Permaculture Design 2014

New Concord Farmstead

Jeremy Anderson
Design Exercise
Geoff Lawton's 2014 Online PDC

Contents

1. The Property 2
1.1 Location: 2
1.2 Eco-region: 2
1.3 Description: 3
1.4 History: 3
1.5 Slope: 5
1.6 Climate: 6
1.7 Sector Analysis: 9
1.8 Design Restrictions: 10
2. Permaculture Design 11
2.1 Owner Goals: 11
2.2 Water: 11
2.3: Access 16
2.4: Structure 18
2.5: Zone 0- Dwelling 20
2.6: Zone 1- Intensively managed 20
2.7: Zone 2- Regularly managed 20
2.8: Zone 3- Pasture and Food Forest 21
2.9: Zone 4- Forestry and Hedgerows 23
2.10: Zone 5- Wilderness 23
3. Implementation Plan 24
3.1 Phase 1 24
3.2 Phase 2 24
3.3 Phase 3 24
3.4 Phase 4 24
4. Appendix 25
4.A: Design Map 25
4.B: Plant lists 26
4.C: Water flow calculations 28

1. The Property

Figure 1

1.1 Location:

The property is 41.9 acres located less than a half of a mile west of the city limits of Greenville, TX, USA. The main entrance is at 33° 6'52.25"N and 96° 9'46.40"W.[1] The physical address is FM 3211, Greenville, TX 75401. Figure 1 shows the property boundary in blue. Elevation is 549 ft.

The property is bordered on three sides by county maintained roads. The southern edge of the property is FM 3211, a well paved road with moderate vehicle traffic. The western and the northern edges of the property is CR 2108, a gravel and dirt road with minimal traffic. Along the southern edge of the property is a 1.7 acre home site. This home site is NOT part of the property discussed in this design. At the NW corner of the property is a 2 acre parcel with a City of Greenville electrical substation. This parcel is also NOT part of the property discussed in this design.

The adjacent properties are mostly residential or agricultural.

1.2 Eco-region:

The property lies within the northern portion of the Blackland Prairie Eco-region. Texas A&M University describes this region as follows:

> <u>Topography</u>
>
> Topography ranges from gently rolling hills to level land. Forested areas are typically restricted to drainages and waterways.
>
> <u>Soils</u>
>
> The region is underlain by Upper Cretaceous marine chalks, limestone, and shale which give rise to the development of the characteristic black, heavy clay soils; along major rivers and tributaries a slightly more sandy soil.
>
> <u>Vegetation Description</u>
>
> The Blackland Prairie is a true prairie grassland community which is dominated by a diverse assortment of perennial and annual grasses. The soil is considered some of the richest soil in the world. Live oaks are the trees that dominate a large part of this eco-region. The northern and central portions of this area are

[1] Location in Google Maps can be found here.

> predominately comprised of post oak, blackjack oak, American elm, winged elm, cedar elm, sugarberry, green ash, osage-orange, honey mesquite, and eastern redcedar. In addition to the species listed for the northern and central areas, the southern area is comprised of live oak and Ashe juniper. Pecan, black walnut, black willow, American sycamore, honey locust and bur oak are commonly found in bottomland woodlands throughout this region. [2]

1.3 Description:

The Block Branch of the East Caddo Creek runs from the NE corner of the property to the SW corner. It runs when there is heavy rain, dries up completely in the summer, and has standing shallow water at most other times. The creek bed varies is size across the property, but it is typically less than 6 foot wide and 2 foot deep. There are two small gullies on the property that both drain into the Block Branch. Both of these gullies only contain water immediately after a large rainfall and both are typically less than two feet wide and one foot deep.

The perimeter of the property is barbed wire fence, but much of it is in poor condition. The main access onto the property is along the southern border where there is a culvert and an old concrete road. Unfortunately this road is badly damaged and is currently impassible by most vehicles.

There are tall power lines on the West side of the property and the North side of the property. Another power line (residential sized) runs roughly north to south through the property.

Along the southern edge of the property there is a buried water line for connection to Greenville city water.

The low-lying areas of the property are in various stages of early successional forest regrowth. Most of the trees are Honey Locust, Bois d'arc, and Cedar elm. The largest of the trees are approximately 50 foot tall with a 2 foot diameter trunk.

The soil is heavy black clay. Very little organic matter and/or sand are present. Soil tests confirm the high percentage of clay. The soil has a pH of approximately 6.5-7.0.

1.4 History:

This area of Texas was settled in the mid 1850's and called New Concord. In that time-frame much of the surrounding areas were used for cotton production. Eventually the cotton boom died out and so did the community of New Concord. The last building burned down in the mid 1950's. On the property are the foundation remains of the New Concord schoolhouse. I have been unable to find out when the building was destroyed. On the southern edge of the property is a granite marker commemorating the community of New Concord.

[2] http://texastreeid.tamu.edu/content/texasecoregions/BlacklandPrairies/

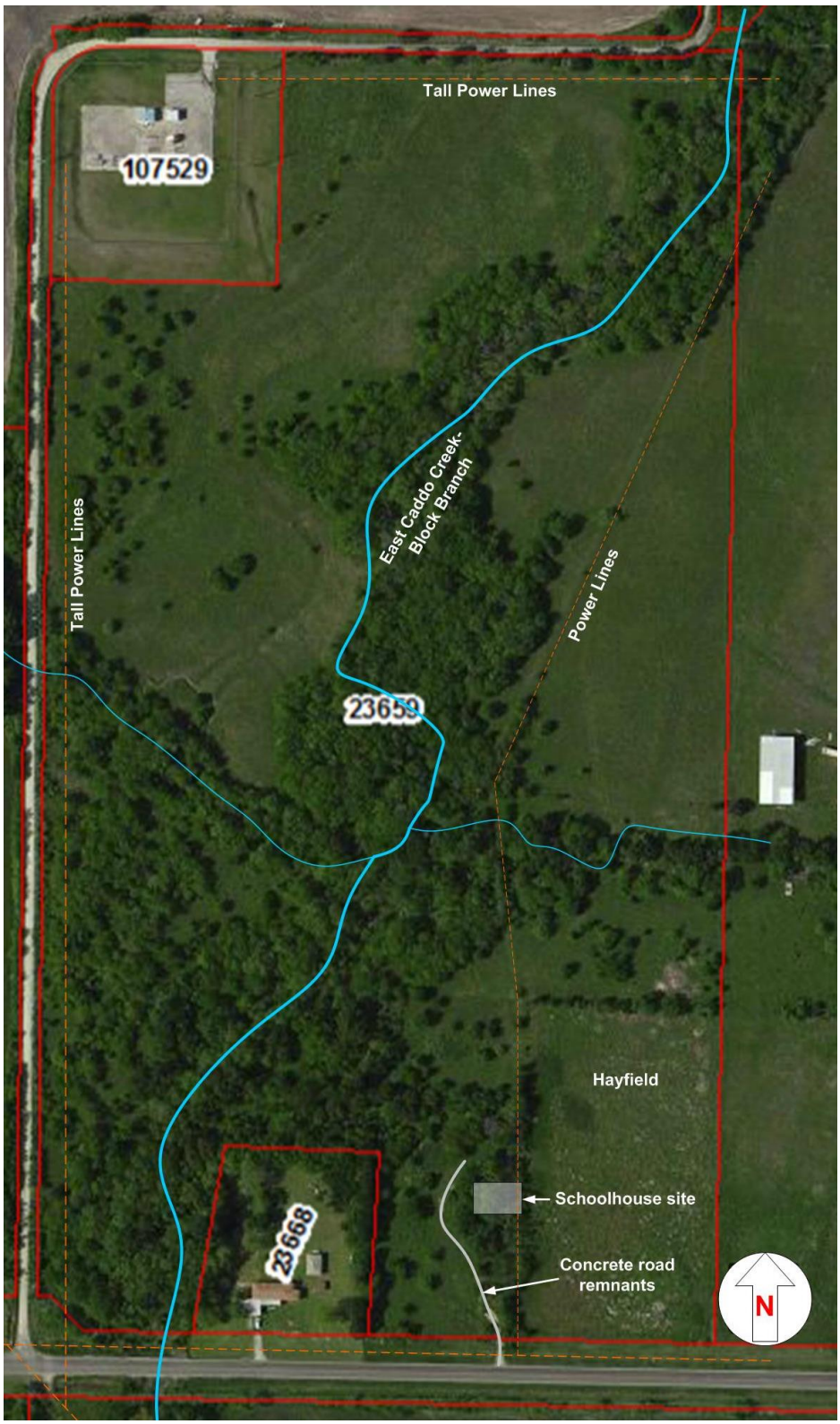


Figure 2

There may have been other structures on the property at one time, but no evidence remains. Based on the size and types of trees on the property, I suspect that the area has been clear cut within the last 50 years, but I have been unable to verify that. The low-lying areas of the property have been allowed to reforest since the heavy clay soil makes the low areas hard to farm when wet.

1.5 Slope:

See Figure 3 for a contour map. Available contour maps do not show a high enough resolution to be useful for design. 1 foot contour lines shown in Figure 3 were generated from Google Maps. Contour lines are to be used for planning purposes only and require on-the-ground verification.

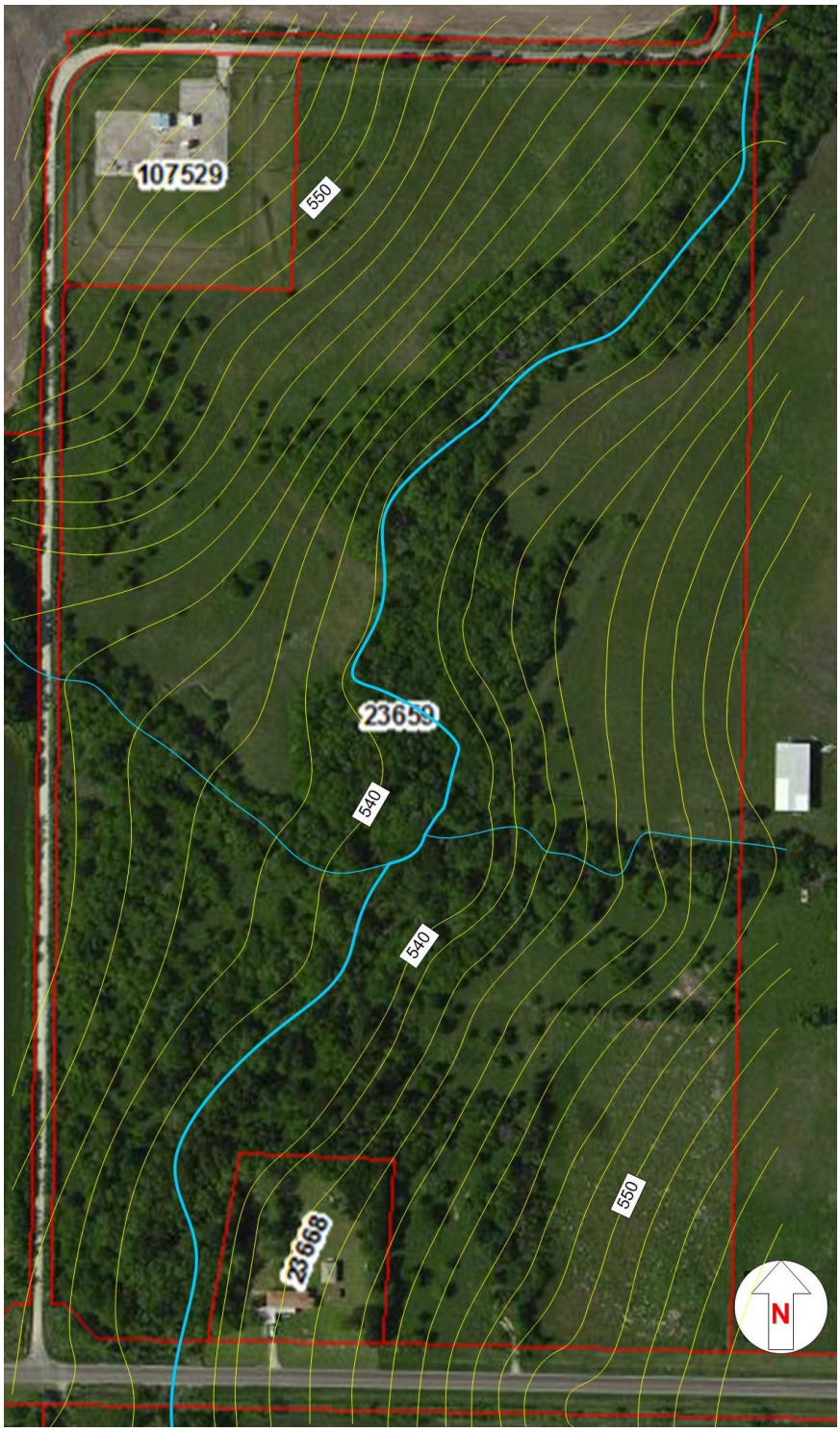


Figure 3

Slopes are NW facing on the Eastern side of the property and SE facing on the Western side of the property. All slopes are very gentle ranging from ½ to 2 degrees.

1.6 Climate:

Greenville, TX is considered Humid Sub-tropical, Köppen classification Cfa.

C - In Humid Middle Latitude Climates land/water differences play a large part. These climates have warm, dry summers and cool, wet winters.

f - Moist with adequate precipitation in all months and no dry season.

a - Hot summers where the warmest month is over 22°C (72°F).[3]

Most of the Eastern Unites States, western China, and some parts of South America are also included in this bio-region. When looking specifically at Greenville, we must consider climate data specific to this location.

Precipitation/Evaporation: The average precipitation in Greenville is 41 inches. This is spread throughout the year with the highest average rainfall in May (5.29 inches). The driest month is August (2.28 inches). Although Greenville has good rainfall throughout the year in the summer the evaporation rate climbs well above the rate of precipitation. This pattern of evaporation greater than precipitation is more typical of dryland environments. See Figure 4 for a chart of Precipitation vs Evaporation.[4]

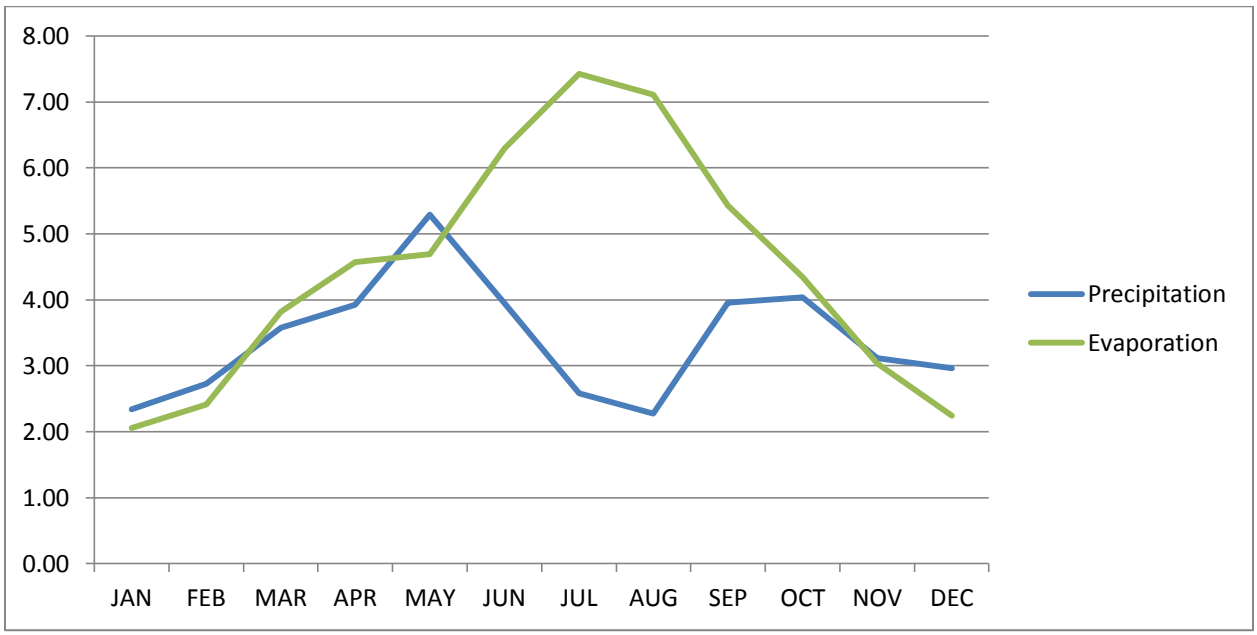


Figure 4

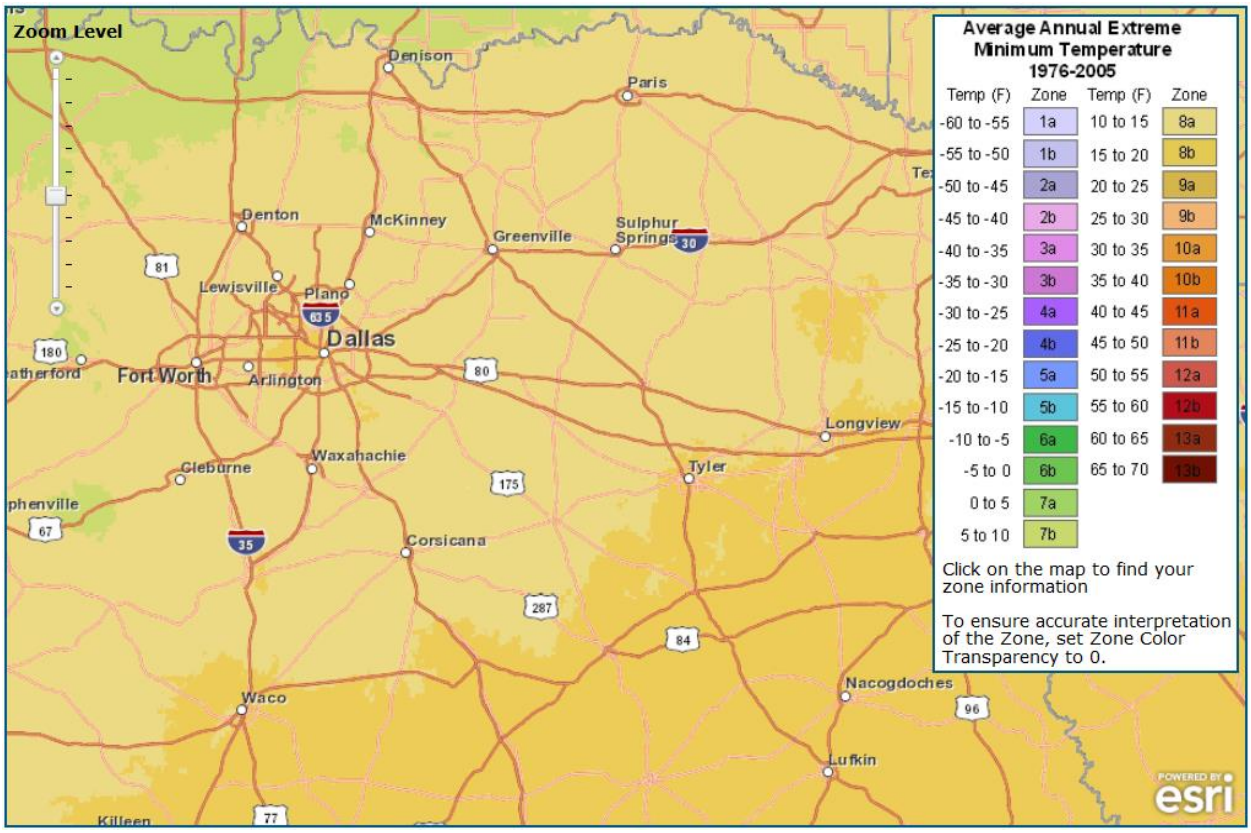
[3] http://www.blueplanetbiomes.org/climate.htm

[4] Precipitation and Evaporation rates are based on Texas Water Development Board data, 1945-2013. http://www.twdb.texas.gov/surfacewater/conditions/evaporation/index.asp

Temperature: The hottest month of the year is August with an average high of 98° F. The coldest month is January with an average low of 33° F. See Figure 5 for an average temperature chart.[5] Although the average low temperature is above freezing, cold snaps regularly reach 10° F. This relates to a hardiness zone of 8a. See figure 6 for hardiness zone map.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
avg high	58	62	69	77	85	92	96	98	91	80	69	59
avg low	33	37	44	52	62	69	73	73	65	54	44	35

Figure 5



[5] Temperature averages based on 1981-2001 data.

Wind: Although Greenville does experience thunderstorms and the occasional tornado, the average wind speeds are generally low, ranging from 5-10 mph. The predominant wind direction is south. One notable exception to this is cold winter fronts blown in by north winds. See figures 5 and 6 for additional information.[6]

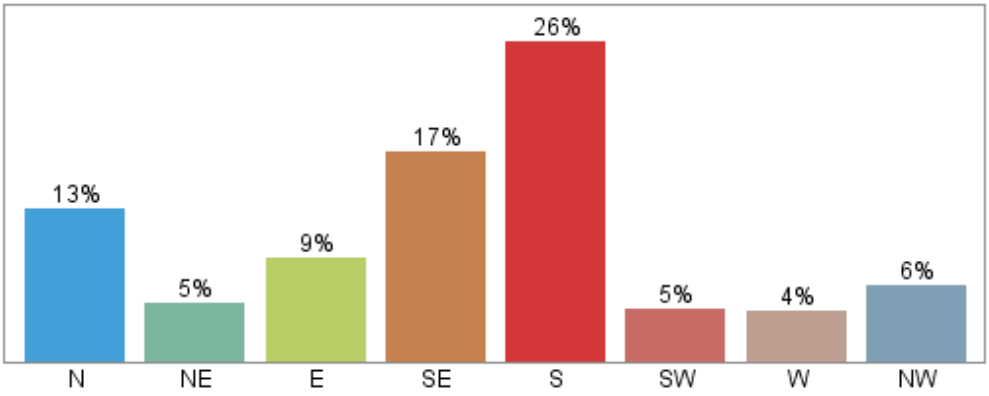


Figure 6 - Average Wind Direction

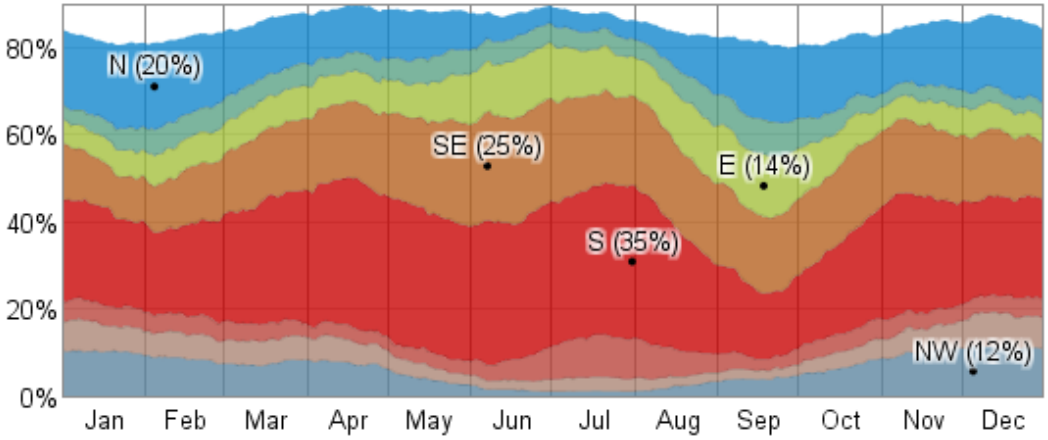


Figure 7- Time spent with various wind directions

[6] http://weatherspark.com/averages/30424/Greenville-Texas-United-States

1.7 Sector Analysis:

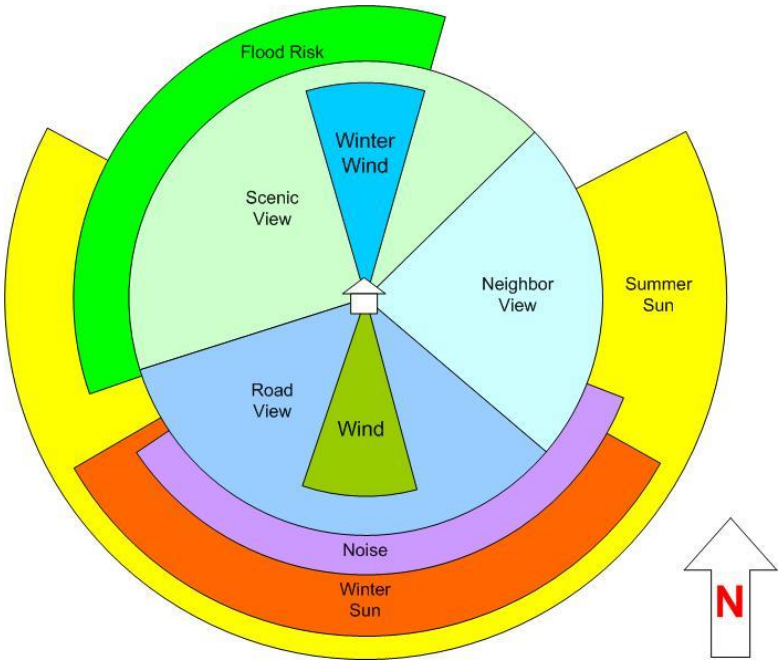


Figure 8: Sector Analysis

Sector analysis is based on a home site location described in section 2.4, Permaculture Design - structure. Sectors are as follows:

Flood Risk: Home site is outside of the 100 year floodplain, yet there is still a flood risk from the direction of the creek.

Noise: There is road noise from the road on the southern edge of the property as well a high traffic road to the SSE.

Summer Sun: Sun exposure on the Summer Solstice

Winter Sun: Sun exposure on the Winter Solstice

Neighbor View: neighbor's property is visible in this direction. On that property there is currently nothing unsightly, but a visual screen would be appreciated.

Road View: direction where the road on the south side of the property is visible.

Scenic View: The trees along the creek are scenic.

Wind: Predominate wind direction is South

Winter Wind: Cold winter winds come from the North.

1.8 Design Restrictions:

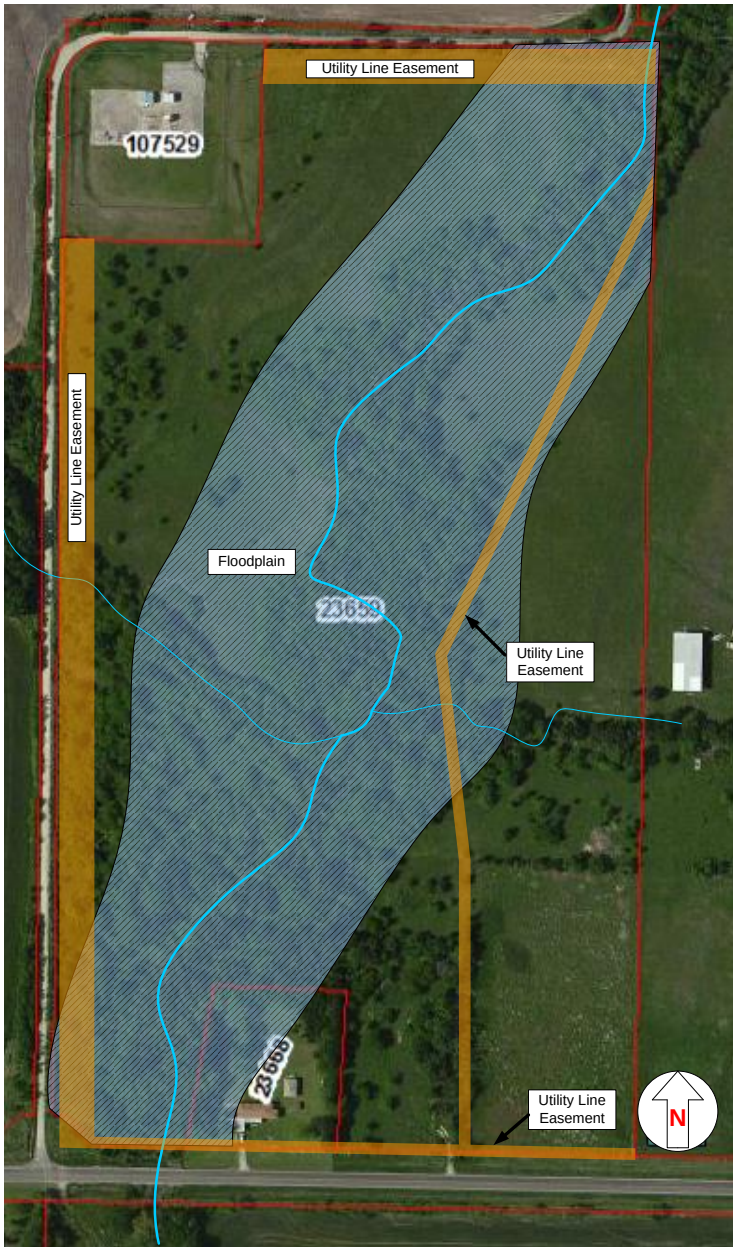


Figure 9: Design Restrictions

Flood Plain: The 2013 FEMA floodplain maps include the area directly adjacent to the Block Branch of the East Caddo Creek.[7] FEMA has not conducted a detailed study of this area, so the floodplain boundaries are approximate, and are not defined directly by elevation or distance from the creek bed. Special permits would be required for structures or earthworks within the floodplain. Negatively impacting the holding capacity within the floodplain is prohibited.

Water Easement: There is a 2" water line that runs along the southern edge of the property. The exact location of this water line is not documented, but according to the utility company it should lie 15' within the southern fence line.

Power Line Easements: There are tall power lines with 30' easements on the Eastern and Northern edges of the property. Running through the property and on the Southern edge are residential sized power lines with 10' easements.

Agricultural exemption: The property is currently taxed under an agricultural exemption. This is a significant reduction in property taxes. If this status is not continuously maintained it will result in a large tax penalty and would require 5 years to re-qualify. Currently the exemption is maintained by cutting hay in the open spaces.

Planned Road Expansion: In the summer of 2015 there are plans to begin road work on the Western side of the property. This would make CR2108 a through road with moderate traffic. The current road plans are not final and could easily change before construction begins.

[7] FIRM, Flood Insurance Rate Map, Hunt county Texas, map number 48231C0360G, revised Jan 6, 2012

2. Permaculture Design

2.1 Owner Goals:

I currently co-own the property along with my wife and my wife's parents. The primary goal for development of the property is to improve our quality of life with better food, more time outside, and space to relax and entertain.
This includes the following (in no particular order):

- Space: We'd like to get out of the neighborhood setting where we feel crowded by nearby houses. I'd also like enough open space for an informal, yet safe, archery or shooting range.
- Children: We have a 2 year old son and a daughter due in October. We want to raise our children in a place where they can run in the grass and explore the woods. If we tell them to go outside and play I want to give them more options than a small yard in the back or a road in the front.
- Food: In our area high quality food is hard to get and/or very expensive. We'd like to eat more organic fresh produce and naturally raised meat, but the only way that we'll be able to afford it is to grow/raise it ourselves.
- Low Maintenance: We do not plan on being full time farmers. I will be keeping my current full time job. My wife and kids will be able to perform some tasks during the day, but most maintenance will be limited to evenings and weekends.
- Family: The design should include two home sites. One will be for me and my growing family. The other will be a retirement home for my wife's parents.
- Wildlife: Rather than having wildlife visit us at a bird feeder or a pool of water, we'd like to have our home in a place where wildlife is comfortable living around us.
- Entertaining: We are part of a bible study with four other families, all with young children. We meet at various homes, yet we are unable to host at our current home due to space limitations. The design should include space for study and play both indoors and outdoors.
- History: There is not much left of the foundations of the New Concord school house, but we'd like to preserve what little there is. The design should work around the site and not disturb or degrade it.

2.2 Water:

Although there are natural creeks on the property, at this time it is not worth the effort to pursue earthworks within the floodplain. Layers of permits and bureaucracy increase the effort, while low elevation and occasional flooding decrease the benefits from such features. For this design all water features will be limited to the area outside the 100 year floodplain. Catchment analysis, based on surface flow above the lowest swale, is shown in figure 10. Above grade roadways interrupt the surface flow and decrease catchment area in several locations. The design includes three ponds and four swales as shown in Figure 11.

Pond A: This pond is a below grade impoundment situated on a small existing gulley. It is the source for fill dirt used for the gravel access road described in Section 2.3, Permaculture Design - Access. Since the pond is below grade, only a short dam wall is required to span the gulley. The top of the dam is graveled and used for all weather access to the areas north of the gulley. There are 12 foot long spillways at the southern and northern ends of the pond.[8] Two 6" dribbler pipes keep the spillways dry between rainfall events. A small silt trap lies on the existing gulley east of pond A.

Approximate surface area is .18 acres.
Average depth is 6 ft.
Approximate volume is 36,000 gal.

Swale 1: This is a 9 foot wide swale whose cross section is shown in Figure 12. This swale extends along a contour line north of pond A. The increased catchment from this swale will fill pond A before it is then backfilled. At the north end of the swale is an 8 foot long spillway.[8]

Swale 2: This is a 9 foot wide swale whose cross section is shown in Figure 12. This swale extends along a contour line southwest of Pond A, connecting Pond A to Pond B. The increased catchment from this swale will fill ponds A and B before it is then backfilled. At the south end of the swale is an 8 foot long spillway. [8]

Pond B: This is a contour dam linked to Swales 1 and 2 as well as Pond A. This area of the property currently retains standing water after a rainfall event and fills with small wildlife adapted to vernal pools. This pond should naturalize easily, spreading frogs, turtles, crawfish, and other native species throughout the connected features.

Approximate surface area is .23 acres.
Average depth is 6 ft.
Approximate volume is 46,000 gal.

Pond C: This is a small "pocket pond" connected to Swale 3. This will retain water and create habitat for aquatic species that will spread throughout the swale after a rainfall event. It may be possible to irrigate select areas or water livestock from the water stored in this pond, but experimentation will be required to determine the best use of this limited storage capacity.

Approximate surface area is .07 acres.
Average depth is 6 ft.
Approximate volume is 14,000 gal.

Swale 3: This is a 6 foot wide swale whose cross section is shown in Figure 13. This swale extends along a contour line southwest of pond C. The increased catchment from this swale will fill pond C before it is then backfilled. At the south end of the swale is an 8 foot long spillway. [8]

---

[8] See Appendix 4.C for spillway length calculations based on max flow events.

Pond D: This impoundment is an earthen tank, or "turkey's nest" dam. Water will be pumped into this dam for storage. This pond will be used to irrigate select areas or water livestock. Shade strategies will be explored to reduce evaporation from this storage tank.

Approximate surface area is .04 acres.

Depth is 12 ft.

Approximate volume is 17,000 gal.

Swale 4: This is a 9 foot wide swale whose cross section is shown in Figure 12. This is the only water element on the North West area of the property. This catchment area in this part of the property is greatly reduced by the gravel road that intercepts surface flow. An 8 foot spillway is located at the south end of the swale.[8]

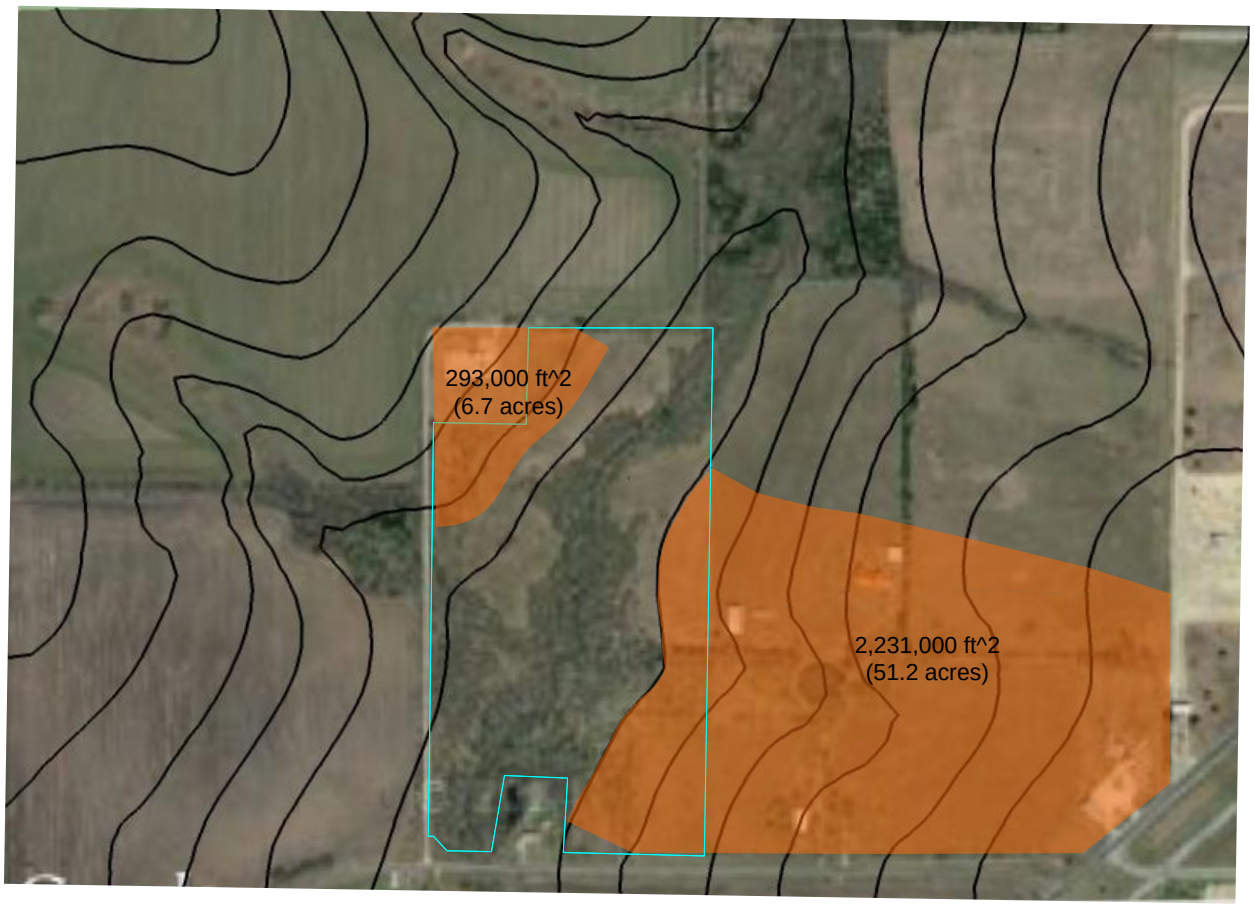


Figure 10

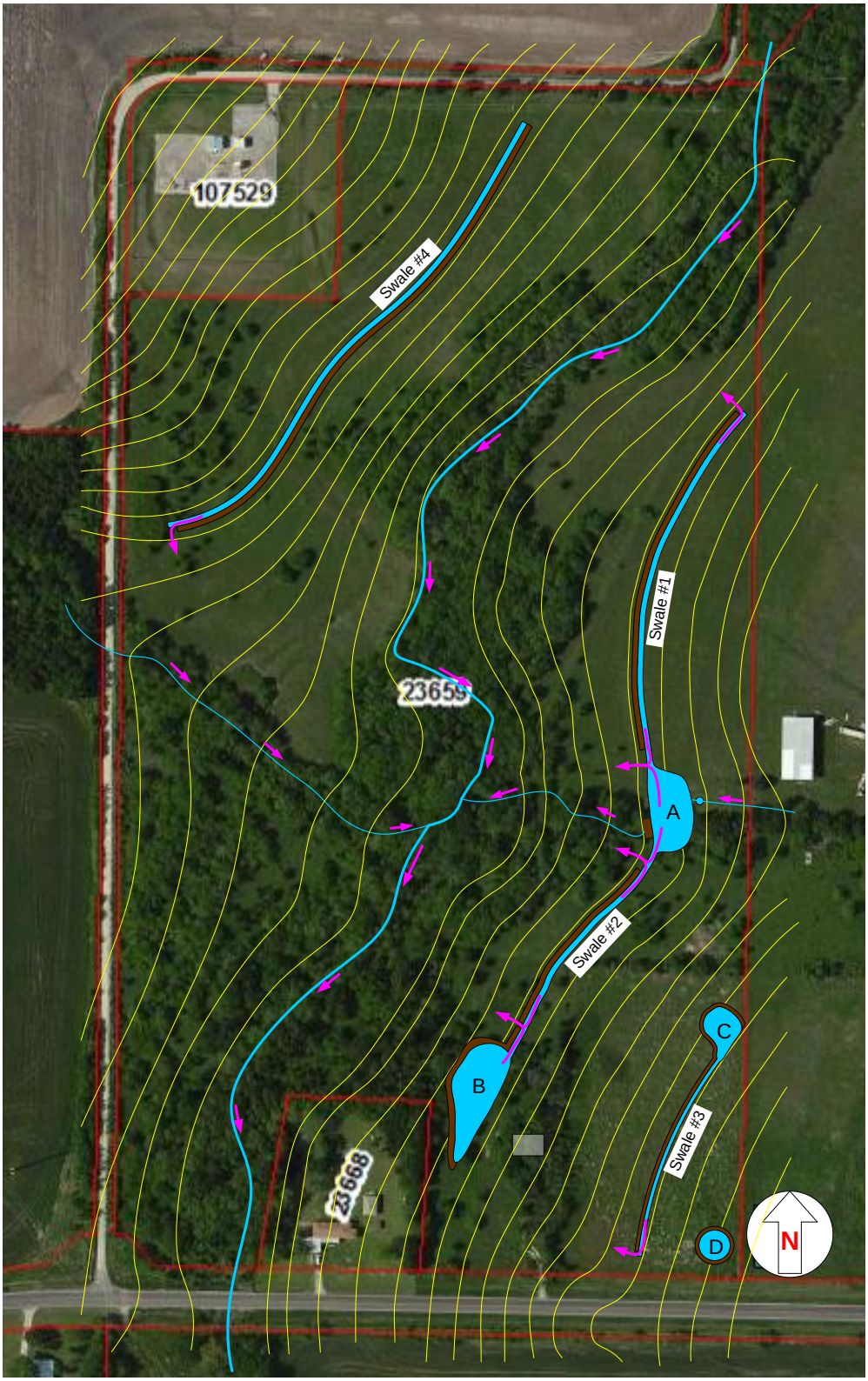


Figure 11

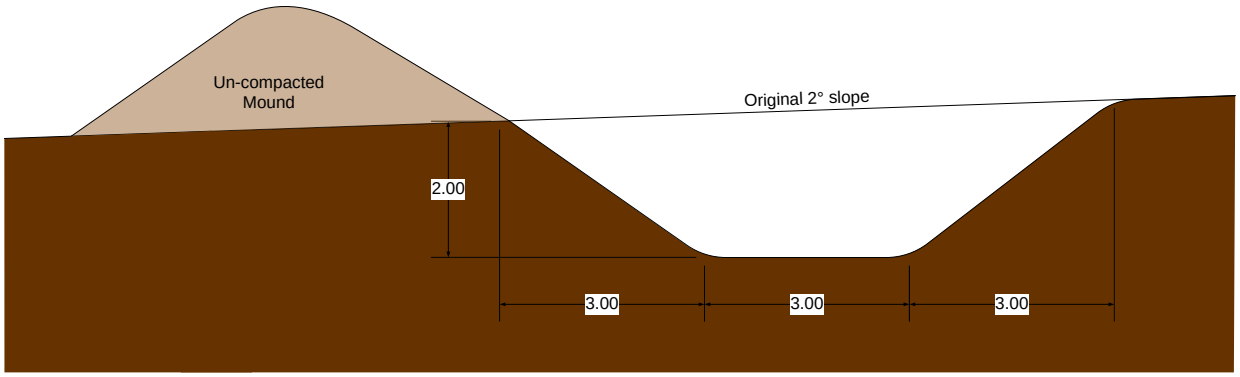


Figure 12

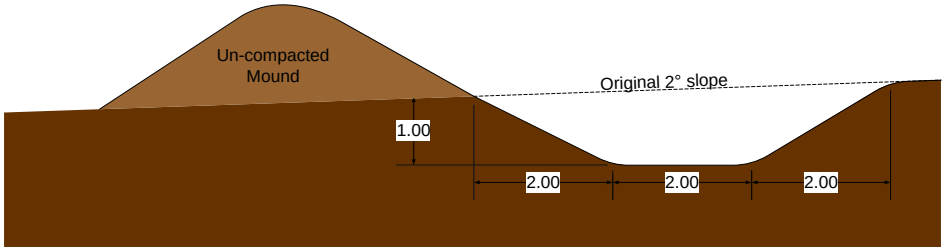


Figure 13

<u>Future possibilities with Water</u>: These ideas are not described in detail within this design. They can be researched in more depth at a future date. Most involve earthworks within the floodplain, something that was not explored in this design.

- Spreader swales: Within the floodplain, swales connected into the creek bed would spread water sideways when the creek is full. These swales could be angled to concentrate flow into the creek when the creek is flooding.
- Summer water hole: The creek dries up in summer. Deep holes could be dug into the creek bed to store water through the summer.
- Ponds within the floodplain: There are two areas in the NW side of the property where ponds could be dug below grade. Both are within the floodplain. Ponds within the floodplain may be permissible if they are completely below grade. When the road is expanded on the Western side of the property TXDOT may be willing to dig these ponds in exchange for the fill dirt.
- Diversion from roadside ditch: Water from the roadside ditch along the southern edge of the property could be diverted into Swale 3. This may allow for a second pond along Swale 3, or increased capacity of Pond C.

2.3: Access

The property can be accessed from FM 3211 along the southern edge, and from CR 2108 on the Western and Northern edges. CR 2108 is a county maintained gravel road, but the road conditions along the northern border can be fairly poor after a rain. The western section of 2108 is more frequently maintained since the utility company needs access to the utility substation. The western section of 2108 is better than the northern section, but it can still be rough in spots after a heavy rain. The most reliable all weather access to the property is from FM 3211, a well paved two lane road.

At one time there was a concrete road going north from the southern edge of the property, passing the old schoolhouse. This road is beyond repair. Since there was no foundation, the soil eroded below the road and has broken it into chunks roughly 4' X 4'.

A culvert over the drainage ditch along 3211 connects to the old concrete road. This culvert is in fair condition. Utilizing the existing culvert was considered, but that would require additional tree removal and complexity to avoid the remains of the old schoolhouse.

See Figure 14 for the current design for access across the property.

Culvert 1: A permit will be required before installing this culvert. The size and max width will be dictated by the county permitting office. Removal of the existing culvert may be required.

Gravel Road: This is a 12' wide gravel road and is the main all weather access onto the property. It is raised above grade using fill dirt from the excavation of Pond A.

Culvert 2: The East side of the Gravel Road will gather water. This 18" culvert drains water under the road directing it toward Swale 2 and Pond B.

Gravel topped dam wall: The Gravel Road extends over the top of the small dam wall of Pond A. This roadway is 2' above the spillways on either side of Pond A.

Unpaved Track: This unpaved access way is used for getting vehicles or livestock from one side of the property to the other. It will only see occasional use. Although this track is within the floodplain, no permits will be required since it is not above grade.

Bridge: This bridge crosses the Block Branch creek. Permits will be required for construction. It may be possible to utilize a large culvert instead of a bridge, but the culvert would need to be designed to tolerate occasional submersion. Additional research is required.

Path: A footpath is utilized to access the remainder of the property. The path also closes a ½ mile walking route through all of the properties main areas.

Footbridge 1 & 2: Two footbridges are required along the path. These are small structures since they are designed for foot traffic only. Footbridge 2 is longer than Footbridge 1 since it crosses a larger watershed. Both of these are within the floodplain, so they will both require permits, but I expect that Footbridge 2 will have more stringent requirements.

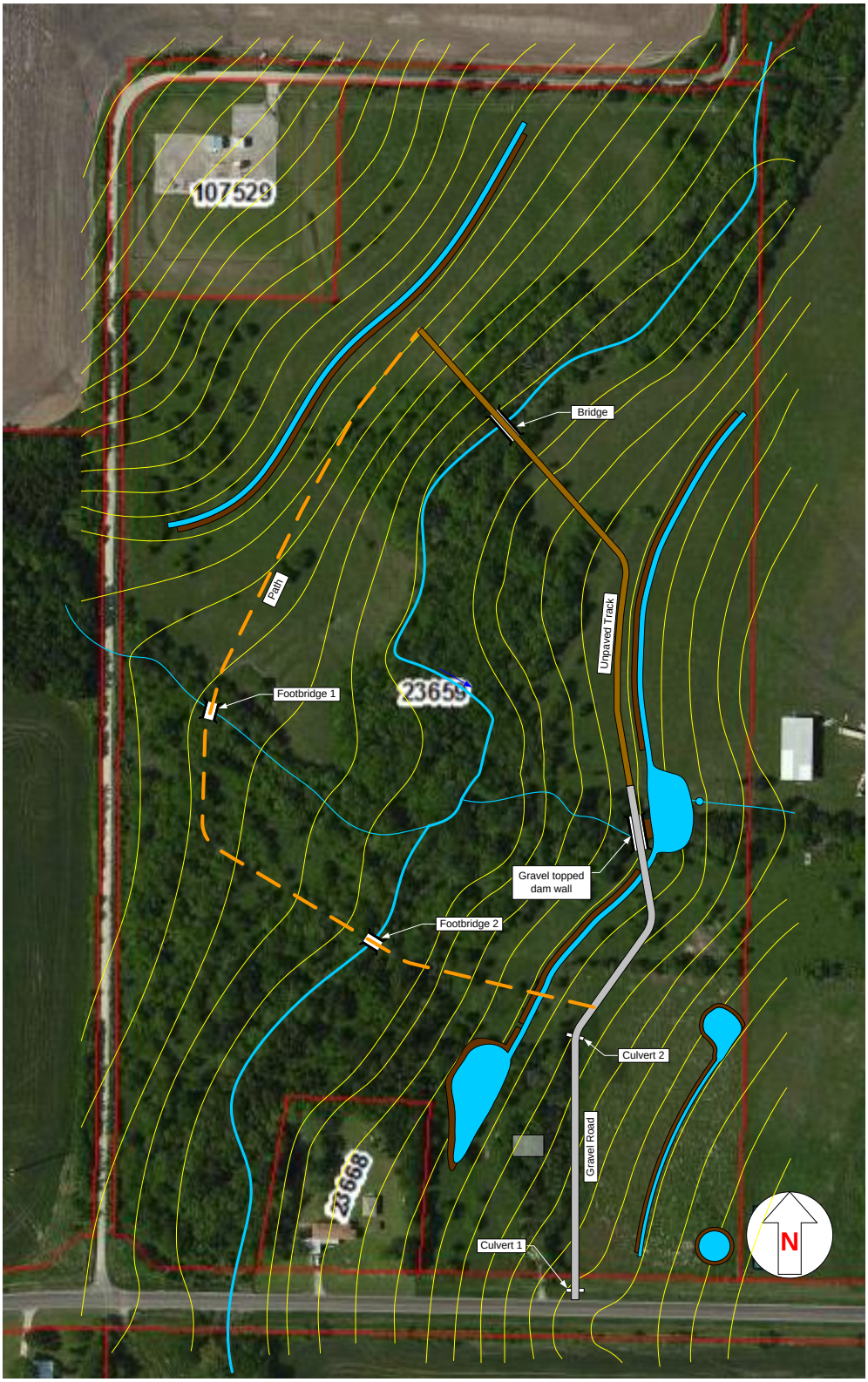


Figure 14: Access

2.4: Structure

Perimeter barbed wire fencing is the only existing structure on the property. Most of this fencing requires repair or replacement. New structures include 2 home sites, 2 outbuildings, and interior permanent fencing. See Figure 15 for location of new structures.

Home site 1: Located well away from FM 3211 for the sake of privacy and noise control. There is plenty of room to experiment with several methods of windbreaks and noise buffers. The site has good southern exposure and easy access.

Home site 2: Located along the gravel road a comfortable distance from Home site 1 (200 ft. apart). If we are forced to sell the property in the future this spacing between home sites would allow the property to be split and sold to different buyers. The site has good southern exposure and easy access.

Outbuilding A: 2 car carport located on the north side of Home site 1.

Outbuilding B: Workshop and farm equipment storage located north of the carport and oriented along the gravel road.

Outbuilding C: Three car garage with RV storage. Located on the north side of Home site 2, but located so it does not entirely block the view of Pond A.

Fencing: Permanent fencing is shown with green lines in Figure 15. Aside from perimeter fencing, no permanent fencing is within the floodplain. Permanent fences keep livestock out of swales, ponds, and zones 1 and 2. Temporary electric fencing will be used to subdivide grazing areas as necessary.

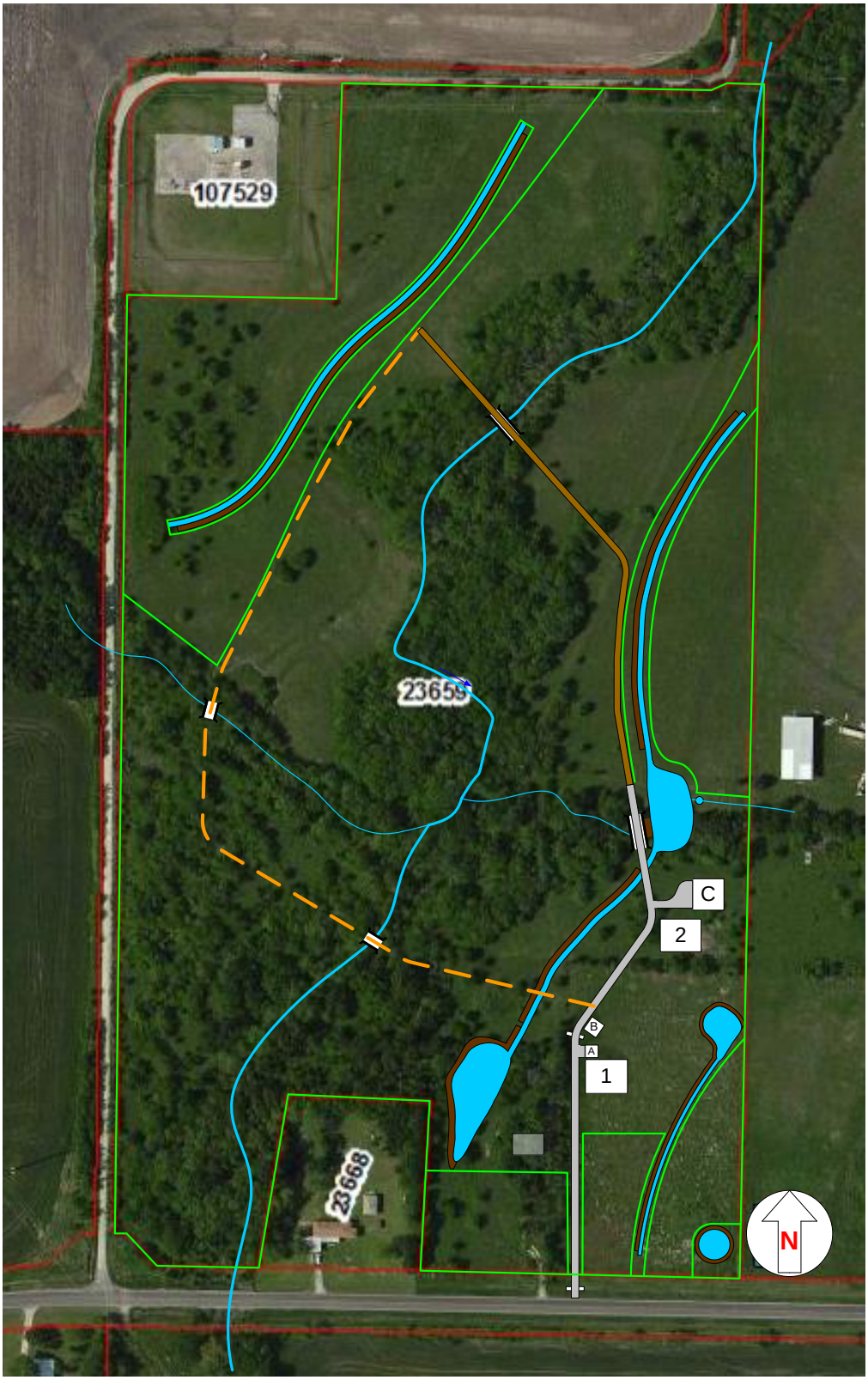


Figure 15: Structure

2.5: Zone 0- Dwelling

Floor plans and styles have not been finalized. Further research is required. Final designs will include the following elements:

- Living areas on the south side of the house.
- Large windows on the south wall, properly sized eaves, and stained concrete flooring (thermal mass) allow for winter passive solar heating.
- Heavily insulated ceiling and northern wall.
- Deep eaves on Northern, Western, and Eastern sides for outdoor sitting and entertaining.
- Covered outdoor living area with a grill, fireplace, and additional sitting and entertaining space.
- Storm shelter

Figure 16

2.6: Zone 1- Intensively managed

Zone 1 is shaded blue in Figure 16. This zone includes garden, lawn, and playground areas. It also includes a chicken yard and the route for walking between home sites.

2.7: Zone 2- Regularly managed

Zone 2 is shown in Figure 16 as the shaded yellow area. This includes pruned fruit trees, chicken paddocks, and deciduous shade trees on the southern sides of the homes.

Future possibilities in zone 2 include ducks, geese, bees, Hugelkultur, mushroom cultivation, and a shade house for plant cultivation.

2.8: Zone 3- Pasture and Food Forest

Pasture areas are shown in Figure 17. Areas shaded in purple lie within the floodplain. Appropriate fencing will be coordinated with the county floodplain administration. Permits may be required. Approximately 13.6 acres are available for pastured grazing. Most paddocks will require additional subdivisions using temporary electric fencing to maintain appropriate stocking density for rotational cell grazing.

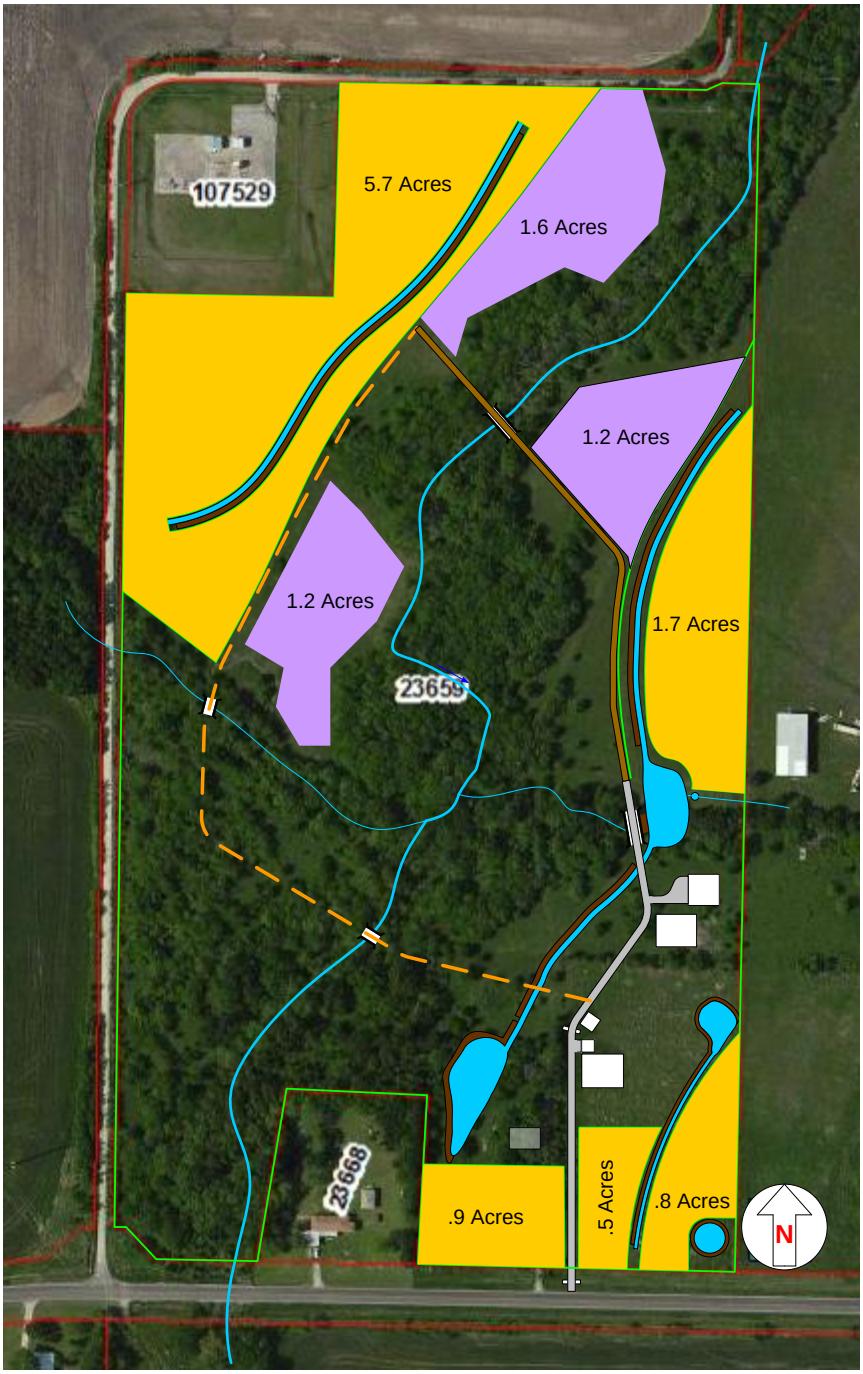


Figure 17: Pasture

In addition to controlled grazing, pasture will be improved with subsoil plowing and broadcast over-seeding.

Cattle and sheep will be grazed and housed in the pasture. Selection of appropriate livestock breeds and stocking density requires additional research and experimentation. Finish mowing may be required while stocking densities are adjusted and fencing is installed.

Figure 18 shows the layout of food forests along swales. Fruit and nut bearing species selected will be maintenance free and well adapted to the unique soil and weather patterns of this area. To achieve that, as many plants as possible will be grown from seed. Experimentation is required to determine the species that will best accomplish this. See Appendix 4.B for plant lists.

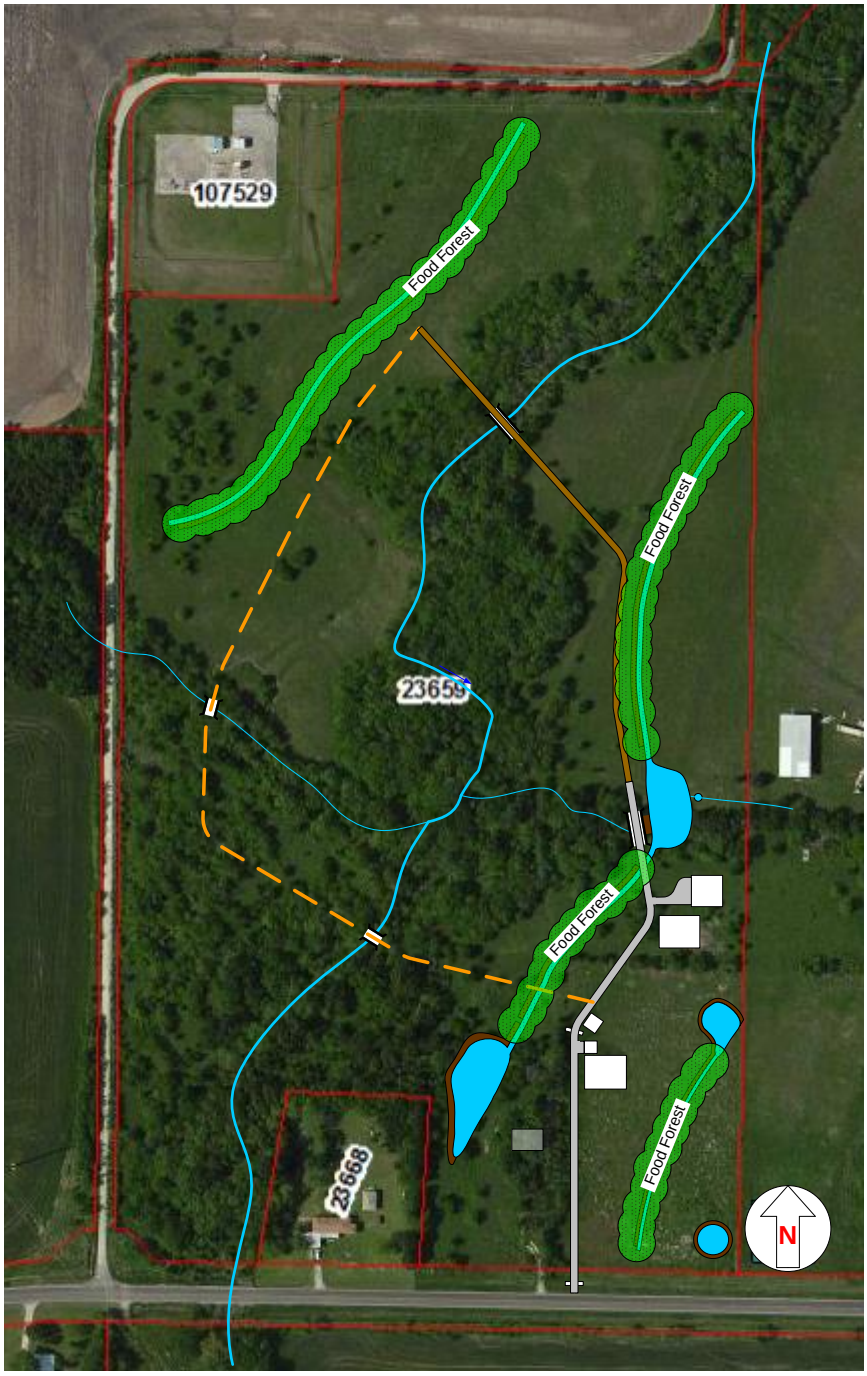


Figure 18: Food Forest

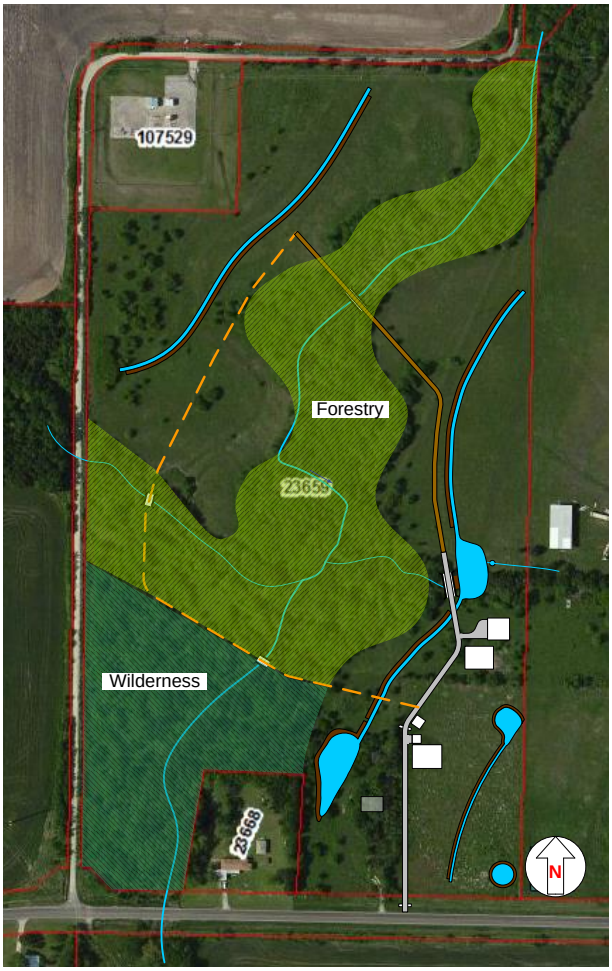


Figure 19: Zones 4 & 5

2.9: Zone 4- Forestry and Hedgerows

Most of the floodplain is currently undergoing early successional regrowth forest. Native lowland forests in this eco-region include elm, cedar, oak, pecan, walnut, and willow. These native trees produce high value timber yields as well as nut and craft materials. Few of these native tree species are currently present on the property. These species will be encouraged and/or planted in the forestry areas of the property as shown in Figure 19. These areas total approximately 11 Acres. Select areas may be suitable for managed grazing below the canopy. Other areas may be suitable for wildlife exclusion zones.

Experimentation with hedgerows is required. Any internal fences detailed in section 2.4 may be suitable for coppiced hedgerows instead of wire or woven fencing.

2.10: Zone 5- Wilderness

Approximately 5.5 acres of the property are reserved for wilderness area. This area is shown in Figure 19.

3. Implementation Plan

This design will be implemented incrementally over a long period of time. Even if time and budget limitations were not an issue the design would not be installed all at one time. The property is simply too extensive to be maintained with our current knowledge base and available time. By implementing the design incrementally we will grow into the property. We will be able to learn the ins and outs of the design and tweak it or change it to meet our needs. This property has potential to far exceed the needs of one family. Once production exceeds our ability to use it or share it with friends, we will explore options to monetize the surplus.

3.1 Phase 1

- Dig Pond A.
- Construct the gravel road using fill dirt from the excavation of pond A.
- Repair of perimeter fencing.
- Connect to city power and water.

3.2 Phase 2

- Install Swales and remaining ponds.
- Seed swales with hardy nitrogen fixing trees and ground cover.
- Construct Home sites.

3.3 Phase 3

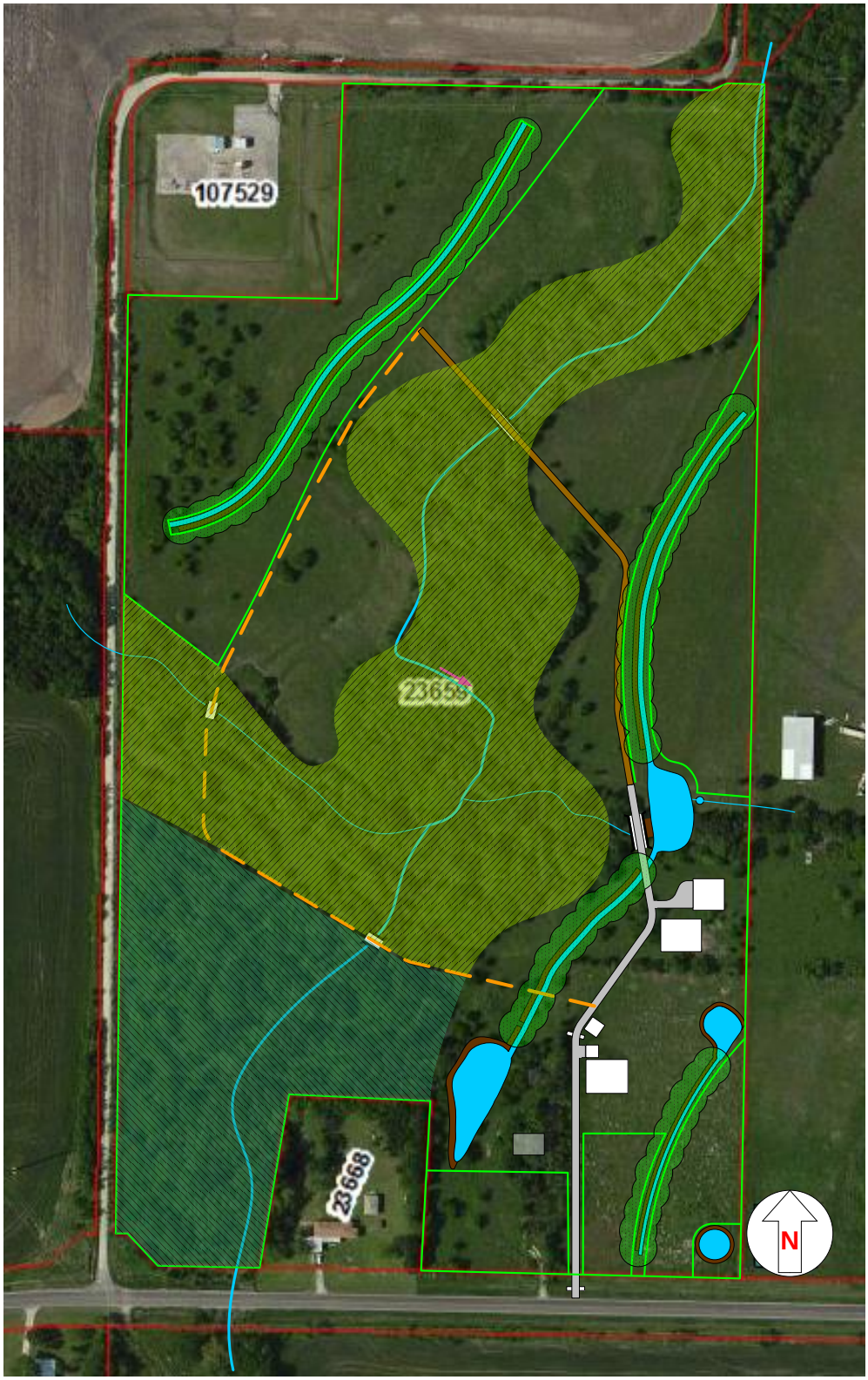
- Move onto the property.
- Establish Zones 1 and 2.
- Construct remaining access ways.

3.4 Phase 4

- Plant productive species into the food forest as time and budget allows. Zone 1 and Zone 2 plantings will be utilized to propagate food forest species.
- Develop forested areas within the floodplain for lumber and craft material yields.

4. Appendix

4.A: Design Map



4.B: Plant lists

Below are plant lists for nitrogen fixing support species and food forest productive species. These lists are starting points. Trials will be required before planting large quantities of any one species in the food forests or the zone 2 plantings. I have not attempted to list all of the possible varieties of each type of fruit. For early trials, variety selection will be based upon availability.

Nitrogen Fixing species

Name	scientific name	type
Dwarf Prairie Acacia	Acaciella angustissima	small tree
Honey Pod Mesquite	Prosopis glandulosa	small tree
Texas Mountain Laurel	Sophora secundiflora	shrub
Redbud	Cercis canadensis	small tree
Redroot	Ceanothus herbaceous	small tree
Leucaena	Leucaena leucocephala	tree
Mimosa	Albizia julibrissin	small tree
Kaimi Clover	Desmodium incanum	ground cover
Black Locust	Robinia pseudoacacia	tree
Alder	Alnus spp	tree
Japanese Pagoda Tree	Styphnolobium japonicum	tree
Amur	Maackia chinensis	small tree
Autumn Olive	Elaeagnus umbellata	shrub
Brooms	Cytisus and Spartium spp.	shrub
Hairy Locust	Robinia hispida	shrub
False Indigo	Amorpha fruticosa	shrub
Bladder Senna	Colutea arborescens	shrub
Miracle Plant	Lespedeza bicolor	shrub
Tree Lupin	Lupinus arboreus	shrub
New Jersey Tea	Ceanothus americanus	shrub
Bayberry	Myrica pensylvanica	shrub
Sea Buckthorn	Hippophae rhamnoides	shrub
Goumi	Elaeagnus multiflora	shrub

Food Forest productive species

Name	scientific name	type
Advocado	Persea americana	tree
Almond	Prunus dulcis	tree
Apple	Malus domestica	tree
Blackberry	Rubus spp	shrub
Blueberry	Vaccinium spp	shrub
Cherry	prunus spp	tree
Chestnut	Castanea spp.	tree
Chinquapin	Castanopsis spp	tree
Fig	Ficus carica	small tree
Goumi	Elaeagnus multiflora	shrub
Grapes	Vitis spp	vine
Jerusalem Artichoke	Helianthus tuberosus	root
Jujube	Ziziphus jujuba	tree
Mayhaw	Crataegus aestivalis	shrub
Maypop	Passiflora incarnata	vine
Mulberry	Morus spp.	tree
Peach	Prunus persica	tree
Pear	Pyrus spp	tree
Persimmon	Diospyros spp.	tree
Plum	prunus spp	tree
Raspberry	Rubus strigosus	shrub
Southern Hackberry	Celtis laevigata	tree
Sweet Potato	Ipomoea batatas	root
Walking Onion	Allium proliferum	root

4.C: Water flow calculations

<u>Spillway sizing based on a max 24 hour rainfall event of 7 inches</u>

$$flow\left({}^{gal}/_{sec}\right) = \frac{catchment\ area(ft^2) \times rainfall(in)}{1(day)} \times \frac{1(ft)}{12(in)} \times \frac{1(day)}{24(hrs)} \times \frac{1(hr)}{60(min)} \times \frac{1(min)}{60(sec)} \times \frac{7.48(gal)}{1(ft^3)}$$

Pond A will be installed first, so the catchment of Pond A without swales needs to be considered.

$Pond\ A\ Catchment = 1383853(ft^2)$

$East\ Catchment\ bottom\ swale\ flow = 70\left({}^{gal}/_{sec}\right)$

If we assume that 3 gallons can cross 1 foot of spillway each second results in a required 23.3 feet of spillway. Two 12 foot spillways will result in 24 linear feet for spillway.

Pond A will be installed first, so the catchment of Pond A without swales needs to be considered.

$Pond\ A\ Catchment = 1383853(ft^2)$

$East\ Catchment\ bottom\ swale\ flow = 70\left({}^{gal}/_{sec}\right)$

If we assume that 3 gallons can cross 1 foot of spillway each second results in a required 23.3 feet of spillway. Two 12 foot spillways will result in 24 linear feet for spillway.

The Upper East catchment includes Swale 3 and Pond C.

$Upper\ East\ Catchment = 167047(ft^2)$

$East\ Catchment\ bottom\ swale\ flow = 8.4\left({}^{gal}/_{sec}\right)$

If we assume that 3 gallons can cross 1 foot of spillway each second results in a required 2.8 feet of spillway. A single 3 foot spillway is sufficient, but an 8 foot spillway is utilized for consistency.

$West\ Catchment = 293153(ft^2)$

$East\ Catchment\ bottom\ swale\ flow = 4.9\left({}^{gal}/_{sec}\right)$

If we assume that 3 gallons can cross 1 foot of spillway each second results in a required 4.9 feet of spillway. A single 5 foot spillway is sufficient, but an 8 foot spillway is utilized for consistency.

Rainfall required to fill the swales and ponds if ponds are 2/3 full before the rain.

30% absorption is assumed since the majority of the catchment area is degraded clay soil prairie.

$$catchment\ area(ft^2) \times \frac{3}{10} \times rainfall(in) \times \frac{1(ft)}{12(in)} = \frac{1}{3} \times pond\ volume(ft^3) + swale\ volume(ft^3)$$

Rearranged:

$$rainfall(in) = \left\{\frac{1}{3} \times pond\ volume(ft^3) + swale\ volume(ft^3)\right\} \times \frac{1}{catchment\ area(ft^2)} \times \frac{10}{3} \times \frac{12(in)}{1(ft)}$$

Pond A will be installed first, so the volume of Pond A without swales needs to be considered.
$Pond\ A\ volume = 1383853(ft^3)$
$rainfall = .46(in)$
This pond will overflow frequently until Phase 2 is implemented.

When Swale 1, Swale 2, and Pond B are installed the total East volume must be considered.
Pond A volume $= 1383853(ft^3)$
Swale 1 volume $= 7380(ft^3)$
Swale 2 volume $= 4872(ft^3)$
Pond B volume$= 61068(ft^3)$
$rainfall = .87(in)$
There is capacity to upsize the ponds slightly

The Upper East catchment includes Swale 3 and Pond C.
Swale 3 volume $= 1368(ft^3)$
Pond C volume$= 18972(ft^3)$
$rainfall = 1.84(in)$
It may be difficult to keep this pond full.

Since much of the catchment area is compacted gravel base for the utility substation 50% runoff was used instead of 30%
Swale 4 volume $= 10512(ft^3)$
$rainfall = .86(in)$
There is capacity in this system. Once the system is tested, expansions can be considered.