall be determined as a percentage of annual rainfall, for climate data shown in Appendix A. The size of the treatment area must be adequate to assure the annual nitrogen load does not exceed the average annual uptake by the vegetation, based upon a realistic yield goal. Nitrogen uptake or consumption by crop or type of vegetation may be taken from NRCS Agronomy Technical Note No. 78, Colorado State University Cooperative Extension publications, Chapter 6 of the NRCS Agricultural Waste Management Field Handbook, or another appropriate reference. The operation and maintenance plan for the treatment area should include periodic sampling and testing of sediment basin effluent and the infiltration area soils as needed to assess the actual nutrient loading and removal rates in order to evaluate treatment system performance.

Vegetation Design Element. Permanent herbaceous vegetation consisting of a single species or a mixture of grasses, legumes and/or other forbs adapted to the soil and climate shall be established in the treatment strip according to NRCS Conservation Practice Standard Critical Area Planting, Code 342. Vegetation shall be selected based on its ability to withstand anticipated alternating dry and wet conditions and nutrient assimilative capacity as described in Colorado Plant Materials Technical Note

59 for wastewater treatment strips. The vegetation will be established prior to allowing any discharge from the sediment basin, and it will be maintained with a minimum height of four inches.

PLANS AND SPECIFICATIONS

Construction Drawings. Construction drawings will contain the following details:

1. Sediment basin: Dimensions, channel grades, cuts and fills and other related information for earthwork. Pipe spillway dimensions, materials, inlet and outlet elevations, orifice and riser details and pipe trench elevations and grades will also be included.

2. Flow distribution device: Dimensions, materials, elevations and location of device components.

3. Grass filter area: Grading requirements including cuts, fills and finished slopes; dimensions of border areas and berms; and vegetation seeding and establishment requirements.

4. Drawings of other pertinent components such as diversions or gutters.

5. A table of quantities to include but is not limited to excavation, embankment fill, pipe material and fittings, and other appurtenances such as timber, concrete, etc.

Specifications. Construction specifications will be developed for each design which address materials and construction methods. Excavation and embankment grading tolerances, seed quality, and material and installation requirements for pipe, concrete, lumber, and fences, as applicable, are to be included in the specifications. Specifications may be shown in the form of notes on the drawings or a separate document, such as the construction specification for Conservation Practice Standard 635 - Wastewater Treatment Strip.

Acknowledgement
This technical note was adapted primarily from Kansas NRCS publication “Wastewater Treatment Strip Design Supplement”, NRCS, Salina, Kansas.

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APPENDIX A – DESIGN TOOLS

Contents

TABLE A1. Basic Climate Data for Feedlot Runoff Treatment System Design

County	Climate Station	Design Rainfall [1]		Average Precipitation [2]	Annual Runoff [3] (% of Annual Precipitation)	
		2yr-24hr	25yr-24hr			
		(inches)	(inches)	(inches/year)	Concrete Lots	Earth Lots
Adams	Beyers 5ENE	1.8	3.4	15.0	40%	13%
Alamosa	Alamosa WSO AP	0.9	1.9	7.1	35%	10%
Alamosa	Great Sand Dunes NM	0.9	1.9	10.3	35%	10%
Archuleta	Pagosa Springs	1.8	3.0	19.9	33%	10%
Baca	Campo	2.5	5.2	15.5	51%	21%
Baca	Springfield 7WSW	2.5	5.2	15.3	51%	21%
Baca	Walsh	2.5	5.2	15.9	51%	21%
Bent	John Martin Dam	2.1	4.2	11.7	50%	20%
Bent	Las Animas	2.1	4.2	12.2	50%	20%
Boulder	Boulder	2.2	4.0	18.5	35%	11%
Boulder	Longmont 2ESE	2.1	4.0	13.2	35%	11%
Chaffee	Buena Vista	1.4	2.4	10.4	32%	10%
Chaffee	Salida 3W	1.4	2.6	7.3	32%	10%
Cheyenne	Cheyenne Wells	2.3	4.6	15.3	50%	20%
Cheyenne	Kit Carson	2.1	4.2	13.5	50%	20%
Conejos	Manassa	1.0	2.4	13 - 40	32%	10%
Costilla	San Luis	1.0	2.2	11.3	33%	10%
Crowley	Ordway	2.0	3.8	11.2	45%	16%
Custer	Westcliffe	1.6	2.8	14.5	35%	10%
Delta	Cedaredge	1.4	2.0	12.3	30%	10%
Delta	Delta	1.0	2.0	7.9	30%	10%
Denver	Denver WSO AP	2.1	3.9	15.4	36%	12%
Dolores	Rico	1.6	2.8	27.7	31%	10%
Douglas	Castle Rock	2.0	3.4	14 - 20	36%	12%
Eagle	Eagle FAA AP	1.2	2.0	10.7	30%	10%
El Paso	Colorado Springs WSO AP	2.1	3.8	15.8	35%	13%
Fremont	Canon City	1.6	2.8	12.6	32%	10%
Garfield	Glenwood Springs #2	1.2	2.0	17.0	30%	10%
Grand	Grand Lake	1.4	2.4	13.5	33%	10%
Grand	Hot Sulphur Springs	1.0	2.0	12.1	33%	10%
Grand	Kremling	1.0	2.0	11.9	33%	10%
Gunnison	Gunnison	1.0	2.0	10.4	30%	10%
Huerfano	Walsenburg	2.1	3.6	15.5	35%	11%
Jackson	Walden	1.0	2.0	10.4	33%	10%
Kiowa	Eads	2.1	4.5	14.5	50%	20%
Kit Carson	Burlington	2.2	4.2	16.2	50%	17%
Kit Carson	Flagler	2.1	4.0	15.8	50%	17%
Kit Carson	Stratton	2.1	4.2	15.9	50%	17%
La Plata	Durango	1.6	2.6	19.1	32%	10%
La Plata	Ignacio	1.5	2.6	14.2	32%	10%
La Plata	Valecito Dam	2.5	4.0	26.3	32%	10%
Larimer	Estes Park	2.0	3.4	14.0	35%	11%
Larimer	Fort Collins	2.0	3.8	14.9	35%	11%
Las Animas	Branson	2.2	4.3	15.2	45%	13%
Las Animas	Delhi	2.1	3.9	12.2	45%	13%

TABLE A1. continued

County	Climate Station	Design Rainfall		Average	Annual Runoff	
		2yr-24hr	25yr-24hr	Precipitation	(% of Annual Precipitation)	
		(inches)	(inches)	(inches/year)	Concrete Lots	Earth Lots
Las Animas	Trinidad	2.0	3.4	14.7	45%	13%
Lincoln	Arriba	2.0	3.9	16.0	45%	16%
Lincoln	Genoa	1.9	3.8	14.9	45%	16%
Lincoln	Karval	2.0	3.9	13.0	45%	16%
Lincoln	Limon	1.9	3.6	14.4	45%	16%
Logan	Sterling	2.0	3.4	15.4	45%	16%
Mesa	Colbran	1.6	2.4	14.8	30%	10%
Mesa	Fruita 1W	1.2	2.0	8.5	30%	10%
Mesa	Grand Junction	1.0	2.0	8.7	30%	10%
Mesa	Palisade	1.0	1.8	9.8	30%	10%
Moffat	Craig	1.1	2.1	13.2	30%	10%
Moffat	Dinosaur Ntl Monument	1.2	2.2	12.3	30%	10%
Moffat	Maybell	1.0	2.0	12.7	30%	10%
Moffat	Sunbeam	1.0	2.0	9.9	30%	10%
Montezuma	Cortez	1.4	2.5	13.4	33%	10%
Montezuma	Mesa Verde NP	1.5	2.5	18.0	33%	10%
Montrose	Cimmaron 3S	1.2	2.4	13.1	30%	10%
Montrose	Uravan	1.2	2.2	12.9	30%	10%
Morgan	Fort Morgan	1.9	3.4	12.7	43%	15%
Morgan	Wiggins 7SW	1.7	3.2	16.1	43%	15%
Otero	La Junta	2.1	4.0	15.7	45%	16%
Otero	Rocky Ford 2SE	2.0	3.9	11.7	45%	16%
Park	Bailey	1.6	2.6	16.4	30%	10%
Phillips	Holyoke	2.4	4.2	18.1	47%	17%
Prowers	Holly	2.5	5.0	15.1	51%	21%
Prowers	Lamar	2.2	4.5	14.9	51%	21%
Pueblo	Pueblo	2.0	3.7	11.4	37%	13%
Pueblo	Rye	2.0	3.7	22.6	37%	13%
Rio Blanco	Meeker 2	1.4	2.4	14.1	30%	10%
Rio Blanco	Rangely 1E	1.0	2.1	10.3	30%	10%
Rio Grande	Del Norte	1.1	2.2	9.8	32%	10%
Rio Grande	Monte Vista	1.0	1.9	7.1	32%	10%
Routt	Hayden	1.2	2.1	16.7	30%	10%
Routt	Steamboat Springs	1.4	2.8	23.9	30%	10%
Routt	Yampa	1.2	2.2	16.1	30%	10%
Saguache	Saguache	1.0	2.0	8.3	32%	10%
San Miguel	Norwood	1.2	2.5	14.8	30%	10%
Washington	Akron 4e	2.0	3.6	16.7	46%	16%
Weld	Greeley UNC	1.7	3.4	14.2	40%	14%
Weld	New Raymer	1.8	3.4	14.0	40%	14%
Weld	Nunn	1.7	3.4	12.9	40%	14%
Yuma	Bonny Dam 2 NE	2.2	4.4	16.5	48%	17%

[1] *From NOAA Atlas II.*
[2] *From NRCS Temperature and Precipitation (TAPS) Data Files.*
[3] *From NRCS Waste Management Field Handbook, Appendix 10C.*

<u>TABLE A2. Runoff Curve Numbers for Feedlot Runoff Treatment System Design</u>

Runoff Curve Numbers	Hydrologic Soil Group		
Soil Cover Complex & Condition	B	C	D
Feed Lot or Confinement Area, Earth surface	90	90	90
Feed Lot or Confinement Area, Concrete Surface	97	97	97
Treatment Area – Undisturbed Grass (>95% ground cover)	58	71	78
Treatment Area – Grass, Lightly Grazed (>75% ground cover)	61	74	80
Treatment Area – Close Seeded Legume (>50% ground cover)	72	81	85

TABLE A3. Runoff Depths for Selected Curve Numbers and Rainfall Amounts

Curve Number	58	61	71	72	74	80	81	85	90	97
Rainfall Depth	*Runoff Depths in Inches*									
0.8						0.03	0.04	0.09	0.20	0.52
0.9						0.06	0.07	0.13	0.26	0.61
1.0			0.01	0.01	0.02	0.08	0.10	0.17	0.32	0.71
1.1			0.02	0.02	0.04	0.12	0.13	0.22	0.39	0.80
1.2			0.03	0.04	0.06	0.15	0.17	0.27	0.46	0.89
1.3			0.05	0.06	0.09	0.19	0.22	0.33	0.53	0.99
1.4			0.07	0.09	0.12	0.24	0.26	0.39	0.61	1.09
1.5		0.01	0.10	0.11	0.15	0.29	0.31	0.45	0.68	1.18
1.6		0.02	0.13	0.14	0.18	0.34	0.37	0.52	0.76	1.28
1.7	0.01	0.03	0.16	0.18	0.22	0.39	0.42	0.58	0.84	1.38
1.8	0.02	0.04	0.19	0.21	0.26	0.44	0.48	0.65	0.93	1.48
1.9	0.03	0.06	0.23	0.25	0.30	0.50	0.54	0.72	1.01	1.57
2.0	0.04	0.07	0.27	0.29	0.35	0.56	0.60	0.80	1.09	1.67
2.1	0.05	0.09	0.31	0.34	0.40	0.62	0.67	0.87	1.18	1.77
2.2	0.07	0.12	0.35	0.38	0.45	0.69	0.73	0.94	1.27	1.87
2.3	0.09	0.14	0.40	0.43	0.50	0.75	0.80	1.02	1.35	1.97
2.4	0.11	0.17	0.44	0.48	0.55	0.82	0.87	1.10	1.44	2.06
2.5	0.13	0.20	0.49	0.53	0.61	0.89	0.94	1.18	1.53	2.16
2.6	0.16	0.23	0.54	0.58	0.67	0.96	1.01	1.26	1.62	2.26
2.7	0.18	0.26	0.59	0.64	0.72	1.03	1.09	1.34	1.71	2.36
2.8	0.21	0.29	0.65	0.69	0.78	1.10	1.16	1.42	1.80	2.46
2.9	0.24	0.33	0.70	0.75	0.85	1.18	1.24	1.50	1.89	2.56
3.0	0.27	0.37	0.76	0.81	0.91	1.25	1.31	1.59	1.98	2.66
3.1	0.31	0.40	0.82	0.87	0.97	1.33	1.39	1.67	2.08	2.76
3.2	0.34	0.44	0.88	0.93	1.04	1.40	1.47	1.76	2.17	2.86
3.3	0.38	0.49	0.94	0.99	1.10	1.48	1.55	1.84	2.26	2.96
3.4	0.41	0.53	1.00	1.06	1.17	1.56	1.63	1.93	2.35	3.06
3.5	0.45	0.57	1.06	1.12	1.24	1.64	1.71	2.02	2.45	3.15
3.6	0.49	0.62	1.13	1.19	1.31	1.72	1.79	2.10	2.54	3.25
3.7	0.53	0.67	1.19	1.25	1.38	1.80	1.87	2.19	2.64	3.35
3.8	0.58	0.71	1.26	1.32	1.45	1.88	1.95	2.28	2.73	3.45
3.9	0.62	0.76	1.33	1.39	1.52	1.96	2.04	2.37	2.82	3.55
4.0	0.66	0.81	1.39	1.46	1.60	2.04	2.12	2.46	2.92	3.65
4.1	0.71	0.86	1.46	1.53	1.67	2.12	2.21	2.55	3.01	3.75
4.2	0.76	0.92	1.53	1.60	1.74	2.21	2.29	2.64	3.11	3.85
4.3	0.81	0.97	1.60	1.67	1.82	2.29	2.38	2.73	3.20	3.95
4.4	0.85	1.02	1.67	1.75	1.90	2.38	2.46	2.82	3.30	4.05
4.5	0.90	1.08	1.75	1.82	1.97	2.46	2.55	2.91	3.40	4.15
4.6	0.96	1.14	1.82	1.89	2.05	2.55	2.63	3.00	3.49	4.25
4.7	1.01	1.19	1.89	1.97	2.13	2.63	2.72	3.09	3.59	4.35
4.8	1.06	1.25	1.97	2.05	2.21	2.72	2.81	3.18	3.68	4.45
4.9	1.11	1.31	2.04	2.12	2.28	2.81	2.90	3.28	3.78	4.55
5.0	1.17	1.37	2.12	2.20	2.36	2.89	2.99	3.37	3.88	4.65

Intake Family Curves. Most soils map units described in published surveys in irrigated areas have been assigned to Intake Family groups. The Intake Family curves (accumulated intake vs. time) were developed from the following equation:

$$F = aT_o^b + 0.275$$, where:

F = accumulated water intake, in inches;
***T**$_o$* = intake opportunity time, in minutes; and
a and **b** are curve fitting parameters, as described below:

TABLE A5. Soil Intake Family Curve Parameters

Intake Family	Parameter Values	
	a	**b**
0.1	0.0244	0.661
0.3	0.0368	0.7204
0.5	0.0467	0.7475
0.6	0.052	0.7572
0.7	0.0568	0.7656

Intake Family	Parameter Values	
	a	**b**
0.8	0.0614	0.7728
0.9	0.0659	0.7792
1.0	0.0701	0.785
1.5	0.0899	0.799

Available Water Capacity (AWC). AWC is the amount of water held in the soil and available for use by plants. Major soil characteristics affecting AWC are texture, structure, bulk density, salinity, sodicity, mineralogy, soil chemistry and organic matter content. Of these texture is the predominant factor in mineral soils. Table A5 describes AWC by soil texture.

TABLE A6. Available Water Capacity (AWC) by Soil Texture

USDA Soil Texture	AWC Range		Typical AWC Value
	(inches per inch)	(inches per feet)	(inches per feet)
Coarse sand	0.01 – 0.03	0.1 – 0.4	0.25
Sand	0.01 –0.03	0.1 – 0.4	0.25
Fine Sand	0.05 – 0.07	0.6 – 0.8	0.75
Very Fine Sand	0.05 – 0.07	0.6 – 0.8	0.75
Loamy coarse sand	0.06 – 0.08	0.7 – 1.0	0.85
Loamy sand	0.06 – 0.08	0.7 – 1.0	0.85
Loamy fine sand	0.09 – 0.11	1.1 – 1.3	1.25
Loamy very fine sand	0.10 – 0.12	1.0 – 1.4	1.25
Coarse sandy loam	0.10 – 0.12	1.2 – 1.4	1.30
Sandy loam	0.11 – 0.13	1.3 – 1.6	1.45
Fine sandy loam	0.13 – 0.15	1.6 – 1.8	1.70
Very fine sandy loam	0.15 – 0.17	1.8 – 2.0	1.90
Loam	0.16 – 0.18	1.9 – 2.2	2.0
Silt Loam	0.19 – 0.21	2.3 – 2.5	2.4
Silt	0.16 – 0.18	1.9 – 2.2	2.0
Sandy clay loam	0.14 – 0.16	1.7 – 1.9	1.80
Clay loam	0.19 – 0.21	2.3 – 2.5	2.40
Silty clay loam	0.19 – 0.21	2.3 – 2.5	2.40
Sandy Clay	0.15 – 0.17	1.8 – 2.0	1.90
Silty clay	0.15 – 0.17	1.8 – 2.0	1.90
Clay	0.14 – 0.16	1.7 – 1.9	1.80

SEDIMENT BASIN STORAGE AND RELEASE RATE FACTORS

Detention time, flood storage volume and outlet release rates shall be determined based on inflow and outflow hydrographs and standard reservoir routing procedures. For drainage areas of 20 acres or less the following factors may be used in lieu of more detailed analysis:

TABLE A7. Sediment Basin Storage and Release Rate Factors

Detention Time (hours)	Outflow Rate Factor (cfs/ac-in of runoff)	Flood Storage Factor (% of Runoff Volume)	Detention Time (hours)	Outflow Rate Factor (cfs/ac-in of runoff)	Flood Storage Factor (% of Runoff Volume)
2	0.502	25	15	0.056	56
3	0.335	31	18	0.056	59
6	0.168	42	24	0.042	63
9	0.112	48	36	0.028	69
12	0.084	53	48	0.021	75

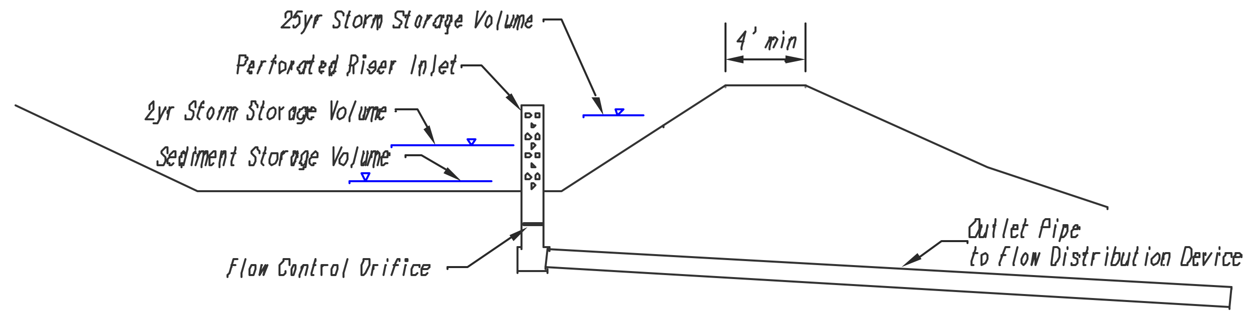
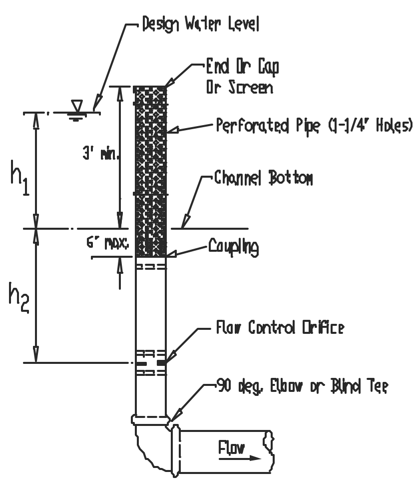


FIGURE A1. Typical Sediment Basin Layout



$$Q_{orifice} = CA\sqrt{2gH}\,,\qquad \text{where:}$$

$\boldsymbol{Q_{orifice}}$ = flow rate through orifice, cfs
C = orifice flow coeficient. *Use **0.6***
A = area of orifice opening
H = head in feet = $0.7\mathbf{h_1} + \mathbf{h_2}$.

FIGURE A2. Typical Inlet Riser Detail

Orifice diameter may be 3” to 6” in ¼” increments. Minimum riser diameter is 2x orifice diameter, with a minimum number of evenly spaced 1¼” holes, as follows:

Riser diameter	6”	8”	10”	12”
# holes per foot	30	40	50	60

DEPTH AND VELOCITY RELATIONSHIPS
FOR SHALLOW FLOW IN VEGETATED CHANNELS

Channel Dimensions. Assuming the treatment area has a cross section similar to a trapezoidal channel across its width, its width will be significantly greater than the flow depth during the design event. Therefore the amount of flow carried in the triangular portions of the channel between the bottom edge and the top of the side slopes can be ignored, and flow velocity and resulting depth computations made assuming a rectangular cross section will result in negligible error for the purpose of this technical note. The following relationships apply for a unit width of rectangular channel:

Manning's equation: $V = \frac{1.486}{n} R^{2/3} S^{1/2}$, where:

V = average flow velocity, in feet per second (fps);
R = hydraulic radius = flow area / wetted perimeter. For a rectangular channel R = wd/w = d, where d is the flow depth.
S = Slope of the Hydraulic grade line, which is similar to the land slope for this application, in feet per foot.
n = Manning's roughness coefficient, which varies in relation to flow velocity, depth and degree of vegetative retardance as follows:

$$n = e^{(0.01333 C_1 \ln(VR)^2 - 0.0945 C_1 \ln(VR) + 0.297 C_1 - 4.16)}$$, and

C1 is c coefficient from the following table:

Vegetative Retardance	C_1	n_{max}
A	10.00	-
B	7.64	-
C	5.60	0.30
D	4.44	0.20
E	2.88	-

From continuity the flow rate, Q = VA , and from above, Q = VR = Vd for the unit width of flow. Therefore by substitution the expression for n becomes:

$$n = e^{(0.01333 C_1 (\ln Q_u)^2 - 0.0945 C_1 \ln(Q_u) + 0.297 C_1 - 4.16)}$$, where

Qu = the unit flow rate, in cubic feet per second

Solution of the equations to obtain V & D for a given Qu is a trial and error procedure. Its recommended these values be obtained from published charts for vegetated channel design or by use or several computer programs available for this purpose. Tables A8 – A10 have been prepared for this purpose. NRCS Colorado Plant Material Technical Note 59 lists appropriate retardance values for selected vegetation species. The solutions must be determined to assure adequate capacity under the highest retardance condition and stability under the lowest or most erosive condition. In addition ARS software "SRFR" or other similar models can be used to optimize graded border design for the treatment area, and provide an estimate of system application uniformity and efficiency for the design storms.

TABLE A8. Vegetated Filter Flow Depth, Velocity and Unit Flow Rate at **C** Retardance

Depth		Slope = 0.5%		Slope = 1.0%		Slope = 1.5%		Slope = 2%		Slope = 2.5%		Slope = 3%		Slope = 3.5%		Slope = 4.0%	
		v	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**
(inches)	(feet)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)
0.1	0.0083	0.0144	0.0001	0.0204	0.0002	0.0250	0.0002	0.0289	0.0002	0.0323	0.0003	0.0354	0.0003	0.0382	0.0003	0.0408	0.0003
0.2	0.0167	0.0229	0.0004	0.0324	0.0005	0.0397	0.0007	0.0458	0.0008	0.0512	0.0009	0.0561	0.0009	0.0606	0.0010	0.0648	0.0011
0.3	0.0250	0.0300	0.0008	0.0425	0.0011	0.0520	0.0013	0.0601	0.0015	0.0671	0.0017	0.0736	0.0018	0.0794	0.0020	0.0849	0.0021
0.4	0.0333	0.0364	0.0012	0.0514	0.0017	0.0630	0.0021	0.0727	0.0024	0.0813	0.0027	0.0891	0.0030	0.0962	0.0032	0.1029	0.0034
0.5	0.0417	0.0422	0.0018	0.0597	0.0025	0.0731	0.0030	0.0844	0.0035	0.0944	0.0039	0.1034	0.0043	0.1117	0.0047	0.1194	0.0050
0.6	0.0500	0.0477	0.0024	0.0674	0.0034	0.0826	0.0041	0.0953	0.0048	0.1066	0.0053	0.1168	0.0058	0.1261	0.0063	0.1348	0.0067
0.7	0.0583	0.0528	0.0031	0.0747	0.0044	0.0915	0.0053	0.1056	0.0062	0.1181	0.0069	0.1294	0.0075	0.1398	0.0082	0.1494	0.0087
0.8	0.0667	0.0577	0.0038	0.0817	0.0054	0.1000	0.0067	0.1155	0.0077	0.1291	0.0086	0.1414	0.0094	0.1528	0.0102	0.1633	0.0109
0.9	0.0750	0.0625	0.0047	0.0883	0.0066	0.1082	0.0081	0.1249	0.0094	0.1397	0.0105	0.1530	0.0115	0.1652	0.0124	0.1767	0.0132
1.0	0.0833	0.0670	0.0056	0.0948	0.0079	0.1161	0.0097	0.1340	0.0112	0.1498	0.0125	0.1641	0.0137	0.1773	0.0148	0.1895	0.0158
1.1	0.0917	0.0714	0.0065	0.1010	0.0093	0.1237	0.0113	0.1428	0.0131	0.1597	0.0146	0.1749	0.0160	0.1889	0.0173	0.2019	0.0185
1.2	0.1000	0.0757	0.0076	0.1070	0.0107	0.1311	0.0131	0.1513	0.0151	0.1692	0.0169	0.1853	0.0185	0.2002	0.0200	0.2140	0.0214
1.3	0.1083	0.0798	0.0086	0.1129	0.0122	0.1382	0.0150	0.1596	0.0173	0.1785	0.0193	0.1955	0.0212	0.2112	0.0229	0.2257	0.0245
1.4	0.1167	0.0839	0.0098	0.1186	0.0138	0.1452	0.0169	0.1677	0.0196	0.1875	0.0219	0.2054	0.0240	0.2219	0.0259	0.2372	0.0277
1.5	0.1250	0.0878	0.0110	0.1242	0.0155	0.1521	0.0190	0.1756	0.0219	0.1963	0.0245	0.2151	0.0269	0.2323	0.0290	0.2483	0.0310
1.6	0.1333	0.0917	0.0122	0.1296	0.0173	0.1588	0.0212	0.1833	0.0244	0.2050	0.0273	0.2245	0.0299	0.2425	0.0323	0.2593	0.0346
1.7	0.1417	0.0954	0.0135	0.1350	0.0191	0.1653	0.0234	0.1909	0.0270	0.2134	0.0302	0.2338	0.0331	0.2525	0.0358	0.2699	0.0382
1.8	0.1500	0.0991	0.0149	0.1402	0.0210	0.1717	0.0258	0.1983	0.0297	0.2217	0.0333	0.2429	0.0364	0.2623	0.0393	0.2804	0.0421
1.9	0.1583	0.1028	0.0163	0.1454	0.0230	0.1780	0.0282	0.2056	0.0325	0.2298	0.0364	0.2518	0.0399	0.2719	0.0431	0.2907	0.0460
2.0	0.1667	0.1064	0.0177	0.1504	0.0251	0.1842	0.0307	0.2127	0.0355	0.2378	0.0396	0.2605	0.0434	0.2814	0.0469	0.3008	0.0501
2.1	0.1750	0.1099	0.0192	0.1554	0.0272	0.1903	0.0333	0.2198	0.0385	0.2457	0.0430	0.2691	0.0471	0.2907	0.0509	0.3108	0.0544
2.2	0.1833	0.1133	0.0208	0.1603	0.0294	0.1963	0.0360	0.2267	0.0416	0.2534	0.0465	0.2776	0.0509	0.2999	0.0550	0.3206	0.0588
2.3	0.1917	0.1167	0.0224	0.1651	0.0316	0.2022	0.0388	0.2335	0.0448	0.2611	0.0500	0.2860	0.0548	0.3089	0.0592	0.3302	0.0633
2.4	0.2000	0.1201	0.0240	0.1699	0.0340	0.2080	0.0416	0.2402	0.0480	0.2686	0.0537	0.2942	0.0588	0.3178	0.0636	0.3397	0.0679
2.5	0.2083	0.1234	0.0257	0.1745	0.0364	0.2138	0.0445	0.2468	0.0514	0.2760	0.0575	0.3023	0.0630	0.3265	0.0680	0.3491	0.0727
3.0	0.2500	0.1394	0.0348	0.1971	0.0493	0.2414	0.0604	0.2787	0.0697	0.3116	0.0779	0.3414	0.0853	0.3687	0.0922	0.3942	0.0986
3.5	0.2917	0.1545	0.0450	0.2184	0.0637	0.2675	0.0780	0.3089	0.0901	0.3454	0.1007	0.3783	0.1103	0.4087	0.1192	0.4369	0.1274
4.0	0.3333	0.1688	0.0563	0.2388	0.0796	0.2924	0.0975	0.3377	0.1126	0.3775	0.1258	0.4136	0.1379	0.4814	0.1605	0.6511	0.2170
4.5	0.3750	0.1826	0.0685	0.2583	0.0969	0.3163	0.1186	0.3653	0.1370	0.4894	0.1835	0.7094	0.2660	0.9234	0.3463	1.1320	0.4245
5.0	0.4167	0.1959	0.0816	0.2771	0.1154	0.3393	0.1414	0.5764	0.2401	0.8508	0.3545	1.1159	0.4650	1.3727	0.5720	1.6220	0.6758
5.5	0.4583	0.2088	0.0957	0.2952	0.1353	0.5560	0.2549	0.8937	0.4096	1.2177	0.5581	1.5289	0.7007	1.8283	0.8380	2.1170	0.9703
6.0	0.5000	0.2212	0.1106	0.4036	0.2018	0.7384	0.3692	1.2162	0.6081	1.5900	0.7950	1.9455	0.9727	2.2854	1.1427	2.6114	1.3057

TABLE A9. *Vegetated Filter Flow Depth, Velocity and Unit Flow Rate at D Retardance*

Depth		Slope = 0.5%		Slope = 1.0%		Slope = 1.5%		Slope = 2%		Slope = 2.5%		Slope = 3%		Slope = 3.5%		Slope = 4.0%	
		v	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**
(inches)	(feet)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)
0.1	0.0083	0.0217	0.0002	0.0306	0.0003	0.0375	0.0003	0.0433	0.0004	0.0484	0.0004	0.0530	0.0004	0.0573	0.0005	0.0612	0.0005
0.2	0.0167	0.0344	0.0006	0.0486	0.0008	0.0595	0.0010	0.0687	0.0011	0.0769	0.0013	0.0842	0.0014	0.0909	0.0015	0.0972	0.0016
0.3	0.0250	0.0450	0.0011	0.0637	0.0016	0.0780	0.0020	0.0901	0.0023	0.1007	0.0025	0.1103	0.0028	0.1192	0.0030	0.1274	0.0032
0.4	0.0333	0.0546	0.0018	0.0772	0.0026	0.0945	0.0032	0.1091	0.0036	0.1220	0.0041	0.1337	0.0045	0.1444	0.0048	0.1543	0.0051
0.5	0.0417	0.0633	0.0026	0.0895	0.0037	0.1097	0.0046	0.1266	0.0053	0.1416	0.0059	0.1551	0.0065	0.1675	0.0070	0.1791	0.0075
0.6	0.0500	0.0715	0.0036	0.1011	0.0051	0.1238	0.0062	0.1430	0.0071	0.1599	0.0080	0.1751	0.0088	0.1892	0.0095	0.2022	0.0101
0.7	0.0583	0.0792	0.0046	0.1121	0.0065	0.1372	0.0080	0.1585	0.0092	0.1772	0.0103	0.1941	0.0113	0.2096	0.0122	0.2241	0.0131
0.8	0.0667	0.0866	0.0058	0.1225	0.0082	0.1500	0.0100	0.1732	0.0115	0.1937	0.0129	0.2122	0.0141	0.2292	0.0153	0.2450	0.0163
0.9	0.0750	0.0937	0.0070	0.1325	0.0099	0.1623	0.0122	0.1874	0.0141	0.2095	0.0157	0.2295	0.0172	0.2479	0.0186	0.2650	0.0199
1.0	0.0833	0.1005	0.0084	0.1421	0.0118	0.1741	0.0145	0.2010	0.0168	0.2247	0.0187	0.2462	0.0205	0.2659	0.0222	0.2843	0.0237
1.1	0.0917	0.1071	0.0098	0.1515	0.0139	0.1855	0.0170	0.2142	0.0196	0.2395	0.0220	0.2623	0.0240	0.2834	0.0260	0.3029	0.0278
1.2	0.1000	0.1135	0.0113	0.1605	0.0161	0.1966	0.0197	0.2270	0.0227	0.2538	0.0254	0.2780	0.0278	0.3003	0.0300	0.3210	0.0321
1.3	0.1083	0.1197	0.0130	0.1693	0.0183	0.2074	0.0225	0.2394	0.0259	0.2677	0.0290	0.2932	0.0318	0.3167	0.0343	0.3386	0.0367
1.4	0.1167	0.1258	0.0147	0.1779	0.0208	0.2179	0.0254	0.2516	0.0293	0.2812	0.0328	0.3081	0.0359	0.3328	0.0388	0.3558	0.0415
1.5	0.1250	0.1317	0.0165	0.1863	0.0233	0.2281	0.0285	0.2634	0.0329	0.2945	0.0368	0.3226	0.0403	0.3484	0.0436	0.3725	0.0466
1.6	0.1333	0.1375	0.0183	0.1944	0.0259	0.2381	0.0318	0.2750	0.0367	0.3074	0.0410	0.3368	0.0449	0.3638	0.0485	0.3889	0.0519
1.7	0.1417	0.1432	0.0203	0.2025	0.0287	0.2480	0.0351	0.2863	0.0406	0.3201	0.0453	0.3507	0.0497	0.3788	0.0537	0.4049	0.0574
1.8	0.1500	0.1487	0.0223	0.2103	0.0315	0.2576	0.0386	0.2974	0.0446	0.3325	0.0499	0.3643	0.0546	0.3935	0.0590	0.4206	0.0631
1.9	0.1583	0.1542	0.0244	0.2180	0.0345	0.2670	0.0423	0.3084	0.0488	0.3448	0.0546	0.3777	0.0598	0.4079	0.0646	0.4361	0.0690
2.0	0.1667	0.1595	0.0266	0.2256	0.0376	0.2763	0.0461	0.3191	0.0532	0.3567	0.0595	0.3908	0.0651	0.4221	0.0704	0.4513	0.0752
2.1	0.1750	0.1648	0.0288	0.2331	0.0408	0.2855	0.0500	0.3296	0.0577	0.3685	0.0645	0.4037	0.0707	0.4361	0.0763	0.4662	0.0816
2.2	0.1833	0.1700	0.0312	0.2404	0.0441	0.2945	0.0540	0.3400	0.0623	0.3801	0.0697	0.4164	0.0763	0.4498	0.0825	0.4809	0.0882
2.3	0.1917	0.1751	0.0336	0.2477	0.0475	0.3033	0.0581	0.3502	0.0671	0.3916	0.0751	0.4290	0.0822	0.4633	0.0888	0.4953	0.0949
2.4	0.2000	0.1802	0.0360	0.2548	0.0510	0.3120	0.0624	0.3603	0.0721	0.4029	0.0806	0.4413	0.0883	0.4767	0.0953	0.5096	0.1019
2.5	0.2083	0.1851	0.0386	0.2618	0.0545	0.3207	0.0668	0.3703	0.0771	0.4140	0.0862	0.4535	0.0945	0.4898	0.1020	0.5436	0.1133
3.0	0.2500	0.2091	0.0523	0.2957	0.0739	0.3621	0.0905	0.4181	0.1045	0.5560	0.1390	0.7153	0.1788	0.8722	0.2180	1.0266	0.2566
3.5	0.2917	0.2317	0.0676	0.3277	0.0956	0.4784	0.1395	0.7057	0.2058	0.9268	0.2703	1.1416	0.3330	1.3496	0.3936	1.5520	0.4527
4.0	0.3333	0.2533	0.0844	0.4431	0.1477	0.7501	0.2500	1.0434	0.3478	1.3235	0.4412	1.5914	0.5305	1.8488	0.6163	2.0965	0.6988
4.5	0.3750	0.2739	0.1027	0.6567	0.2463	1.0391	0.3897	1.3966	0.5237	1.7333	0.6500	2.0525	0.7697	2.3566	0.8837	2.6480	0.9930
5.0	0.4167	0.3805	0.1585	0.8821	0.3675	1.3381	0.5575	1.7576	0.7323	2.1488	0.8954	2.5168	1.0487	2.8656	1.1940	3.1983	1.3326
5.5	0.4583	0.5215	0.2390	1.1155	0.5113	1.6425	0.7528	2.1217	0.9725	2.5647	1.1755	2.9793	1.3655	3.3705	1.5448	3.7423	1.7152
6.0	0.5000	0.6694	0.3347	1.3531	0.6765	1.9489	0.9745	2.4851	1.2425	2.9778	1.4889	3.4367	1.7183	3.8684	1.9342	4.2772	2.1386

TABLE A10. Vegetated Filter Flow Depth, Velocity and Unit Flow Rate at E Retardance

Depth		Slope = 0.5%		Slope = 1.0%		Slope = 1.5%		Slope = 2%		Slope = 2.5%		Slope = 3%		Slope = 3.5%		Slope = 4.0%	
		v	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**	**v**	**Qu**
(inches)	(feet)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)	(fps)	(cfs/ft)
0.1	0.0083	0.0217	0.0002	0.0306	0.0003	0.0375	0.0003	0.0433	0.0004	0.0484	0.0004	0.0530	0.0004	0.0573	0.0005	0.0612	0.0005
0.2	0.0167	0.0344	0.0006	0.0486	0.0008	0.0595	0.0010	0.0687	0.0011	0.0769	0.0013	0.0842	0.0014	0.0909	0.0015	0.0972	0.0016
0.3	0.0250	0.0450	0.0011	0.0637	0.0016	0.0780	0.0020	0.0901	0.0023	0.1007	0.0025	0.1103	0.0028	0.1192	0.0030	0.1274	0.0032
0.4	0.0333	0.0546	0.0018	0.0772	0.0026	0.0945	0.0032	0.1091	0.0036	0.1220	0.0041	0.1337	0.0045	0.1444	0.0048	0.1543	0.0051
0.5	0.0417	0.0633	0.0026	0.0895	0.0037	0.1097	0.0046	0.1266	0.0053	0.1416	0.0059	0.1551	0.0065	0.1675	0.0070	0.1791	0.0075
0.6	0.0500	0.0715	0.0036	0.1011	0.0051	0.1238	0.0062	0.1430	0.0071	0.1599	0.0080	0.1751	0.0088	0.1892	0.0095	0.2022	0.0101
0.7	0.0583	0.0792	0.0046	0.1121	0.0065	0.1372	0.0080	0.1585	0.0092	0.1772	0.0103	0.1941	0.0113	0.2096	0.0122	0.2241	0.0131
0.8	0.0667	0.0866	0.0058	0.1225	0.0082	0.1500	0.0100	0.1732	0.0115	0.1937	0.0129	0.2122	0.0141	0.2292	0.0153	0.2450	0.0163
0.9	0.0750	0.0937	0.0070	0.1325	0.0099	0.1623	0.0122	0.1874	0.0141	0.2095	0.0157	0.2295	0.0172	0.2479	0.0186	0.2650	0.0199
1.0	0.0833	0.1005	0.0084	0.1421	0.0118	0.1741	0.0145	0.2010	0.0168	0.2247	0.0187	0.2462	0.0205	0.2659	0.0222	0.2843	0.0237
1.1	0.0917	0.1071	0.0098	0.1515	0.0139	0.1855	0.0170	0.2142	0.0196	0.2395	0.0220	0.2623	0.0240	0.2834	0.0260	0.3029	0.0278
1.2	0.1000	0.1135	0.0113	0.1605	0.0161	0.1966	0.0197	0.2270	0.0227	0.2538	0.0254	0.2780	0.0278	0.3003	0.0300	0.3210	0.0321
1.3	0.1083	0.1197	0.0130	0.1693	0.0183	0.2074	0.0225	0.2394	0.0259	0.2677	0.0290	0.2932	0.0318	0.3167	0.0343	0.3386	0.0367
1.4	0.1167	0.1258	0.0147	0.1779	0.0208	0.2179	0.0254	0.2516	0.0293	0.2812	0.0328	0.3081	0.0359	0.3328	0.0388	0.3558	0.0415
1.5	0.1250	0.1317	0.0165	0.1863	0.0233	0.2281	0.0285	0.2634	0.0329	0.2945	0.0368	0.3226	0.0403	0.3484	0.0436	0.3725	0.0466
1.6	0.1333	0.1375	0.0183	0.1944	0.0259	0.2381	0.0318	0.2750	0.0367	0.3074	0.0410	0.3368	0.0449	0.3638	0.0485	0.3889	0.0519
1.7	0.1417	0.1432	0.0203	0.2025	0.0287	0.2480	0.0351	0.2863	0.0406	0.3201	0.0453	0.3507	0.0497	0.3788	0.0537	0.4049	0.0574
1.8	0.1500	0.1487	0.0223	0.2103	0.0315	0.2576	0.0386	0.2974	0.0446	0.3325	0.0499	0.3643	0.0546	0.3935	0.0590	0.4206	0.0631
1.9	0.1583	0.1542	0.0244	0.2180	0.0345	0.2670	0.0423	0.3084	0.0488	0.3448	0.0546	0.3777	0.0598	0.4079	0.0646	0.4361	0.0690
2.0	0.1667	0.1595	0.0266	0.2256	0.0376	0.2763	0.0461	0.3191	0.0532	0.3567	0.0595	0.3908	0.0651	0.4221	0.0704	0.4513	0.0752
2.1	0.1750	0.1648	0.0288	0.2331	0.0408	0.2855	0.0500	0.3296	0.0577	0.3685	0.0645	0.4037	0.0707	0.4361	0.0763	0.4662	0.0816
2.2	0.1833	0.1700	0.0312	0.2404	0.0441	0.2945	0.0540	0.3400	0.0623	0.3801	0.0697	0.4164	0.0763	0.4498	0.0825	0.4809	0.0882
2.3	0.1917	0.1751	0.0336	0.2477	0.0475	0.3033	0.0581	0.3502	0.0671	0.3916	0.0751	0.4290	0.0822	0.4633	0.0888	0.4953	0.0949
2.4	0.2000	0.1802	0.0360	0.2548	0.0510	0.3120	0.0624	0.3603	0.0721	0.4029	0.0806	0.4413	0.0883	0.4767	0.0953	0.5096	0.1019
2.5	0.2083	0.1851	0.0386	0.2618	0.0545	0.3207	0.0668	0.3703	0.0771	0.4140	0.0862	0.4535	0.0945	0.4898	0.1020	0.5436	0.1133
3.0	0.2500	0.2091	0.0523	0.2957	0.0739	0.3621	0.0905	0.4181	0.1045	0.5560	0.1390	0.7153	0.1788	0.8722	0.2180	1.0270	0.2568
3.5	0.2917	0.2317	0.0676	0.3277	0.0956	0.4784	0.1395	0.7057	0.2058	0.9268	0.2703	1.1416	0.3330	1.3497	0.3937	1.5520	0.4527
4.0	0.3333	0.2533	0.0844	0.4433	0.1478	0.7501	0.2500	1.0434	0.3478	1.3235	0.4412	1.5913	0.5304	1.8486	0.6162	2.0965	0.6988
4.5	0.3750	0.2739	0.1027	0.6567	0.2463	1.0391	0.3897	1.3967	0.5238	1.7333	0.6500	2.0525	0.7697	2.3566	0.8837	2.6480	0.9930
5.0	0.4167	0.3805	0.1585	0.8821	0.3675	1.3382	0.5576	1.7576	0.7323	2.1487	0.8953	2.5167	1.0486	2.8656	1.1940	3.1983	1.3326
5.5	0.4583	0.5215	0.2390	1.1155	0.5113	1.6425	0.7528	2.1217	0.9725	2.5647	1.1755	2.9793	1.3655	3.3706	1.5449	3.7423	1.7152
6.0	0.5000	0.6694	0.3347	1.3532	0.6766	1.9488	0.9744	2.4851	1.2425	2.9778	1.4889	3.4367	1.7183	3.8684	1.9342	4.2772	2.1386

Feedlot Runoff Treatment System Design Computations

Project Name:	Tech Note 26 Example
Location:	Greeley, CO

Computed By:	*JEA*	*Checked By:*	
Date:	1/9/03	*Date:*	

RAINFALL AND RUNOFF ESTIMATION FOR FEEDLOT AREA

Climate Station: Greeley UNC

	Earth Surfaces		Paved Surfaces		Roofed Surfaces	
Contributing Lot Area:	**5**	*acres*	**0**	*sqft*	**0**	*sqft*
Runoff Curve Numbers:	**90**		**97**		**100**	
2yr-24hr Rainfall:	**1.7**	*inches*	**1.7**	*inches*	**1.7**	*inches*
2yr-24hr Runoff:	**0.84**	*inches*	**1.38**	*inches*	**1.70**	*inches*
25yr-24hr Rainfall:	**3.4**	*inches*	**3.40**	*inches*	**3.40**	*inches*
25yr-24hr Runoff:	**2.35**	*inches*	**3.06**	*inches*	**3.40**	*inches*
Ave. Annual Precipitation:	**14.2**	*inches*	**14.2**	*inches*	**14.2**	*inches*
Average Annual Runoff:	**14%**		**40%**		**100%**	
Average Annual Runoff:	**1.99**	*inches*	***5.68***	*inches*	***14.20***	*inches*

2yr-24hr Runoff Volume:	**4.22**	*Acre-inches*
25yr-24hr Runoff Volume:	**11.77**	*Acre-inches*
Average Annual Runoff Volume:	**9.94**	*Acre-inches*
Average Annual Sediment Yield:	**0.20**	*Acre-inches (2% of runoff volume)*
Average Annual Nitrogen Yield:	**497**	*Pounds/year (50#/Acre-inch of runoff)*

PHYSICAL DATA FOR PROPOSED TREATMENT AREA

Soil Type: **Weld Sandy Loam**

Hydrologic Group:	C		Intake Family:	0.3
Water Holding Capacity:	**0.18**	*in/in*	a =	0.0368
Maximum rooting Depth:	**60**	*inches*	b =	0.7204
Maximum Infiltration Depth:	**5.4**	*inches (50% AWC)*		
Land Slope in Direction of Flow:	**0.01**	*ft/ft*		
Maximum Available Length:	**600**	*feet*	Available Width:	**300** *feet*

Feedlot Runoff Treatment System Design Computations

PROPOSED TREATMENT AREA VEGETATION TYPE AND CHARACTERISTICS

Species	Mix Fraction	Rooting Depth (inches)	N Content (% DM)
Smooth Brome	**60.0%**		**1.75%**
Alfalfa	**40.0%**		**2.25%**

Expected Yield: **4.00** tons/acre Annual N Removal: **156** lbs./acre

Vegetation Condition: Close Seeded Legume (>50% ground cover), C Soil:

Runoff Curve Number: **81** 2yr-24hr Runoff: **0.42** inches I_{TA} = **1.28** inches

Flow Retardence: C Time to Infiltrate I_{TA} = **98** minutes

PROPOSED TREATMENT AREA DIMENSIONS

Minimum Area for N Removal:	**3.19**	acres (To utilize annual N Yield from feedlot)
Minimum Area for Runoff Infiltration:	**0.78**	acres (To Infiltrate 2yr Lot Runoff Event)
Use:	**3.2**	acres *Is Adequate Land Available*? ***YES***
Approximate Dimensions:	**600**	ft long x **231** feet wide (W = Area/Length)
Use:	**600**	ft long x **240** feet wide
Target Infiltration Amount, I_{LR}:	**1.32**	inches (for infiltration of 2yr Runoff Event)
Total Infiltration Amount, I_T:	**2.60**	inches (lot runoff + direct precip. on treatment area)
Time to Infiltrate I_T:	**316**	minutes Time to Infiltrate I_{LR}, T_A= **218** minutes

SEDIMENT BASIN DESIGN REQUIREMENTS

For the 2yr-24hr Event:

Required Detention Period >	**3.6**	hours Use **6** hours
Storage Factor =	**0.42**	(Vs/Vr)
Minimum Storage Volume =	**1.77**	acre-inches, or **6,430** cu.ft.
Release Rate Factor =	**0.168**	cfs/ac-in runoff
Design Release Rate =	**0.71**	cfs Unit Q = **0.0030** cfs/ft (Q/W)
		Limiting Qu = **0.0051** cfs/ft

For the 25yr-24hr Event: Is Qu > Unit Q ? ***OK***

Maximum allowable flow velocity =	**0.0833**	fps (L, ft. / 7,200 sec.)
Flow Depth =	**0.82**	inches depth < 6" ? **OK**
Maximum Unit Flow Rate =	**0.0057**	cfs/ft
Minimum Detention Period:	**8.6**	hours - - -> ***USE*** **10** hours
Storage Factor =	**0.5**	(Vs/Vr)
Minimum Storm Storage Volume =	**5.89**	acre-inches, or **21,367** cuft
Release Rate Factor =	**0.101**	cfs/ac-in
Maximum Basin Release Rate =	**1.19**	cfs

APPENDIX C – BLANK FORMS

Project Name:

Location:

Computed By:		Checked By:	
Date:		Date:	

RAINFALL AND RUNOFF ESTIMATION FOR FEEDLOT AREA

	Earth Surfaces		Paved Surfaces		Roofed Surfaces	
Contributing Lot Area:		acres		sqft		sqft
Runoff Curve # (Table A2):						
2yr-24hr Rainfall (Table A1):		inches		inches		inches
2yr-24hr Runoff (Table A3):		inches		inches		inches
25yr-24hr Rainfall (Table A1):		inches		inches		inches
25yr-24hr Runoff (Table A3):		inches		inches		inches
Ave. Annual Precip. (Table A1):		inches		inches		inches
Ave. Annual Runoff (Table A1):		%		%		%
Ave. Annual Runoff:		inches		inches		inches

	Total	
2yr-24hr Runoff Volume:		Acre-inches
25yr-24hr Runoff Volume:		Acre-inches
Average Annual Runoff Volume:		Acre-inches
Average Annual Sediment Yield:		Acre-inches (2% of runoff volume)
Average Annual Nitrogen Yield:		Pounds/year (50#/Acre-inch of runoff)

PHYSICAL DATA FOR PROPOSED TREATMENT AREA

Predominant Soil Type:

Hydrologic Group:			NRCS Intake Family:		
Available Water Holding Capacity (AWC):		in/in	a =		(Table A5)
Maximum rooting Depth:		inches	b =		(Table A5)
Maximum Infiltration Depth:		inches (50% AWC)			
Land Slope in Direction of Flow:		ft/ft			
Maximum Available Length:		feet	Available Width:		feet

PROPOSED TREATMENT AREA VEGETATION TYPE AND CHARACTERISTICS

Species	Mix Fraction %	Rooting Depth (inches)	N Content (% DM)

Expected Yield: ______ tons/acre Annual N Removal: ______ lbs./acre

Vegetation Condition: ______

Runoff Curve Number: ______ (table A2) 2yr-24hr Runoff: ______ inches (table A3)

Flow Retardance @ Maturity: ______

2yr Precip. - Runoff = $\mathbf{I}_{\mathbf{TA}}$ = ______ inches Infiltration time T_{TA} = ______ minutes

PROPOSED TREATMENT AREA DIMENSIONS

Minimum Area for N Removal: ______ acres (To utilize annual N Yield from feedlot)

Minimum Area for Runoff Infiltration: ______ acres (To Infiltrate 2yr Lot Runoff Event)

Use: ______ acres

Approximate Dimensions: ______ ft long x ______ feet wide (W = Area/Length)

Use: ______ ft long x ______ feet wide

Target Infiltration Amount, $\mathbf{I}_{\mathbf{LR}}$: ______ inches (for infiltration of 2yr Runoff Event)

Total Infiltration Amount, $\mathbf{I}_{\mathbf{T}}$: ______ inches (lot runoff + direct precip. on treatment area)

Time to Infiltrate I_T, $\mathbf{T}_{\mathbf{IT}}$: ______ minutes

Time to Infiltrate I_{LR}, $\mathbf{T}_{\mathbf{LR}}$: ______ minutes

SEDIMENT BASIN DESIGN REQUIREMENTS

For the 2yr-24hr Event:

Required Detention Period > ______ hours Use ______ hours

Storage Factor = ______ (Vs/Vr)

Minimum Storage Volume = ______ acre-inches, or ______ cu.ft.

Release Rate Factor (Table A7) = ______ cfs/ac-in runoff

Design Release Rate = ______ cfs Unit Q = ______ cfs/ft (Q/W)

Limiting Qu = ______ cfs/ft

For the 25yr-24hr Event:

Maximum allowable flow velocity = ______ fps (L, ft. / 7,200 sec.)

Flow Depth = ______ inches depth < 6" ?

Maximum Unit Flow Rate = ______ cfs/ft (calculated or from table)

Minimum Detention Period: ______ hours - - -> ***USE*** ______ hours

Storage Factor = ______ (Vs/Vr)

Minimum Storm Storage Volume = ______ acre-inches, or ______ cuft

Release Rate Factor = ______ cfs/ac-in

Maximum Basin Release Rate = ______ cfs