STREAMSIDE LIVESTOCK EXCLUSION:

A tool for increasing farm income and improving water quality

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Introduction

Did you know that livestock prefer a clean water source and that they are healthier and more productive when they drink clean water? Livestock producers who restrict or eliminate access to streams and/or farm ponds and convert to a cleaner, alternative water source can expect increased productivity, and improvements in riparian vegetation and in-stream water quality. Livestock stream exclusion practices are gaining popularity across Virginia. This publication, produced through the cooperation of Virginia Cooperative Extension and the Department of Conservation and Recreation, describes selected reasons for implementing streamside livestock exclusion fencing, and briefly describes how to implement streamside livestock exclusion fencing.

Information gleaned from an extensive search of peer-reviewed research literature, extension publications, and trade publications is used throughout this publication and is referenced accordingly. In addition, a non-scientific selected group of twenty producers who have implemented various aspects of streamside livestock exclusion fencing and/or pasture management in Virginia were interviewed. Anecdotes from these producers regarding their experiences with streamside livestock exclusion fencing and pasture management are included.

Use of trade names in this publication does not imply a product endorsement.

Why limit livestock access to streams?

There are several reasons why a producer might choose to limit livestock stream access and implement a grazing management system. The reasons discussed below include the potential to increase livestock productivity and improve animal health, the opportunity to better manage forage resources, and the possible benefits that may result from establishing and maintaining riparian buffers, including alternative uses for riparian buffer vegetation and environmental benefits like reduced erosion and improved water quality.

Reason 1: Increased Productivity

Various references cite the importance of providing ample clean water to cattle to maximize production[5, 12, 13, 17, 35, 47, 53, 75]. Restricting livestock access to streams, especially slow moving streams, and ponds, and providing an alternative water source can improve drinking water quality for the animals. Drinking water quality can be characterized in a variety of ways, including measuring the type and quantity of various chemical constituents in the water (e.g., iron, nitrates, sodium, sulfates, metals), measuring the biological constituents in the water (e.g., bacteria, parasites), and assessing the animal's desire to drink the water[5, 35]. Improving water quality can increase water and feed consumption[10, 35, 55, 60, 63, 72]. Increases in both dry matter intake and water will lead to increased productivity[5, 28, 33, 48, 63]. A dairy producer in Rockingham County interviewed for this publication observed increased milk production and quality after restricting stream access and providing alternative water sources for his operation. Beef producers in Augusta, Rockingham, and Washington Counties indicated they had observed increased beef cattle weight gains after providing alternative water sources.

A Total Maximum Daily Load (TMDL) implementation plan completed in 2006 in the Big Otter River basin of Virginia indicates that the average cost to the producer to install a system that includes off-stream waterers as well as streamside exclusion fencing and cross fencing to implement controlled grazing is $2,325 (assuming 75% cost-share and a 25% tax credit), based on an average system cost of $12,400[6]. The cost the producer must bear when installing such a system can potentially be recouped with increased animal productivity.

Reason 2: Better Herd Health and Livestock Safety

Disease causing organisms like bacteria, viruses, and parasites can be present in any stream or pond[16, 53], but they are more likely to be present if the water has been contaminated by manure[2, 53, 67]. If livestock are allowed unrestricted access to streams, they will defecate in and near the stream. Restricting livestock access to streams and providing an alternative water source will prevent livestock from depositing harmful manure-borne organisms in the stream[36], and will limit the livestock's contact with these organisms. Harmful waterborne organisms can reduce livestock productivity[18, 53]. While restricting stream access and providing an alternative water source can reduce the risk of water-borne illness, it is also important to keep water troughs clean and the pad areas around troughs maintained to prevent them from becoming reservoirs for disease-causing organisms[17, 37]. Producers interviewed for this publication indicated that they believed their overall herd-health improved as a direct result of restricting livestock access to streams, and several commented that incidences of calf scours decreased after restricting stream access and providing an alternative water source. Excluding cattle from streams may also decrease leg injuries associated with traversing muddy and/or steep banks.

> **"It [the overall stream exclusion system] takes a little bit of management, but it's all worth it," and "everything's been a positive."**
>
> **Jack Shutte, Clarke County**

Reason 3: Pasture Management Benefits

Installing streamside exclusion fencing along with an alternate water supply also improves pasture quality. Distributing water sources throughout the pasture increases forage utilization[3, 7, 15, 23, 24, 34]. Many producers interviewed for this publication located waterers according to a desired pasture utilization scheme and were pleased with the results. If waterers are coupled with a controlled grazing system, even greater forage utilization can result. Additionally, controlled grazing distributes livestock manure, and nutrients, more evenly throughout the pasture[3, 19]. Some beef producers who converted to controlled grazing systems have not only increased forage utilization but also decreased fertilizer usage. Because livestock will bunch together not only for water, but also for minerals and shade[3, 5, 15, 19, 29],

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Organisms that cause some livestock diseases dwell in the intestines of cows[4, 46]; therefore, allowing cows in the stream is doubly bad, as they deposit the disease causing organisms in the stream, and can then contract the disease while they're standing in and drinking from the contaminated water[56].

strategic placement of mineral supplements and shade in a pasture can also help distribute manure throughout the grazed area[3, 66]. Many producers cautioned against locating waterers near natural shade. Cattle tend to gather under shade. If a water source is also there, an undesirable trampled, muddy depression may result.

Several producers noted that rotational grazing also saved time, as cattle quickly adapted to the new grazing system. One producer reported using grazing paddocks to separate mares from stallions and to gather horses for trips or veterinary visits. Another finds gathering cattle for veterinary procedures simpler with a grazing system.

> **"The benefit to my public image is worth far more than any money received from cost-share."**
>
> **Dave Johnson,**
> **Washington County**

Figure 1. Controlled grazing paddocks in Fauquier County, Virginia

> **"I have seen weight gain increases of 5-10% over 9-10 months since removing my beef cattle from the stream and providing water from springs and wells."**
>
> **Scott Campbell, Augusta County**

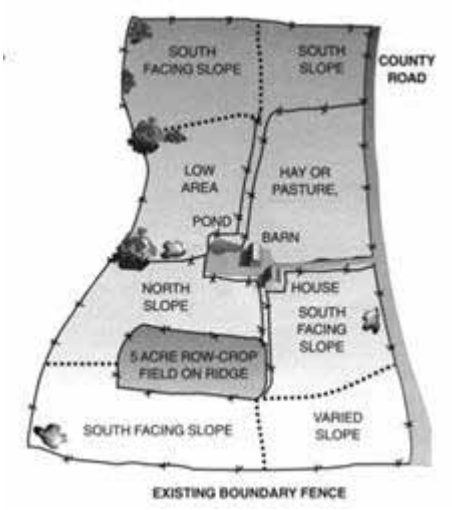


Figure 2. Dividing a large pasture into multiple paddocks increases control of the grazing animals. *Adapted from Controlled Grazing of Virginia's Pastures (http://www.ext.vt.edu/pubs/bse/418-012/418-012.html).*

Reason 4: Alternative Riparian Area Uses

The buffer established between the stream and the streamside livestock exclusion fence can be utilized for agroforestry opportunities. Forested riparian buffers are also eligible for cost-share payments through the Conservation Reserve Enhancement Program (CREP)[40]. For some Virginia producers, CREP payments more than compensate for the labor and maintenance associated with streamside livestock exclusion fencing systems. In addition, farm income can benefit by harvesting lumber and firewood[19, 40].

In addition to potential agroforestry income[61, 76], riparian buffers provide numerous environmental benefits, including erosion control, streambank and stream channel stability, stream temperature moderation, flood control, wildlife habitat, and interception of nonpoint source pollution originating from up-slope areas. Many of these benefits (e.g., pollution prevention and stream stability) are cheaper to achieve with riparian buffers than with constructed best management practices[1].

Learn more

Alternative water supplies should be located so that dairy cattle do not have to walk more than 500-600 feet[73], beef cattle no more than 700-900 feet[56], and other livestock no more than 1000-1200 feet[73] to minimize the animal's energy expenditure.

Reason 5: Improved Water Quality

Unrestricted livestock access to streams is associated with many negative environmental effects. Livestock defecating in streams may deposit harmful manure-borne organisms in the stream[2, 29, 67]; even a small separation of livestock and their manure from the stream can significantly reduce the contribution of manure-borne bacteria to the stream[36]. Good grazing management practices that reduce negative water quality impacts include streamside fencing accompanied by controlled grazing, providing alternative water sources and, when practicable, using portable sources of shade[29]. Poorly managed riparian grazing can lead to increased nutrients and sediment in the stream[57, 58]. Unrestricted stream access and uncontrolled grazing in the riparian zone increases streambank instability and erosion[32, 44, 49, 57, 58, 62] and can potentially lead to changes in stream flow patterns[31, 39]. Excluding livestock from the stream stabilizes streambanks[50, 64] and improves the diversity and abundance of riparian vegetation[25, 50, 74], and wildlife habitat near the stream[31]. Additionally, aquatic life habitat and diversity increases after livestock are excluded from the stream[65].

> **"I enjoy going by and seeing the water so clean."**
>
> **Nick Dunning, Clarke County**

Where a concerted effort to install streamside exclusion fencing has occurred, water quality improved[64, 65, 70, 71]. In the Muddy Creek and Lower Dry River watersheds in Rockingham County (see page12) where many producers are Old Order Mennonites, water quality improved after the community voluntarily installed polywire or single strand high-tensile fencing rather than more expensive fencing required by cost-share programs. Studies report that streamside exclusion fencing reduced sediment concentrations in storm runoff and total sediment transport by 60 and 40%, respectively, compared to pre-fenced conditions[54].

How do you limit livestock access to streams?

An effective streamside livestock exclusion fencing system includes several components including providing off-stream water sources, ensuring that the livestock are comfortable, streamside fencing itself, providing hardened stream crossings, if needed, and establishing riparian buffers that are sufficiently wide enough to provide a water quality benefit. Each of these components is discussed below.

Component 1: Off-stream watering

There are several options for off-stream watering systems. The choice of system will depend on the availability of an energy source, the water source, the required water volume, pasture layout, reliability, cost, and personal preference[7]. Potential sources of water include springs, wells, ponds, and the stream itself[2, 73]. Each of these water sources was used by at least one producer interviewed for this publication. Almost all the producers used an electric pump to deliver water. The most popular types of troughs were Ritchies and MiraFounts, although some used concrete troughs or tire troughs. One producer with horses used troughs specifically designed for horses. For more information on watering systems, refer to page 14 .

Component 2: Livestock comfort

To maintain highly productive livestock, or to lure animals away from streams where streamside exclusion fencing is not installed, salt blocks, scratching posts, dusters, windbreaks, shade, and other shelters should be located away from the stream as much as is practical without producing excessive travel distances[2] and not in the same location as waterers[3].

Figure 3. Portable shade structure, Bedford County, Virginia.

There are times when the riparian buffer width required to receive cost-share funds for streamside exclusion fencing installation will eliminate the only sources of natural shade in the pasture. In these cases, producers might consider providing alternative sources of shade[5]. Studies have shown that shade will improve milk production for dairy cows and weight gain for beef cows[42, 43, 66]. Approximately 40-60 square-feet of shade is needed per head for mature cows[30, 66]. Insufficient shade may be detrimental as animals will bunch together to try and fit under the undersized shade[66]. Options for off-stream shade include portable shade structures (see NRCS Livestock Shade Structure, Code 717 specification), permanent shade structures and trees. Portable structures (Figure 3) may be a viable solution if a rotational grazing system is employed. Such structures can be moved in and among paddocks[66]. Two of the producers interviewed for this publication located their waterers on covered concrete or stone pads. Natural shade created using trees must be carefully planned, as too many animals gathering under any given tree may actually kill the tree[66]. Producers reported using cedars, hedge apples (also known as Osage-orange), and sycamores to provide natural shade.

Figure 4. Recently planted shade trees, Clarke County, Virginia. Trees are protected from grazing by animals during establishement

Component 3: Streamside Fencing

There are several options for streamside livestock exclusion fencing and several issues to consider when choosing fencing materials. Common fence types include woven wire, barbed wire, rail or board, cable wire, high-tensile wire, and electric[9, 21, 77]. Recommendations for fencing materials for various livestock can be found in the Virginia Cooperative Extension Publication Fencing Materials for Livestock Systems[21] (see "For More Information" on page 14). Producers who participate in BMP incentive programs are required to follow specific design and installation guidelines to qualify for cost-share or tax credits[51, 69]. Information about available federal and state BMP incentive programs can be obtained from your local Soil and Water Conservation District office.

Component 4: Stream Crossings

When pasture is present on both sides of a stream, it may be necessary to install a hardened crossing to allow cattle to move between pastures while restricting access to the stream. The width of hardened crossing is typically limited to discourage cattle from loitering in the stream. However, NRCS guidelines require a six feet minimum width for cattle crossings and 10 feet for vehicular crossings[52]. A fenced lane may also require additional maintenance, as debris can get trapped during high flows and the fence may be damaged during flood events[2]. The most common fencing losses due to flooding reported by the producers interviewed occurred at stream crossings. Restricted stream access and hardened crossings protect riparian areas while still allowing livestock to water from the stream.

Figure 5. Example of hardened stream-crossing, Augusta County, Virginia.

Learn more

Cows prefer to drink from a trough rather than from a stream and may walk farther distances to do so[45, 67].

Providing an alternative water source even without streamside fencing may reduce the time livestock spend in the stream by 80-99%[14, 22, 45, 64].

Water quality benefits can be seen when livestock access to streams is limited. A Tennessee study showed that limiting livestock stream access via hardened crossings, can reduce in-stream concentrations of nitrate, ammonia, and fecal coliform bacteria similar to sites where cattle were completely excluded[59].

Component 5: Buffer Strips

If sufficient distance is allowed between the fence and the stream, it is possible to develop a buffer strip to intercept runoff from the up-slope pasture. Studies have found that riparian vegetation will filter sediment, nutrients, and other contaminants from runoff before it reaches the stream[2, 11, 29] and stabilize stream banks and reduce erosion[1, 11]. Additionally, including a buffer strip between the stream and the fence makes it less likely that a streamside fence will be damaged in a flood. A Maryland Cooperative Extension publication recommends a buffer of at least 35 feet to allow for the flooding and changes in stream meanders that characterize the 'floodway'[41].

Figure 6. Riparian buffer, Augusta County, Virginia.

Learn more

Studies have shown a 30-95% reduction in pollutants when runoff passes through a buffer strip[1].

Create the stream access limiting system that works for your operation.

Every livestock stream exclusion system will be unique. Livestock comfort and controlled movement must be a consideration when designing any system. It is possible to have multiple design and component combinations– studies have shown that off-stream watering without fencing can be an effective management tool in some areas[14, 20, 22, 45, 64]; other areas may only need a fence where an alternative source of water is already available; and many areas will likely need a combination of a fence and off-stream watering supply. One should also determine whether supplemental shade and/or hardened crossings are needed.

Figure 7. Polywire fencing, Rockingham County, Virginia.

Are there negative aspects to limiting livestock stream access?

Although all the producers interviewed for this publication were pleased with their stream exclusion systems in general, they did raise a few concerns. The most common complaint was nuisance vegetation in the riparian area. Other less common complaints included the need to clean waterers periodically, the need to have someone available to ensure waterers are functioning properly, more complicated fertilizer applications if a controlled grazing system is used, and nuisance wildlife living in riparian buffers. Despite these issues, all the producers interviewed for this publication believed that the advantages of streamside exclusion fencing outweighed the negative aspects.

What programs are available to help pay for limiting livestock stream access?

There are many cost-share opportunities available through Virginia's Agricultural BMP Cost-Share Program and CREP. Tax credits are also available through Virginia's Agricultural BMP Tax Credit Program[68]. Contact your local Soil and Water Conservation District (http://www.dcr.virginia.gov/sw/swcds.htm) to ask about opportunities for your individual farm. Other cost-share programs available to Virginians for the establishment of riparian forest buffers include the Conservation Reserve Program, Natural Resources Conservation Service (NRCS), Forestry Incentives Program, NRCS and U.S. Forestry Service (USFS), Stewardship Incentive Program (USFS), Environmental Quality Incentives Program (NRCS), and the Wetlands Reserve Program (NRCS)[1]. Conservation easements are also available and provide tax credits[1].

Does water quality improve if livestock stream access is limited?

Producers are responding to the need to improve water quality by installing stream exclusion fencing and limiting livestock stream access. Muddy Creek and Lower Dry River in Rockingham County; Hutton Creek, Hall/Byers Creek, and Cedar Creek in Washington County; and Page Brook in Clarke County are examples of watersheds where water quality is improving (Figure 8).

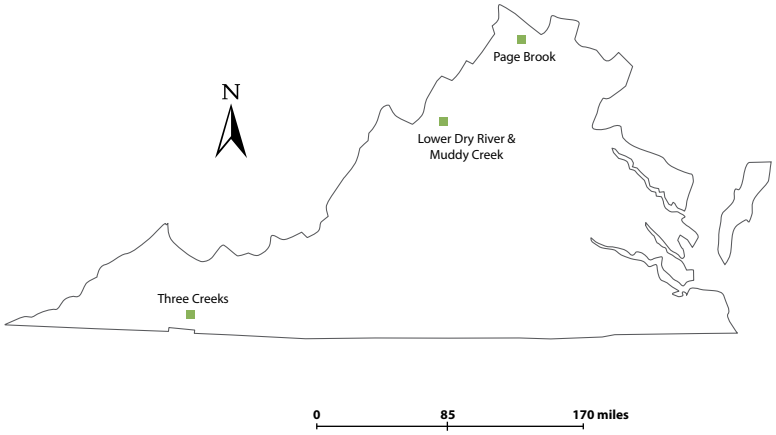


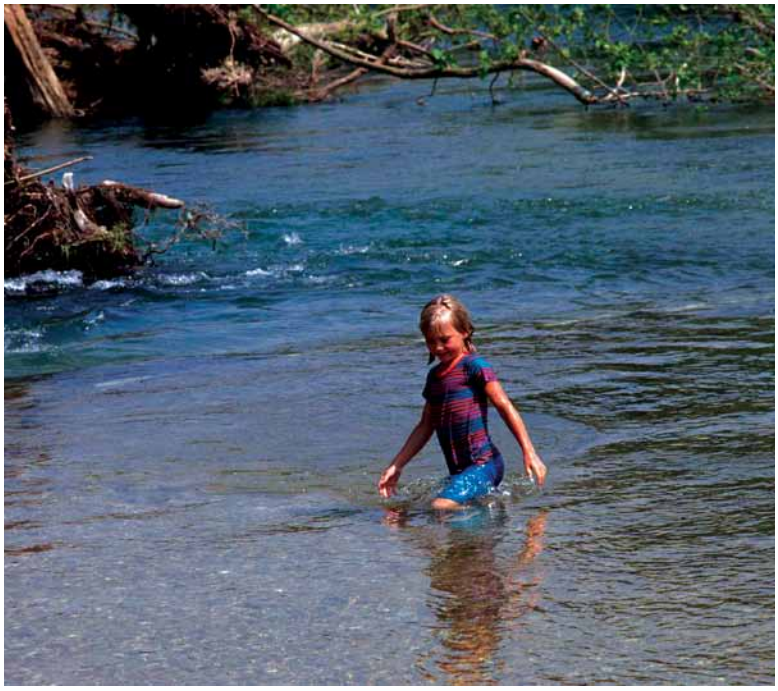
Figure 8. Locations of the Lower Dry River & Muddy Creek, Three Creeks, and Page Brook watersheds.

In the Lower Dry River and Muddy Creek watersheds, a community of Old Order Mennonites is implementing best management practices (BMPs) without cost-share incentives. In fact, 8.3 miles of the 10 miles of stream exclusion fencing installed in these watersheds since 2001 was installed without cost-share. Water quality in both Muddy Creek and Lower Dry River has improved. The number of samples violating the state's fecal coliform bacteria standard dropped from 77% in 1999 to 50% in 2006 for Muddy Creek. Similar improvements were observed in Lower Dry River where the number of samples violating the state's fecal coliform bacteria standard dropped from 50% in 2003 to 17% in 2006.

In the Hutton Creek, Hall/Byers Creek, and Cedar Creek watersheds, BMP implementation to address bacteria and aquatic life use water quality impairments began in 2001. Producers in these watersheds have installed 20 miles of stream exclusion fencing. Comparing data from 2001 and 2006, the number of samples violating the state's fecal coliform bacteria standard dropped from 100% to 17% for Cedar Creek, from 33% to 0% for Hall/Byers Creek, and from 75% to 17% for Hutton Creek.

In the Page Brook watershed, implementation of stream exclusion fencing began in 1996[26]. Following a five year implementation period, Virginia's Department of Environmental Quality sampled Page Brook from 2001 to 2003 and the number of samples violating the state's fecal coliform bacteria standard dropped from 67% in 2001 to 0% in 2003.

While the evidence from these watersheds is promising, year-to-year variability is expected. Long-term water quality monitoring is needed to accurately detect and verify water quality improvement trends from installing and maintaining stream exclusion fencing and other BMPs. Monitoring in these and other watersheds will continue to track water quality improvement as additional miles of fencing and other BMPs are implemented.



For More Information

FOR MORE INFORMATION ON…	REFER TO…
Riparian Buffers and Agroforestry	Chesapeake Bay riparian handbook: a guide for establishing and maintaining riparian forest buffers www.chesapeakebay.net/pubs/subcommittee/nsc/forest/handbook.htm Evaluation of potential gross income from non-timber products in a model riparian forest for the Chesapeake Bay watershed – Robles-Diaz-de-Leon and Kangas[61]
Watering Systems	Selection of Alternative Livestock Watering Systems[8] www.utextension.utk.edu/publications/pbfiles/PB1641.pdf (University of Tennessee Extension) Selection of Beef Watering Systems[7] http://wastemgmt.ag.utk.edu/ExtensionProjects/beef%20waterers.pdf (University of Tennessee Extension) Alternatives to Direct Access Livestock Watering[27] www.agr.gc.ca/pfra/water/facts/directace.pdf (Agriculture and Agri-Food Canada) Pumps and Watering Systems for Managed Beef Grazing[56] http://muextension.missouri.edu/explore/envqual/eq0380.htm (Missouri State Extension)
Fencing	Fencing Materials for Livestock Systems[21] www.ext.vt.edu/pubs/bse/442-131/442-131.html (Virginia Cooperative Extension) NRCS Virginia Conservation Practice Standard: FENCE (Section IV, Conservation Practice, Code 382)[51] http://efotg.nrcs.usda.gov/efotg_locator.aspx?map=VA (Natural Resources Conservation Service) Planning Fencing Systens for Controlled Grazing www.ext.vt.edu/pubs/bse/442-130/442-130.html (Virginia Cooperative Extension)
Portable Shade Structures	Shade Options for Grazing Cattle[66] www.bae.uky.edu/Publications/AEUs/aeu-91.pdf (University of Kentucky Extension)

Shade Trees	Trees for Horse Pastures[38] www.omafra.gov.on.ca/english/livestock/horses/facts/info_livestock_pastures_trees.htm (The Ontario Ministry of Agriculture, Food, and Rural Affairs)
BMPs	Your local Soil & Water Conservation District www.dcr.virginia.gov/sw/swcds.htm OR the Virginia Agricultural BMP Manual[69]
Controlled Grazing	Controlled Grazing of Virginia's Pastures www.ext.vt.edu/pubs/bse/418-012/418-012.html (Virginia Cooperative Extension)
TMDLs and TMDL Implementation	The Virginia Department of Environmental Quality website www.deq.virginia.gov/tmdl OR TMDLs [Total Maximum Daily Loads]: Terms and Definitions www.ext.vt.edu/pubs/bse/442-550/442-550.html AND Implementation: What Happens after the TMDL (Total Maximum Daily Load) is Developed? www.ext.vt.edu/pubs/bse/442-559/442-559.html (Virginia Cooperative Extension)

References

1. 1997. Section XII - Economics of riparian forest buffers. In *Chesapeake Bay riparian handbook: a guide for establishing and maintaining riparian forest buffers.* R. S. Palone, and A. H. Todd, eds. Radnor, PA: USDA Forest Service.
2. Adams, E. B. 1994. Riparian Grazing. EB1775. Washington State University Extension. http://cru.cahe.wsu.edu/CEPublications/eb1775/eb1775.html (last accessed April 2012).
3. Arnold, G. W., and M. L. Dudzinski. 1978. *Ethology of Free-Ranging Domestic Animals: Developments in Animal and Veterinary Sciences*, 2. Elsevier Scientific Publishing Company, New York, NY.
4. Azevedo, J., and P. R. Stout. 1974. *Farm animal manures: an overview of their role in the agricultural environment.* University of California: Division of Agricultural Sciences.
5. Beede, D. K. 1991. Mineral and water nutrition. *Dairy Nutrition Management* 7(2):373-390.
6. Big Otter IP Steering Committee. 2006. Big Otter Watershed TMDL Implementation Plan Summary. Virginia Department of Environmental Quality, Virginia Department of Conservation and Recreation.
7. Burns, R. T. 2001. Selection of Beef Watering Systems. University of Tennessee Agricultural Extension Service.
8. Burns, R. T., and M. J. Buschermohle. 2000. Selection of alternative livestock watering systems. The University of Tennessee Agricultural Extension Service.
9. Buschermohle, M. J., J. B. Wills, W. W. Gill, and C. D. Lane. 2001. Planning & Building Fences on the Farm. University of Tennessee Agricultural Extension Service.
10. Challis, D. J., J. S. Zeinstra, and M. J. Anderson. 1987. Some effects of water quality on the performance of high yielding cows in an arid climate. *Veterinary Record* 120(1):12-15.
11. Chalmers, L. 2000. Livestock management: fence location and grazing controls. Water and Rivers Commission, Government of Western Australia.
12. Chase, L. E. 1988. Water needs of dairy cattle. Agri-Practice 9(2):23-24.
13. Church, D. C. 1991. *Livestock Feeds and Feeding*. 3rd ed. Prentice-Hall, Inc., Englewood Cliffs, NJ.
14. Clawson, J. 1993. The use of off-stream water developments and various water gap configurations to modify the watering behavior of grazing cattle. Oregon State University, Corvallis, OR
15. Dickard, M. L. 1998. Management strategies for improved cattle distribution and subsequent riparian health. University of Idaho, Animal Science
16. Diesch, S. L. 1970. Disease transmission of water-borne organisms of animal origin. In *Agricultural Practices and Water Quality*, 265-285. T. L. Willrich, and G. E. Smith, eds. Ames, Iowa: Conference: The Role of Agriculture in Clean Water, Iowa State University
17. Ensminger, M. E., and C. G. Olentine, Jr. 1978. *Feeds & Nutrition - Complete.* First ed. The Ensminger Publishing Company, Clovis, CA.
18. Esteban, E., and B. C. Anderson. 1995. *Cryptosporidium muris:* prevalence, persistency, and detrimental effect on milk production in a drylot dairy. *Journal of Dairy Science* 78:1068-1072.
19. Fanatico, A., R. Morrow, and A. Wells. 1999. Sustainable beef production: livestock production guide. National Center for Appropriate Technology: Appropriate Technology Transfer for Rural Areas (ATTRA).

20. Franklin, D. H., M. L. Cabrera, H. L. Byers, M. K. Matthews, J. G. Andrae, D. E. Radcliffe, M. A. McCann, H. A. Kuykendall, C. S. Hoveland, and V. H. Calvert, II. 2009. Impact of water troughs on cattle use of riparian zones in the Georgia Piedmont in the United States. *Journal of Animal Science* 87:2151-2159.

21. Gay, S. W., and R. D. Heidel. 2003. Fencing materials for livestock systems. Virginia Cooperative Extension, 442-131.

22. Godwin, D. C., and J. R. Miner. 1996. The potential of off-stream livestock watering to reduce water quality impacts. *Bioresource Technology* 58:285-290.

23. Goebel, C. J. 1956. Water development on the Starkey experimental forest and range. *Journal of Range Management* 9(5):232-234.

24. Gonzalez, M. H. 1964. Patterns of Livestock Behavior and Forage Utilization as Influenced by Environmental Factors on a Summer Mountain Range. Utah State University, Range Management, Logan, UT

25. Gunderson, D. R. 1968. Floodplain use related to stream morphology and fish populations. The *Journal of Wildlife Management* 32(3):507-514.

26. Hagedorn, C., S. L. Robinson, J. R. Filtz, S. M. Grubbs, T. A. Angier, and R. B. Reneau, Jr. 1999. Determining Sources of Fecal Pollution in a Rural Virginia Watershed with Antibiotic Resistance Patterns in Fecal Streptococci. *Applied and Environmental Microbiology* 65(12):5522-5531.

27. Hilliard, C., and S. Reedyk. 2001. Alternatives to Direct Access Livestock Watering. Agriculture and Agri-Food Canada, Prairie Farm Rehabilitation Administration. Available at: http://www.agr.gc.ca/pfra/water/facts/directace.pdf.

28. Holter, J. B., and W. E. Urban, Jr. 1992. Water partitioning and intake prediction in dry and lactating Holstein cows. *Journal of Dairy Science* 75:1472-1479.

29. Hubbard, R. K., G. L. Newton, and G. M. Hill. 2004. Water quality and the grazing animal. *Journal of Animal Science* 82(E. Suppl.):E255-E263.

30. Ittner, N. R., T. E. Bond, and C. F. Kelly. 1954. Increasing summer gains of livestock: with cool water, concentrate roughage, wire corrals, and adequate shades. *Journal of Animal Science* 13(4):867-877.

31. Kauffman, J. B., and W. C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications...a review. *Journal of Range Management* 37(5):430-438.

32. Kauffman, J. B., W. C. Krueger, and M. Vavra. 1983. Impacts of cattle on streambanks in northeastern Oregon. *Journal of Range Management* 36(6):683-685.

33. Kertz, A. F., L. F. Reutzel, and J. H. Mahoney. 1984. Ad libitum water intake by neonatal calves and its relationship to calf starter intake, weight gain, feces score, and season. *Journal of Dairy Science* 67:2964-2969.

34. Landefeld, M., and J. Bettinger. 2002. Water effects on livestock performance. Ohio State University Agriculture and Natural Resources. Columbus, Ohio.

35. Lardner, H. A., B. D. Kirychuk, L. Braul, W. D. Willms, and J. Yarotski. 2005. The effect of water quality on cattle performance on pasture. *Australian Journal of Agricultural Research* 56:97-104.

36. Larsen, R. E. 1994. Water-quality benefits of having cattle manure deposited away from streams. *Bioresource Technology* 48:113-118.

37. LeJeune, J. T., T. E. Besser, N. L. Merrill, D. H. Rice, and D. D. Hancock. 2001. Livestock drinking water microbiology and the factors influencing the quality of drinking water offered to cattle. *Journal of Dairy Science* 84:1856-1862.

38. Leuty, T., and B. Wright. 2002. Trees for Horse Pastures. Ontario Ministry of Agriculture, Food and Rural Affairs. Available at: http://www.omafra.gov.on.ca/english/livestock/horses/facts/info_livestock_pastures_trees.htm.

39. Li, H. W., G. A. Lamberti, T. N. Peasons, C. K. Tait, J. L. Li, and J. C. Buckhouse. 1994. Cumulative effects of riparian disturbances along high desert trout streams of the John Day Basin, Oregon. *Transactions of the American Fisheries Society* 123(4):637-640.

40. Lynch, L., and B. Tjaden. 2000. When a landowner adopts a riparian buffer - benefits and costs. University of Maryland - Maryland Cooperative Extension.

41. Lynch, L., and R. Tjaden. 2002. Riparian buffer financial assistance opportunities. University of Maryland: Maryland Cooperative Extension.

42. McDaniel, A. H., and C. B. Roark. 1956. Performance and grazing habits of Hereford and Aberdeen-Angus cows and calves on improved pastures as related to types of shade. *Journal of Animal Science* 15(1):59-63.

43. McIlvain, E. H., and M. C. Shoop. 1971. Shade for improving cattle gains and rangeland use. *Journal of Range Management* 24:181-184.

44. McInnis, M. L., and J. McIver. 2001. Influence of off-stream supplements on streambanks of riparian pastures. *Journal of Range Management* 54(6):648-652.

45. Miner, J. R., J. C. Buckhouse, and J. A. Moore. 1992. Will a water trough reduce the amount of time hay-fed livestock spend in the stream (and therefore improve water quality)? *Rangelands* 14(1):35-38.

46. Monrad, J., A. A. Kassuku, P. Nansen, and P. Willeberg. 1983. An epidemiological study of foot rot in pastured cattle. *Acta Veterinaria Scandanavia* 24:403-417.

47. Murphy, M. R. 1992. Water metabolism of dairy cattle. *Journal of Dairy Science* 75:326-333.

48. Murphy, M. R., C. L. Davis, and G. C. McCoy. 1983. Factors affecting water consumption by Holstein cows in early lactation. *Journal of Dairy Science* 66:35-38.

49. Myers, T. J., and S. Swanson. 1991. Aquatic habitat condition index, stream type, and livestock bank damage in northern Nevada. *Water Resources Bulletin* 27(4):667-677.

50. Myers, T. J., and S. Swanson. 1996. Long-term aquatic habitat restoration: Mahogany Creek, Nevada as a case study. *Water Resources Bulletin* 32(2):241-252.

51. Natural Resources Conservation Service. 2001. Natural Resources Conservation Service Conservation Practice Standard: Fence (Code 382).

52. Natural Resources Conservation Service. 2003. Natural Resources Conservation Service Conservation Practice Standard: Stream Crossing (Code 578).

53. Olson, M. E., T. A. McAllister, and K.-J. Cheng. 1996. The influence of water-borne diseases on production in ruminants. In *Animal Science Research and Development: Meeting Future Challenges*, 47-56. Lethbridge, Alberta, Canada: Lethbridge Research Centre, Agriculture and Agri-Food Canada.

54. Owens, L. B., W. M. Edwards, and R. W. V. Keuren. 1996. Sediment losses from a pastured watershed before and after stream fencing. *Journal of Soil and Water Conservation* 51(1):90-94.

55. Patterson, H. H., P. S. Johnson, T. R. Patterson, D. B. Young, and R. Haigh. 2002. Effects of water quality on animal health and performance. *Proceedings of the Western Section of the American Society of Animal Science* 53:217-220.

56. Pfost, D., J. Gerrish, M. Davis, and M. Kennedy. 2000. Pumps and watering systems for managed beef grazing. Missouri State Extension.

57. Platts, W. S. 1984. Riparian system/livestock grazing interaction research in the intermountain west. In *California Riparian Systems: Ecology, Conservation, and Productive Management*, 424-429. R. E. Warner, and K. M. Hendrix, eds. Berkeley, CA: University of California Press

58. Platts, W. S. 1991. Chapter 11: Livestock Grazing. In *Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats*, 389-424. W. R. Meehan, ed. Bethesda, MD: American Fisheries Society.

59. Powell, J. R. 1998. Water quality and ecological impacts of watering cattle adjacent to a small middle Tennessee stream. The University of Tennessee, Knoxville, TN

60. Ray, D. E. 1989. Interrelationships among water quality, climate, and diet on feedlot performance of steer calves. *Journal of Animal Science* 67:357-363.

61. Robles-Diaz-de-Leon, L. F., and P. Kangas. 1999. Evaluation of potential gross income from non-timber products in a model riparian forest for the Chesapeake Bay watershed. *Agroforestry Systems* 44:215-225.

62. Schwarte, K. A., J. R. Russell, and D. G. Morrical. 2011. Effects of pasture management and off-stream water on temporal/spatial distribution of cattle and stream bank characteristics in cool-season grass pastures. *Journal of Animal Science* 89:3236-3247.

63. Sexson, J. L., J. J. Wagner, T. E. Engle, and J. W. Spears. 2010. Effects of water quality and dietary potassium on performance and carcass characteristics of yearling steers. *Journal of Animal Science* 88:296-305.

64. Sheffield, R. E., S. Mostaghimi, D. H. Vaughan, J. E. R. Collins, and V. G. Allen. 1997. Off-stream water sources for grazing cattle as a stream bank stabilization and water quality BMP. *Transactions of the ASAE* 40(3):595-604.

65. Thomas, Z., D. Radcliffe, M. Cabrera, and J. Meyer. Restoring water quality to a stream in Putnam County, Georgia. National River Restoration Science Synthesis (NRRSS). Available at: http://www.nrrss.umd.edu/Success_Stories/Success_Story_No_2_WQ_SE_Node.pdf.

66. Turner, L. W. 2000. Shade options for grazing cattle. University of Kentucky College of Agriculture Cooperative Extension Service.

67. Veira, D. M. 2003. Livestock water: impacts on production and behavior. In *Western Range Seminar*. Medicine Hat.

68. Virginia Department of Conservation and Recreation. 2004. Cost-Share and Tax Credit for Virginia Agricultural BMPs. Available at: http://www.dcr.virginia.gov/sw/docs/bmpsbro2.pdf.

69. Virginia Department of Conservation and Recreation. 2005. *Virginia Agricultural BMP Manual*.

70. Virginia Department of Environmental Quality. 2005. TMDL Program Five Year Progress Report. Available at: http://www.deq.virginia.gov/tmdl/pdf/04prgrpt.pdf.

71. Virginia Department of Environmental Quality. 2006. Spotlight on water quality improvements in DEQ's Valley Region. Available at: http://www.deq.state.va.us/tmdl/tmdlimprove.html.

72. Wegner, T. N., and J. D. Schuh. 1988. Effect of water quality and season on milk production and water metabolism in Holstein cows. *Journal of Dairy Science* 71(suppl. 1):185.

73. White, H. E., and D. D. Wolf. 2000. Controlled Grazing of Virginia's Pastures. Virginia Cooperative Extension.

74. Winegar, H. H. 1977. Camp Creek channel fencing - plant, wildlife, soil, and water response. *Rangeman's Journal* 4(1):10-12.

75. Wise, B. L. 2011. Water Quality for Wyoming Livestock and Wildlife. University of Wyoming, Animal and Veterinary Sciences Department, Laramie, WY

76. Workman, S. W., and S. C. Allen. 2004. The practice and potential of agroforestry in the southeastern United States. University of Florida Institute of Food and Agricultural Sciences.

77. Worley, J. W. 2000. Fences for the farm. The University of Georgia College of Agricultural and Environmental Sciences Cooperative Extension Service.

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