

Evaluating a two-stage roadside ditch design to improve environmental performance

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Introduction

Conventional trapezoidal roadside ditches are designed to rapidly deliver runoff, sediment and nutrients to downstream surface water but they can be impacted from erosional downcutting and excessive sedimentation. In agricultural regions, ditches have been modified with a two-stage design that involves modifying the conventional trapezoidal ditch into one that better replicates the features of a natural stream through the addition of adjacent benches. The two-stage design reduces bank slumping and undercutting during high flows while improving water quality by trapping and treating runoff water flowing through them.

Key Findings

- Native species established successfully (>11 seedlings/ m^2) in a two-stage ditch seeded with a wet prairie seed mix.
- Constructing a two-stage ditch using native vegetation increased species richness from 7 to 34.
- More research is needed understand the full multifunctional potential of two-stage ditches using native vegetation

The more natural topography and hydrology of two-stage ditches should also allow the restoration of natural plant communities that resemble native wet prairies and meadows that existed prior to their destruction via agricultural expansion. By restoring diverse native vegetation in these new types of ditches, additional ecosystem services could be provided or enhanced in these relatively small areas. In biodiverse two-stage ditches, further improved water quality metrics could be combined with pollinator habitat, including that of the imperiled monarch butterfly. In Iowa, there is a unique opportunity to implement biodiverse two-stage ditch designs by using revegetation and management techniques honed by the 35-year-old Iowa Roadside Management (IRM) program. Over many years, IRM (administered at the University of Northern Iowa's Tallgrass Prairie Center) has provided technical guidance, resources, and native seed to nearly all Iowa county roadsides. By utilizing existing seed mixes developed by IRM, biodiverse two-stage ditches could be readily implemented in Iowa.

In 2020, a team from the Iowa Geological Survey (IGS), University of Iowa, Department of Transportation (IA DOT), and the Tallgrass Prairie Center (TPC) worked to design and construct a two-stage ditch prototype in eastern Iowa. The objective of this project was to evaluate the vegetation of this prototype ditch constructed along a roadway and assess its composition over time.

Methods

Study Site

The study site was located in Benton County, Iowa on a large right-of-way along US Highway 30 near Keystone. As part of a larger highway construction project, this area was chosen as a prototype two-stage ditch construction site. Within the overall roadside right-of-way, a smaller two-stage ditch was constructed in 2021-2022. Here, excavators leveled out benches on both

sides of a meandering main channel (Fig 1, Fig. 2). After excavation, we used a native seed mix designed for wet-mesic conditions to revegetate the bench areas (Appendix 1). This seed mix was comprised of 50 native species and was seeded at a rate of 1194 seeds/m² during the spring of 2022. No other areas of the right of way were seeded or disturbed by the construction.

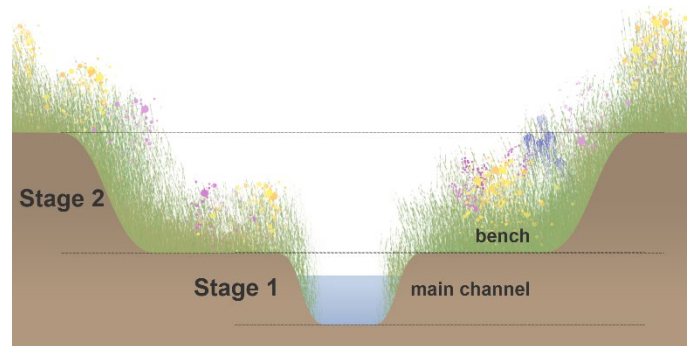


Figure 1. Diagram of a two-stage ditch. Stage 1 consists of the main (or inset) channel; Stage 2 consists of the vegetated benches and slopes.

Data collection and overall approach

My overall sampling strategy was to assess the vegetation of the right-of-way and the two-stage ditch before and after construction/revegetation. I wanted to document changes in plant functional groups and species richness to better understand the potential for two-stage ditches to serve as biodiverse, multifunctional habitat. I also measured seedling establishment in the two-stage ditch to assess potential for native species planted to persist.

I sampled two areas that corresponded to 1) the overall right-of-way and 2) the two-stage ditch. I generally followed an approach similar to Schilling and others (2018) who conducted a comparable survey. For the overall right-of-way, I used QGIS (QGIS Development Team 2022) to delineate a sample area polygon that encompassed the entire area of interest (right-of-way bounded by roads, adjacent fields, and forest) then randomly generated 25 sampling points within the area (Fig. 2). I sampled the overall area prior to construction in Sep 2020 and the year after construction and revegetation in Sep 2022. To define the sampling area for the two-stage ditch, I used distances from roads and property lines in the DOT construction plans to delineate

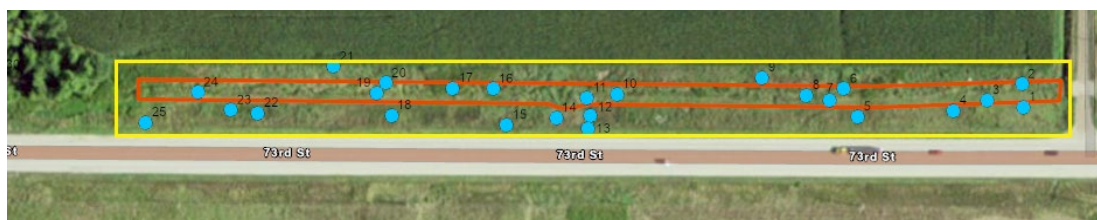


Figure 2. Overall right-of-way sampling area (yellow outline), $n=25$ sample points. Red outlined area shows two-stage ditch extent.



Figure 3. Two-stage ditch sampling area (red outline), $n=24$ sample points.

the area in QGIS (QGIS Development Team 2022) and randomly generated 24 sampling points within (Fig. 3). I sampled this area in Sep 2021 (pre-construction) and 2022 (post-construction).

In the overall right-of-way survey, I used a handheld GPS unit to locate each sampling point. At each point, I sampled vegetation within a 1m² square quadrat. I identified all species present, excluding seedlings, and assessed canopy cover for each species using Daubenmire cover classes. I used the same method to survey the two-stage ditch area, though in 2022 I additionally counted native seedlings (ramets) present in the southwest 0.125m² of the 1m² quadrat. Any sampling point that intersected with the main channel was repositioned to ensure the entire quadrat was on level ground. Thus, I did not assess main channel vegetation.

Results

Pre-Construction Vegetation

Overall vegetation of the right-of-way was entirely dominated by perennial weed species (Table 1). Smooth brome (*Bromus inermis*) was most common, though reed canary grass (*Phalaris arundinacea*) was dominant in a handful of areas. While perennial weeds made up 64% of the cover on site, 3% was comprised of ruderal native perennials like common milkweed (*Asclepias syriaca*) and Pennsylvania smartweed (*Persicaria pensylvanica*). Species richness was 6. Unusually, there was high cover (34% cover) of thatch (corn stover) derived from extensive flooding the previous year.

Pre-construction vegetation of the two-stage ditch area was generally similar to the overall right-of-way (Table 2). Species richness was 7. Perennial weeds were very dominant (87% relative cover) while the remaining vegetation was ruderal native perennials (5% relative cover). Reed canary grass (*P. arundinacea*) was about twice as abundant compared to the overall right-of-way area, likely due to the proximity to the main stream channel. Otherwise most species and species' abundances were similar to the overall area. However, thatch/bare ground was not as prevalent (7% relative cover).

Table 1. Composition of vegetation in the overall right-of-way before (2021) and after (2022) construction/revegetation.

Common Name	Scientific Name	Relative Cover (%)	
		2021	2022
smooth brome	<i>Bromus inermis</i>	49.7%	44.4%
thatch/bare ground		33.8%	24.4%
reed canary grass	<i>Phalaris arundinacea</i>	9.1%	6.7%
stinging nettle	<i>Urtica dioica</i>	4.0%	0.2%
Pennsylvania smartweed	<i>Persicaria pensylvanica</i>	1.7%	1.2%
hedge bindweed	<i>Calystegia sepium</i>	1.0%	0.7%
Canada thistle	<i>Cirsium arvense</i>	0.7%	3.0%
tall water hemp	<i>Amaranthus tuberculatus</i>	0.0%	4.2%
oats	<i>Avena sativa</i>	0.0%	3.9%
Virginia ground cherry	<i>Physalis virginiana</i>	0.0%	1.9%
prickly lettuce	<i>Lactuca serriola</i>	0.0%	1.6%
black eyed Susan	<i>Rudbeckia hirta</i>	0.0%	1.6%
Virginia wild rye	<i>Elymus virginicus</i>	0.0%	1.2%
lambs quarters	<i>Chenopodium album</i>	0.0%	0.8%
giant foxtail	<i>Setaria faberi</i>	0.0%	0.8%
hairy cupgrass	<i>Eriochloa villosa</i>	0.0%	0.6%
dotted smartweed	<i>Persicaria punctata</i>	0.0%	0.6%
Indian grass	<i>Sorghastrum nutans</i>	0.0%	0.4%
velvetleaf	<i>Abutilon theophrasti</i>	0.0%	0.2%
big bluestem	<i>Andropogon gerardii</i>	0.0%	0.2%
false sunflower	<i>Heliopsis helianthoides</i>	0.0%	0.2%
common dandelion	<i>Taraxacum officinale</i>	0.0%	0.2%
ironweed	<i>Vernonia fasciculata</i>	0.0%	0.2%
Showy tick trefoil	<i>Desmodium canadense</i>	0.0%	0.1%
Canada wild rye	<i>Elymus canadensis</i>	0.0%	0.1%
Fall panicum	<i>Panicum dichotomiflorum</i>	0.0%	0.1%
switchgrass	<i>Panicum virgatum</i>	0.0%	0.1%
yellow coneflower	<i>Ratibida pinnata</i>	0.0%	0.1%

Post-Construction Vegetation

After construction, overall vegetation of the right-of-way generally resembled the pre-construction vegetation (Table 1). While I observed some small decreases smooth brome (*B. inermis*) and reed canary grass (*P. arundinacea*), the overall area contained considerable abundance of perennial weeds. Species richness increased from 6 to 27.

In the two-stage ditch, abundance of functional groups after construction/revegetation was more even and species richness increased. Perennial weeds were reduced from 87% to 31% relative cover, while native perennials and annual/biennial weeds increased from 0 to 10% and 0 to 19% relative cover, respectively. Unvegetated areas (bare ground in this case) made up 39% relative cover. Within the perennial weed group, smooth brome (*B. inermis*) and reed canary grass (*P. arundinacea*)

decreased considerably, while Canada thistle (*Cirsium arvense*) increased. The most abundant native perennials were black-eyed Susan (*Rudbeckia hirta*) and Virginia wildrye (*Elymus virginicus*), though most native perennials were quite similar in abundance. Annual/biennial weeds were mostly dominated by oats (*Avena sativa*), tall water hemp (*Amaranthus tuberculatus*) and lamb's quarters (*Chenopodium album*). Abundance of ruderal native perennials remained essentially the same as before construction. Overall species

Table 1. Composition of vegetation in the two-stage ditch before and after construction/revegetation. Seedling density is reported post-revegetation (2022).

Common Name	Scientific Name	Relative Cover (%)		Seedlings /m ²
		2021	2022	
smooth brome	<i>Bromus inermis</i>	57.5%	8.4%	
reed canary grass	<i>Phalaris arundinacea</i>	22.7%	10.8%	
thatch/bare ground		7.3%	39.4%	
stinging nettle	<i>Urtica dioica</i>	4.8%	1.8%	
Penn.smartweed	<i>Persicaria pensylvanica</i>	3.4%	0.1%	
Canada thistle	<i>Cirsium arvense</i>	2.3%	8.2%	
common milkweed	<i>Asclepias syriaca</i>	1.5%	0.1%	
hedge bindweed	<i>Calystegia sepium</i>	0.3%	0.5%	
oats	<i>Avena sativa</i>	0.0%	9.5%	
tall water hemp	<i>Amaranthus tuberculatus</i>	0.0%	3.4%	
black eyed Susan	<i>Rudbeckia hirta</i>	0.0%	3.4%	2
lambs quarters	<i>Chenopodium album</i>	0.0%	2.6%	
Virginia wild rye	<i>Elymus virginicus</i>	0.0%	2.8%	3.67
false sunflower	<i>Heliopsis helianthoides</i>	0.0%	0.9%	1.67
giant foxtail	<i>Setaria faberi</i>	0.0%	0.9%	
common dandelion	<i>Taraxacum officinale</i>	0.0%	0.9%	
Indian grass	<i>Sorghastrum nutans</i>	0.0%	0.8%	3.67
ironweed	<i>Vernonia fasciculata</i>	0.0%	0.8%	1
hairy cupgrass	<i>Eriochloa villosa</i>	0.0%	0.7%	
velvetleaf	<i>Abutilon theophrasti</i>	0.0%	0.4%	
three seed mercury	<i>Acalypha rhomboidea</i>	0.0%	0.4%	
big bluestem	<i>Andropogon gerardii</i>	0.0%	0.2%	1
bull thistle	<i>Cirsium vulgare</i>	0.0%	0.2%	
Vir. ground cherry	<i>Physalis virginiana</i>	0.0%	0.2%	
Canada wild rye	<i>Elymus canadensis</i>	0.0%	0.2%	
yellow coneflower	<i>Ratibida pinnata</i>	0.0%	0.2%	
barnyard grass	<i>Echinochloa crus-galli</i>	0.0%	0.1%	
prickly lettuce	<i>Lactuca serriola</i>	0.0%	0.1%	
rice cut grass	<i>Leersia oryzoides</i>	0.0%	0.1%	
white mulberry	<i>Morus alba</i>	0.0%	0.1%	
yellow wood sorrel	<i>Oxalis stricta</i>	0.0%	0.1%	
common plantain	<i>Plantago major</i>	0.0%	0.1%	
little bluestem	<i>Schizachyrium scoparium</i>	0.0%	0.1%	0.33
New England aster	<i>Symphotrichum novae-angliae</i>	0.0%	0.1%	0.33
wheat	<i>Triticum aestivum</i>	0.0%	0.1%	
golden Alexanders	<i>Zizia aurea</i>	0.0%	0.1%	

richness increased from 7 species to 36 species after revegetation. Of the total species richness, native perennial species richness was 11 and annual/biennial weed richness was 12.

Main channel areas (Stage 1) of the two-stage ditch were dominated by invasive species. While we did not formally survey vegetation in Stage 1 areas of the ditch, we consistently observed reed canary grass (*P. arundinacea*) to be dominant in the bottoms of the constructed ditch (Fig. 3). Other common wetland ruderals (e.g. smartweeds (*Persicaria* spp.), barnyard grass (*Echinocloa crus-gallii*)) were sporadically present.



Figure 4. View of typical main channel vegetation post-construction (September 2022).

Native species established in the seeded bench (Stage 2) areas of the constructed ditch. I found 8 native species in the bench areas established as seedlings, with 4 grasses and 4 forbs. Establishment rates of sown species were quite low, with an overall establishment rate of 1.1%. Though establishment rates were low, I found the density of seedlings to be more moderate, at 13.67 ramets/m². The most common seedlings were Virginia wildrye (*E. virginicus*), Indian grass (*Sorghastrum nutans*), black-eyed susan (*R.hirta*), and ox-eye (*Heliopsis helianthoides*), all species typical of early successional tallgrass prairie reconstruction.

Discussion

In this study, I showed that a prototype two-stage ditch using native vegetation established successfully. Seedling densities in the first growing season were over the threshold some authors set for long-term expectations of stand success (11 stems/m² (Smith et al. 2010)). Additionally, invasive species were reduced below 20% of total cover, providing future potential for native seedlings to mature without excessive competition. Ultimately, patterns of native species establishment in this two-stage ditch appear to be very similar to establishing native species in roadsides generally. An abundance of annual/biennial weeds and bare ground with a considerable presence of sown native species is typical of prairie reconstructions in roadsides and former crop fields (Meissen et al. 2020). Lessons learned across decades of using native vegetation in roadside rights-of-way should be readily applicable to this new and promising practice of roadside two-stage ditch construction.

Our two-stage ditch prototype represented a large ecological improvement from the previous conventional ditch. Where the conventional ditch was dominated by a handful of invasive species, implementing a two-stage ditch with native vegetation increased species richness nearly sixfold. Further study is needed to understand if these gains in biodiversity are typical or lasting. Since invasive species were still common in the overall right of way, it is unclear whether plant species richness will be maintained over long timeframes. Follow up vegetation surveys should occur on new two stage ditches, especially when vegetation is mature. Surveys

conducted five or more years post-construction will provide better evidence about the longer-term nature of two-stage ditch vegetation.

References

Meissen, J. C., A. J. Glidden, M. E. Sherrard, K. J. Elgersma, and L. L. Jackson. 2020. Seed mix design and first year management influence multifunctionality and cost-effectiveness in prairie reconstruction. *Restoration Ecology* 28:807–816.

QGIS Development Team. 2022. QGIS Geographic Information System. QGIS Association. <http://www.qgis.org>.

Schilling, K. E., M. T. Streeter, M. St. Clair, and J. Meissen. 2018. Subsurface nutrient processing capacity in agricultural roadside ditches. *Science of The Total Environment* 637–638:470–479.

Smith D et al. (2010) *The Tallgrass Prairie Center guide to prairie restoration in the Upper Midwest*. First. University of Iowa Press, Iowa City, IA

Appendix 1. Seed mix planted on the constructed two-stage ditch.

Functional Group	Common Name	Scientific Name	Seeds/m ²
warm-season	big bluestem	<i>Andropogon gerardii</i>	32.28
warm-season	switchgrass	<i>Panicum virgatum</i>	21.52
warm-season	Indiangrass	<i>Sorghastrum nutans</i>	21.52
warm-season	prairie cordgrass	<i>Spartina pectinata</i>	5.38
cool-season	yellowfruit sedge	<i>Carex annectens</i>	21.52
cool-season	heavy sedge	<i>Carex grvida</i>	0.54
cool-season	troublesome sedge	<i>Carex molesta</i>	10.76
cool-season	awlfruit sedge	<i>Carex stipata</i>	10.76
cool-season	fox sedge	<i>Carex vulpinoidea</i>	75.32
cool-season	Canada wildrye	<i>Elymus canadensis</i>	21.52
cool-season	Virginia wildrye	<i>Elymus virginicus</i>	32.28
cool-season	fowl mannagrass	<i>Glyceria striata</i>	53.80
cool-season	Dudley's rush	<i>Juncus dudleyi</i>	215.20
cool-season	rice cutgrass	<i>Leersia oryzoides</i>	21.52
cool-season	green bulrush	<i>Scirpus atrovirens</i>	215.20
annual/biennial	nodding beggartick	<i>Bidens cernua</i>	5.38
legume	showy ticktrefoil	<i>Desmodium canadense</i>	2.15
spring forb	Canadian anemone	<i>Anemone canadensis</i>	0.54
spring forb	Virginia iris	<i>Iris virginica</i>	0.22
spring forb	foxglove beardtongue	<i>Penstemon digitalis</i>	32.28
spring forb	purple meadow-rue	<i>Thalictrum dasycarpum</i>	1.08
spring forb	bluejacket	<i>Tradescantia ohiensis</i>	1.08
spring forb	golden zizia	<i>Zizia aurea</i>	5.38
summer forb	swamp milkweed	<i>Asclepias incarnata</i>	2.69
summer forb	common milkweed	<i>Asclepias syriaca</i>	1.08
summer forb	tall tickseed	<i>Coreopsis tripteris</i>	1.08
summer forb	button eryngo	<i>Eryngium yuccifolium</i>	3.23
summer forb	spotted joe pye weed	<i>Eutrochium maculatum</i>	10.76
summer forb	smooth oxeye	<i>Heliopsis helianthoides</i>	2.15
summer forb	great St. Johnswort	<i>Hypericum ascyron</i>	32.28
summer forb	prairie blazing star	<i>Liatris pycnostachya</i>	4.30
summer forb	winged lythrum	<i>Lythrum alatum</i>	10.76
summer forb	wild bergamot	<i>Monarda fistulosa</i>	10.76
summer forb	obedient plant	<i>Physostegia virginiana</i>	5.38
summer forb	narrowleaf mountainmint	<i>Pycnanthemum tenuifolium</i>	21.52
summer forb	Virginia mountainmint	<i>Pycnanthemum virginianum</i>	21.52
summer forb	blackeyed Susan	<i>Rudbeckia hirta</i>	10.76
summer forb	sweet coneflower	<i>Rudbeckia subtomentosa</i>	21.52
summer forb	browneyed Susan	<i>Rudbeckia triloba</i>	10.76
summer forb	swamp verbena	<i>Verbena hastata</i>	21.52
summer forb	Culver's root	<i>Veronicastrum virginicum</i>	32.28
fall forb	common boneset	<i>Eupatorium perfoliatum</i>	21.52
fall forb	flat-top goldentop	<i>Euthamia graminifolia</i>	10.76
fall forb	common sneezeweed	<i>Helenium autumnale</i>	43.04
fall forb	sawtooth sunflower	<i>Helianthus grosseserratus</i>	1.08
fall forb	cardinalflower	<i>Lobelia cardinalis</i>	21.52
fall forb	great blue lobelia	<i>Lobelia siphilitica</i>	43.04
fall forb	smooth blue aster	<i>Symphyotrichum laeve</i>	5.38
fall forb	New England aster	<i>Symphyotrichum novae-angliae</i>	10.76
fall forb	prairie ironweed	<i>Vernonia fasciculata</i>	5.38

