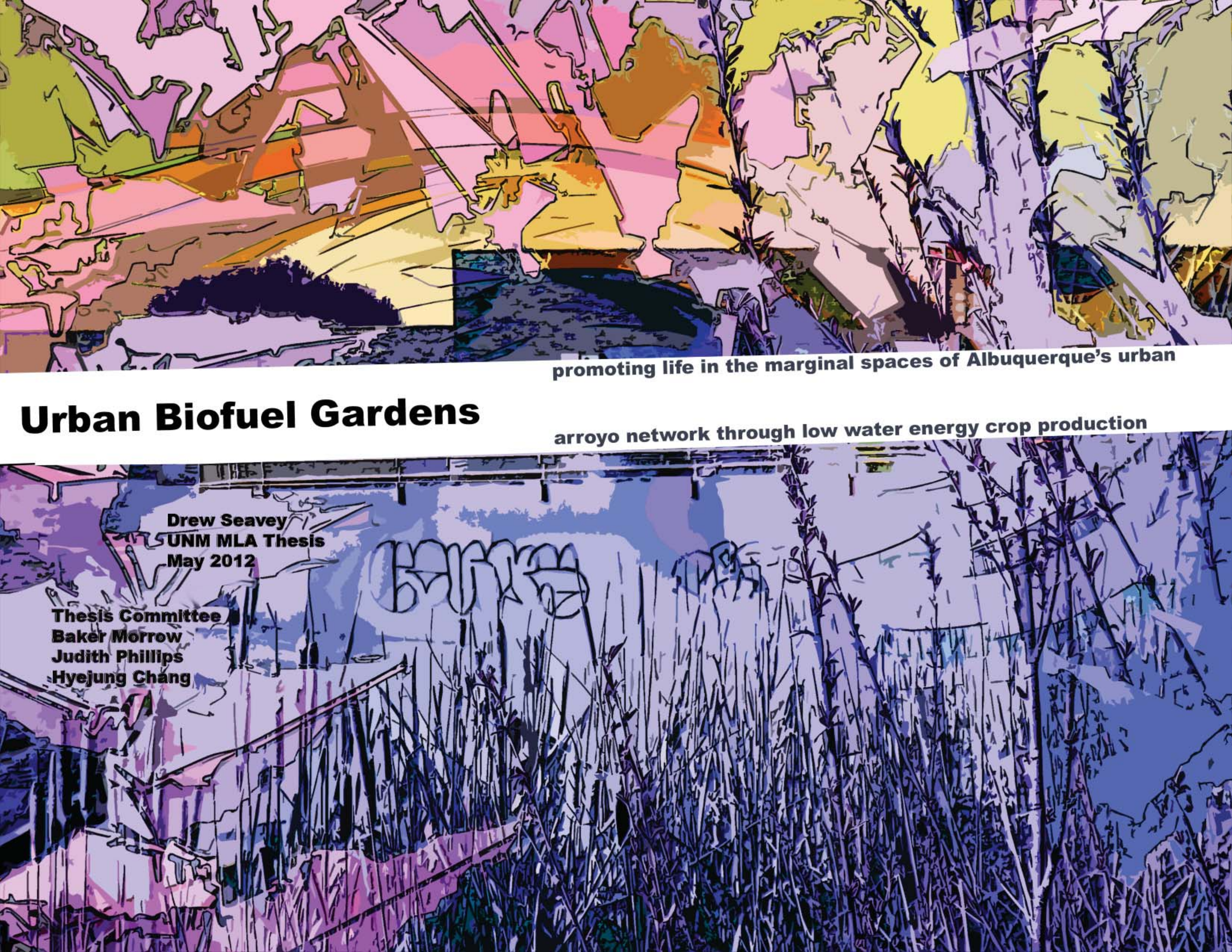

Urban Biofuel Gardens

promoting life in the marginal spaces of Albuquerque's urban arroyo network through low water energy crop production

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Urban Biofuel Gardens

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Drew Seavey

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ABSTRACT

Looking critically at what we plant in the semi-arid Southwest United States is becoming more and more important as weather-related, societal and ecological patterns shift to reveal ever new sets of conditions. Many plants growing around Albuquerque are erroneously lumped into two categories: ornamentals and weeds. Valuable resources in the forms of water, materials and labor are allotted to either the upkeep of ornamentals or the eradication of weeds. This attitude towards landscape widely dismisses the harvest potential of various plants growing throughout the city. Albuquerque has almost two thousand feet of vertical change within its city limits. Arroyos draining from the Sandia Mountains to the Rio Grande have preserved a fairly continuous network of drainage corridors that span the city from east to west. Whether or not the arroyos are paved once they hit the city limits, they still offer a sizable swath of open space on either side of the channel. Some drainage channels widen and turn into parks, some are designed to mimic natural arroyos and some are lined with multi-use paved trails. This thesis takes a closer look at an underused resource that exists within Albuquerque: continuous, bike-accessible swaths of unplanted open space running throughout the entire city, crossing a multitude of microclimates and eco-zones that host a diverse amount of plants that grow with no irrigation or other forms of human endorsement. Arroyos have always been the means of transportation for plants, animals and even people on the gigantic alluvial fans of the Sandias. As the future of petroleum based fuel begins to look progressively dimmer, different methods of producing locally derived energy need to undergo research. While corn, sugar beet, and other crops have been used for the production of biofuel, they take up a lot of land and water. Land and water would not be limiting factors in growing different harvestable biofuel crops along the drainage corridors of Albuquerque. I will demonstrate the feasibility of growing low-maintenance crops, in particular *Cucurbita foetidissima*, along the drainage corridors of Albuquerque, allowing for the creation of a local biofuel production coop.

For Linny

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Intro: Drainage Corridors and the Energy Potential of Marginal Land

Albuquerque is unique in its elevation gain of over 1,300 feet from river valley to foothills. Arroyos carve paths into the massive alluvial fans of the Sandias, draining into the Rio Grande. Arroyos passing through the city are channeled through a system of engineered drainage corridors. The method of flow can vary from culvert to storm drain to naturalistic to open paved channel. The visible portions of this drainage network are public monuments to the power of flowing water. During infrequent but intense bursts of storm activity, these channels rage with water and suspended sediment. Along the drainage corridors there are swaths of empty land serving as a buffer between infrastructure and settlement. These linear patches of unused land vary between 15 and 100 feet in width, featuring a variety of microclimates from exposed and windy to sheltered and lush.

Figure 1.1 This cement truck is using the North Diversion Channel for maintenance access and depicts the scale of the drainage infrastructure.

Background: The upper Embudo channel is a typical upstream hard channel and will grow in depth as it flows downhill.

Figure 1.2 While the channels are normally dry, a storm event can cause incredibly strong flows of water. Photo: www.amafca.org.

A staggering variety of plant species organize themselves along these urban arroyos according to the patterning of microclimates. Though paved and hence frozen in place, these once wild arroyos continue to function much like they always have: as avenues of conveyance for animtals and humans, and as trellises of life for desert plant species. The drainage corridors that run through Albuquerque continue to serve as a means of connection from valley to foothills. A growing network of paved multi-use trail traces many of the urban arroyos, facilitating travel in the spirit of the original geomorphic forms.

Background: The North Diversion Channel multi-use trail. To either side are linear patches of unused, uncultivated land.

The juxtaposition of continuously paved bike path with easily accessible vacant land provides immense acreage of potential space for community involved agriculture. In a historical period when petroleum derived energy is beginning to be questioned for its known global impacts on society and environment, finding a local source for the production of clean and renewable energy has never been more urgent. Biofuel is a developing field of energy production that derives ethanol, biodiesel, and other fuels from mostly plant material. Corn, switchgrass, sugar beets and other crops are used in biofuel production. The only problem with growing these species on farmland previously devoted to agriculture is that a large amount of land and water are allotted to biofuel-related agricultural production. Albuquerque's drainage corridors and the system of paved trails that follow offer a large amount of land that could potentially produce energy.

Figure 1.3 Another stretch of trail showing a sloping linear patch of land that could be planted with energy crops.

Figure 1.4 Grass colonizing a small, 3" deep pile of sediment on top of cement. Certain plants are willing to grow in the harshest of conditions.

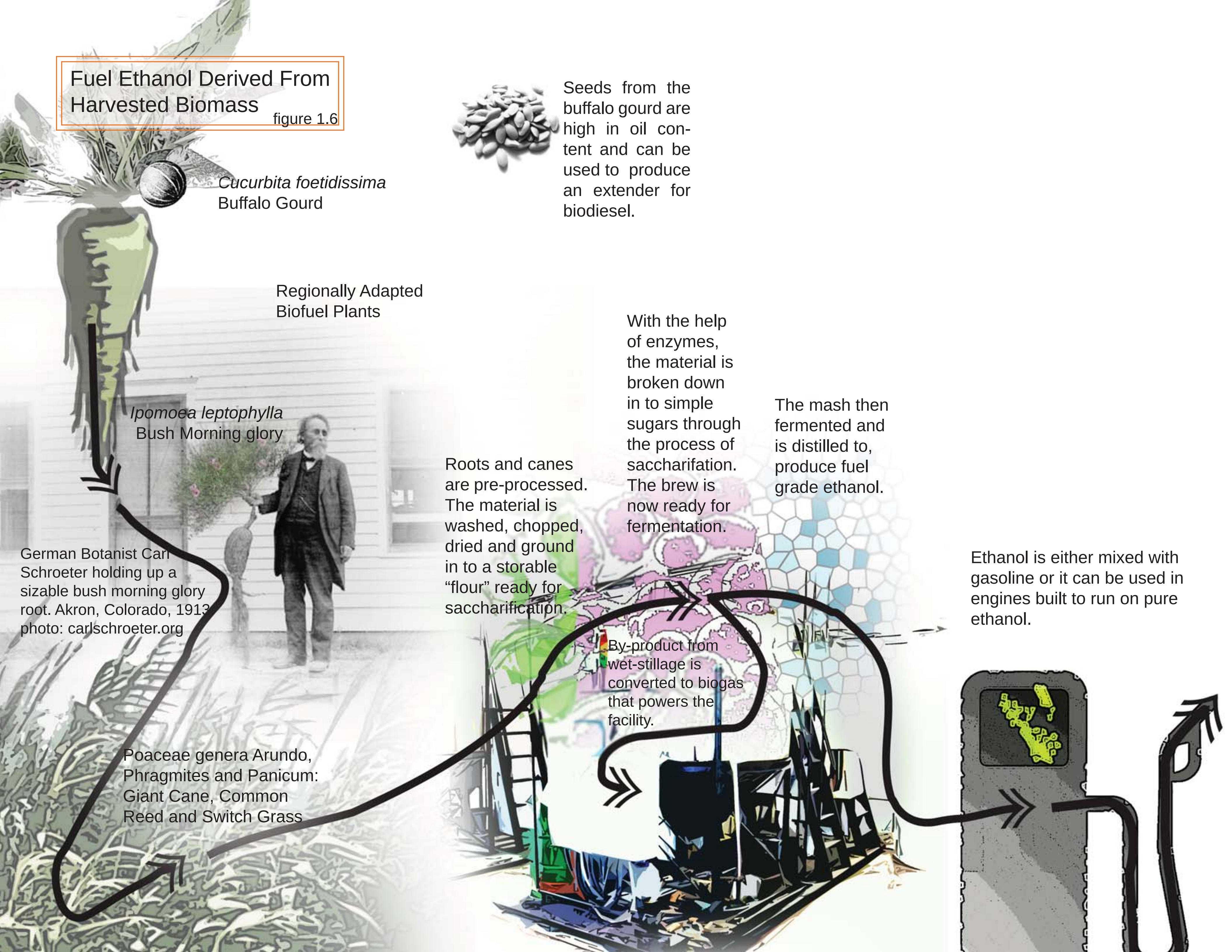
Background: A linear, concave stretch of empty land. The concentration of water in depressions will encourage plant life.

A handful of plants, some native and some naturalized, are candidates for biofuel production within Albuquerque’s city limits. Each life zone from river to mountain has at least one species of prolific demeanor that can thrive under extreme conditions with no planned irrigation and no human endorsement. The empty swaths of land that line the drainage channels of Albuquerque can be used for the passive production of biofuel crops. Taking advantage of the linear and dendritic pattern of these drainage corridors, biomass can be transported to a central processing hub for the production of ethanol and biodiesel using biofuel-powered vehicles and modified bicycles. This thesis is an attempt to demonstrate the feasibility of harvesting the benefits from two unnoticed commodities existing in Albuquerque: amazingly tough plants and space to grow them. Many species can be easily started from seed. Apart from producing local and sustainable energy, strategic planting of the drainage buffer zones will enhance its traditional function as a wildlife corridor, improve the visible character of these public spaces, and encourage more Albuquerque residents to participate in alternative energy through using the bike trails and engaging in biofuel production.

Figure 1.5 Buffalo Gourd, *Cucurbita foetidissima*

Fuel Ethanol Derived From Harvested Biomass

figure 1.6



The Benefits of Infill Planting

Encouraging life in urban marginal spaces will not only increase the visual appeal, it will also provide an opportuntiy to produce energy crops without sacrificing any extra land or water. Leaving any existing vegetation undisturbed, the vacant land adjacent to Albuquerque's drainage network can be planted with a diverse, low-water palette resulting in seasonal bursts of color and residue for biofuel production. Following the arroyos, the growing connectivity of Albuquerque's trail network will provide a linear connection between the growing areas and the biofuel plant.


1.11 Spectacle Pod, *Dimorphocarpa wislizeni*


1.10 Desert Marigold, *Baileya multiradiata* and Prickly Pear Cactus, *Opuntia engelmannii*


1.7 Scorpion Weed, *Phacelia integrifolia*


1.8 Pink Gaura, *Gaura lindheimeri*


1.9 Blazing Star, *Mentzelia decapetala*

Site Analysis: The Urban Arroyo

Background: a sweeping vista of Albuquerque. This shot was taken from the volcanoes on the westside. The slope of Albuquerque is apparent as it gains elevation getting closer to the Sandias.
Facing: Figure 2.2 Natural dendritic form of an untouched arroyo north of Albuquerque on Sandia Pueblo land.

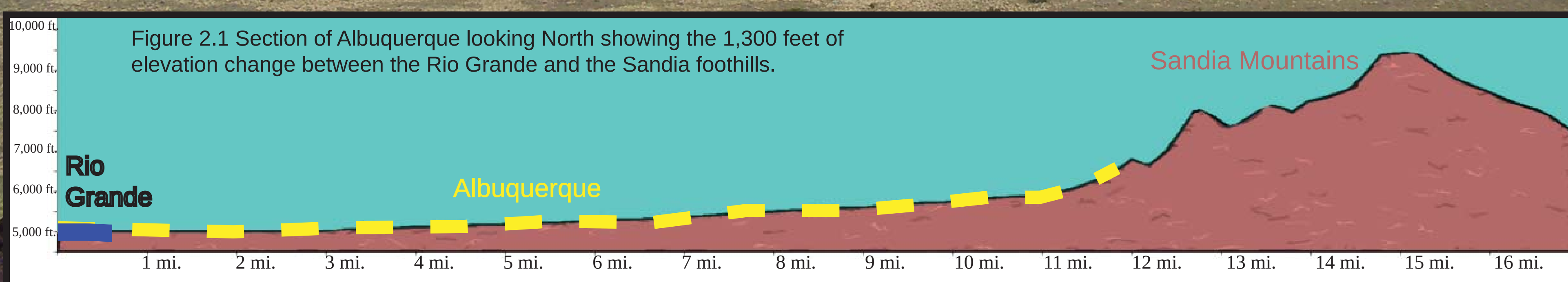
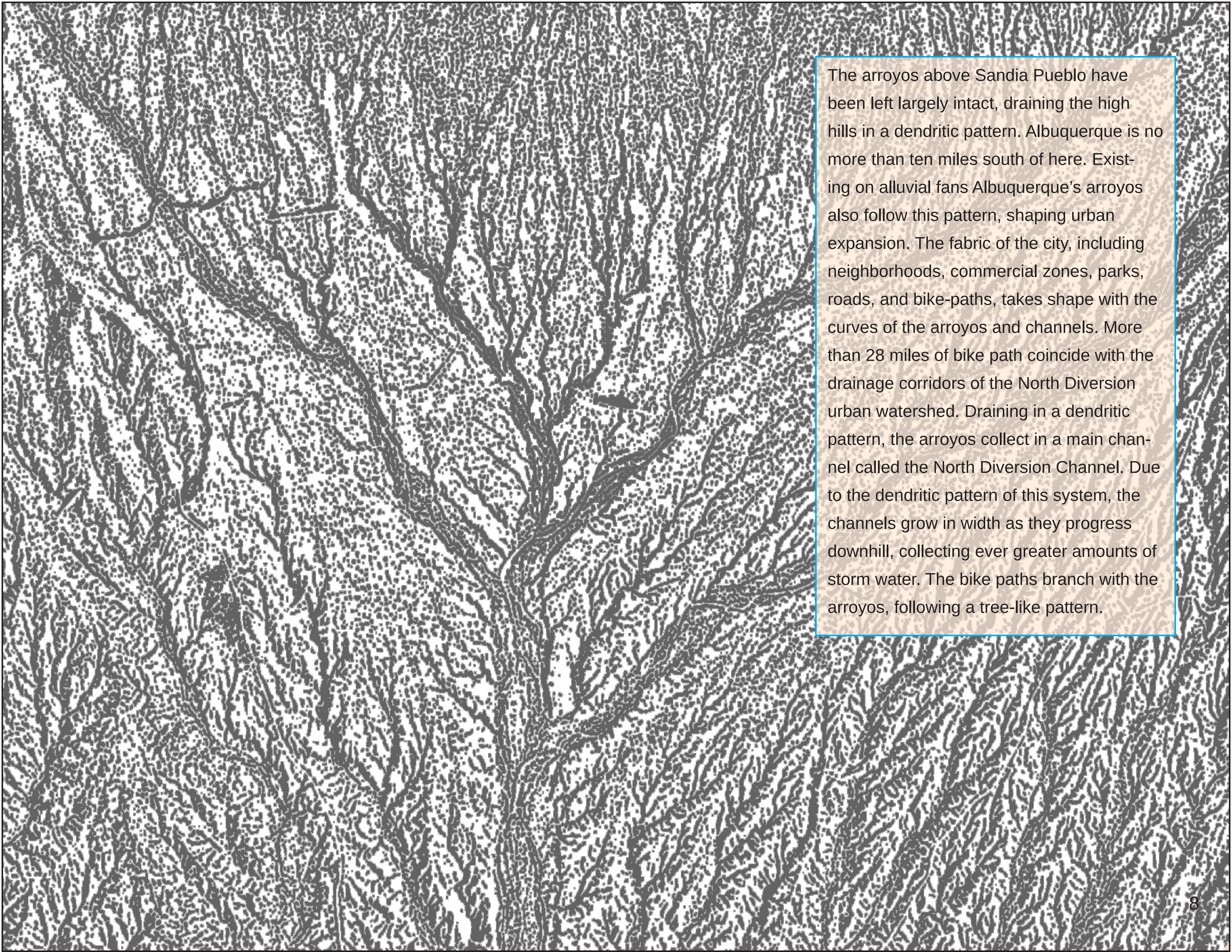


Figure 2.1 Section of Albuquerque looking North showing the 1,300 feet of elevation change between the Rio Grande and the Sandia foothills.



The arroyos above Sandia Pueblo have been left largely intact, draining the high hills in a dendritic pattern. Albuquerque is no more than ten miles south of here. Existing on alluvial fans Albuquerque's arroyos also follow this pattern, shaping urban expansion. The fabric of the city, including neighborhoods, commercial zones, parks, roads, and bike-paths, takes shape with the curves of the arroyos and channels. More than 28 miles of bike path coincide with the drainage corridors of the North Diversion urban watershed. Draining in a dendritic pattern, the arroyos collect in a main channel called the North Diversion Channel. Due to the dendritic pattern of this system, the channels grow in width as they progress downhill, collecting ever greater amounts of storm water. The bike paths branch with the arroyos, following a tree-like pattern.

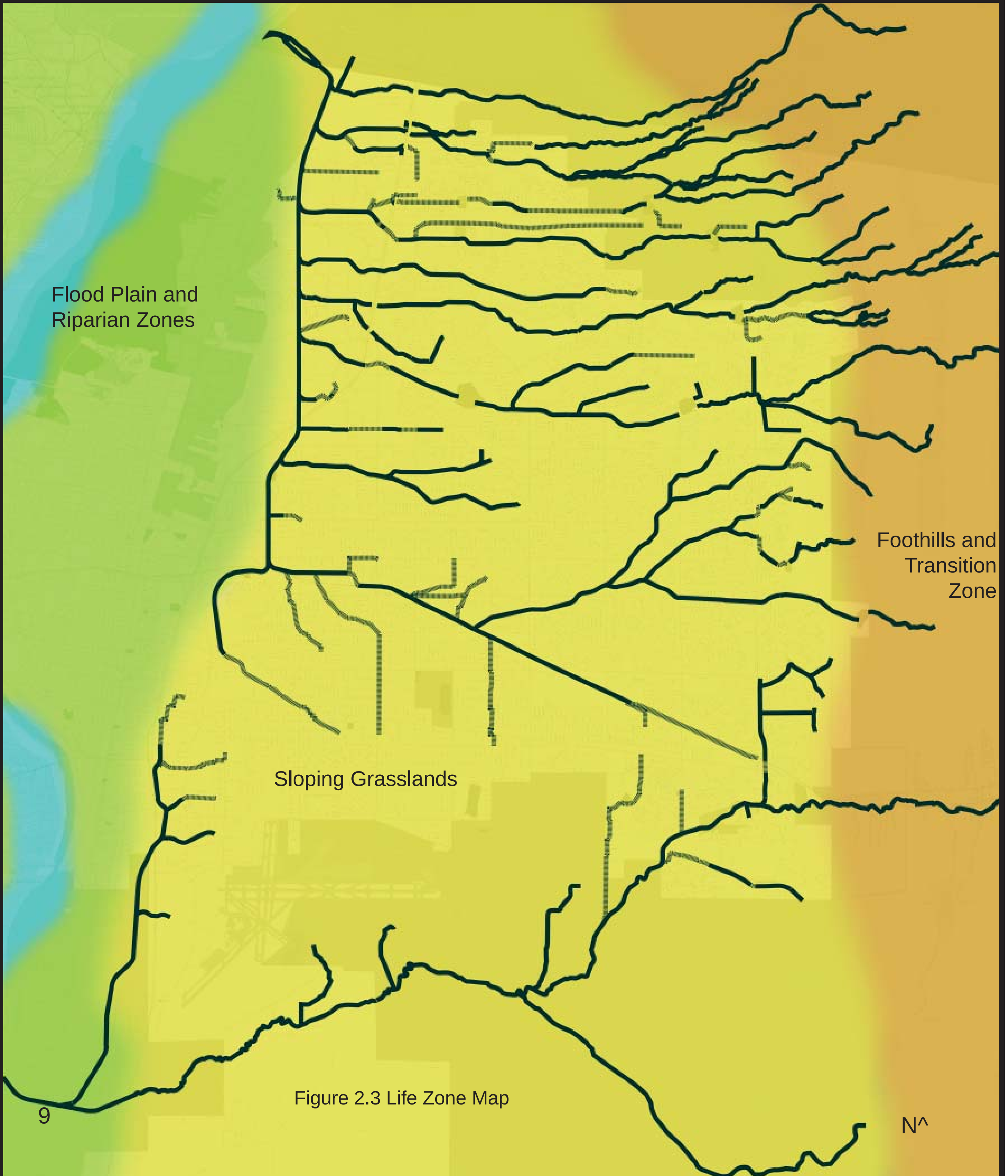


Figure 2.3 Life Zone Map

Numerous arroyos cross Albuquerque's sloping plain from east to west. These drainage corridors that run from the Sandia Mountains to the Rio Grande are places of concentration for water and therefore places of refuge for different forms of life. The arroyo is an archetypal form in this part of the world and conveyance is a verb that can well describe the activities of this geologic feature. Water, plants, animals, even humans have used arroyos for their passage. The Spaniards followed the Rio Grande into what is now New Mexico using the arroyos to get from the river to the mountains. Coyotes, bears and other animals use arroyos in a similar fashion. Certain plants find themselves grouped in arroyos due to increased moisture and unique soil dynamics. These corridors attract moisture and therefore attract life. As Albuquerque expanded from the floodplain up onto the mesa, the arroyos were either diverted, channelized, or occasionally left intact as development continued. The alluvial slope of Albuquerque required drainage paths regardless of development. Seeing the danger of flowing water with suspended sediment, people generally did not build in the arroyos. These drainage corridors remain intact to this day, flowing through the city in different forms.

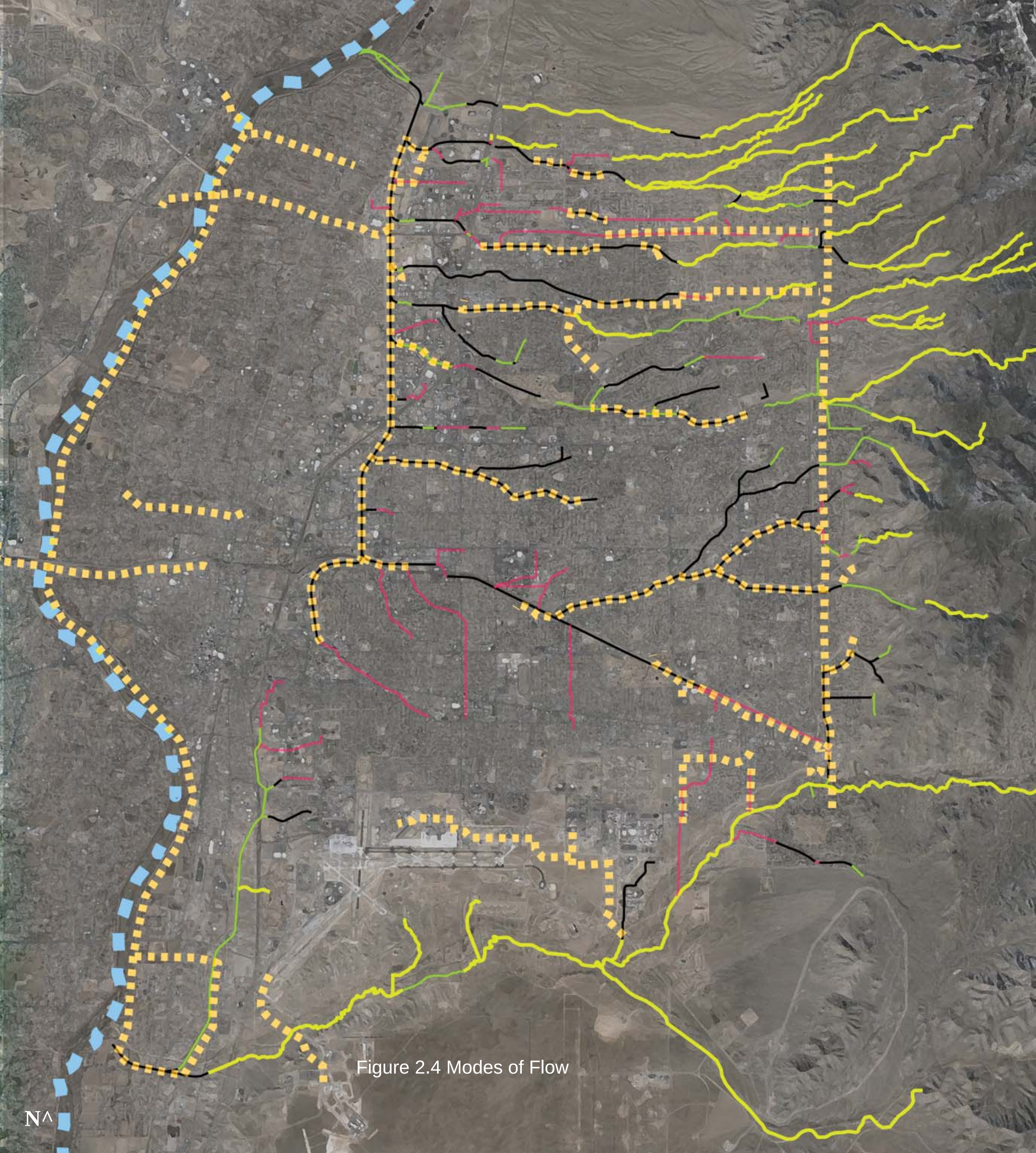
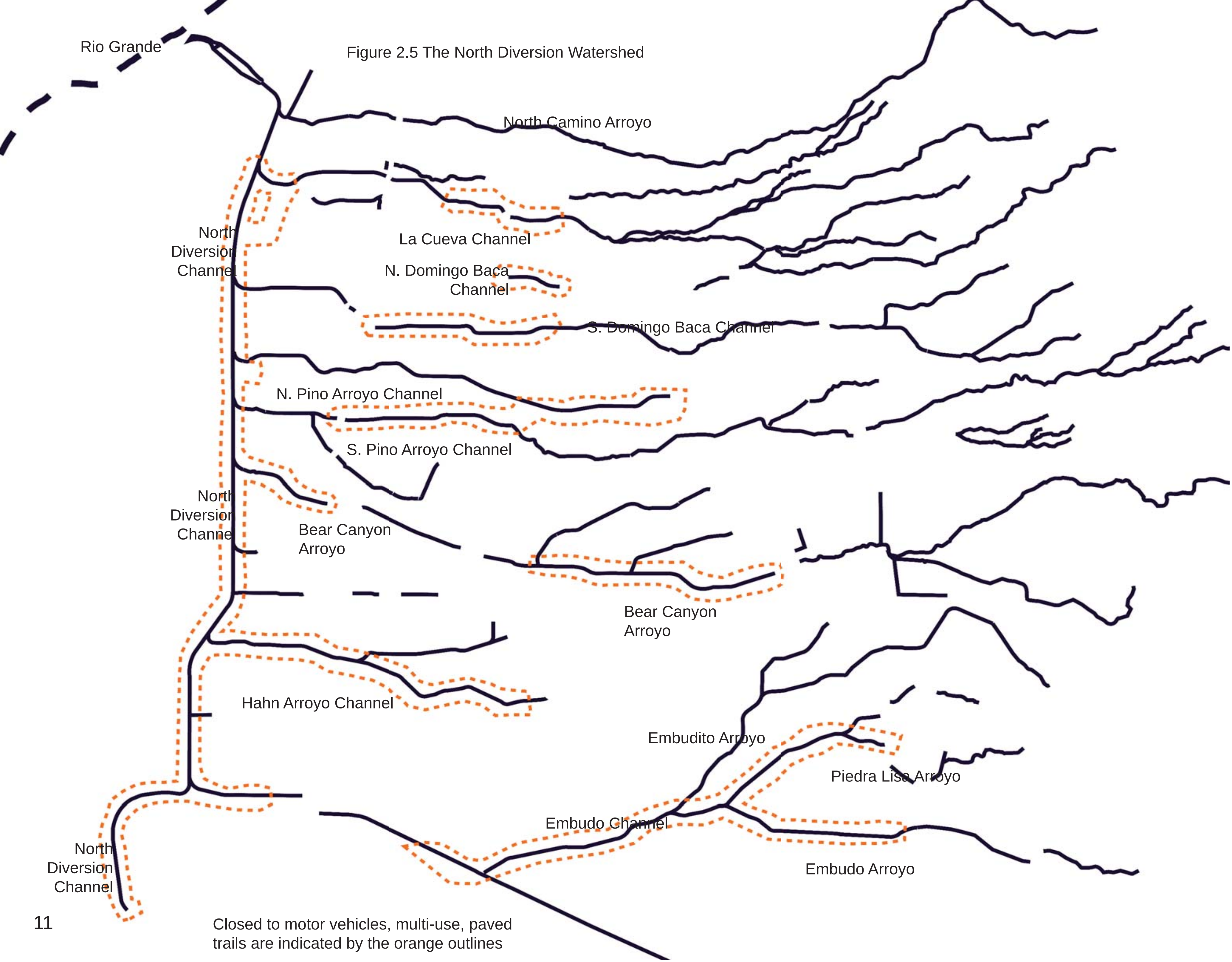


Figure 2.4 Modes of Flow

Figure 2.5 The North Diversion Watershed

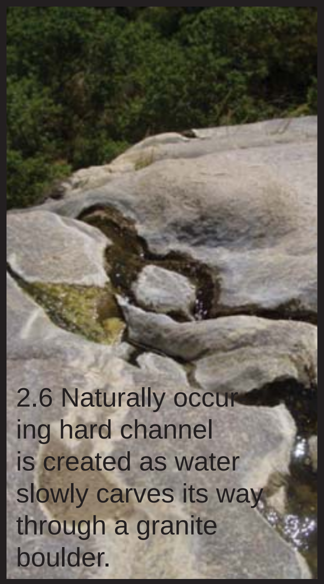


Closed to motor vehicles, multi-use, paved trails are indicated by the orange outlines

Granite Highlands

Starting high in the mountains, the arroyos are deep, impressive crevices that run far into the hills. The ground underfoot is coarse sand of different sizes of decomposing granite. Large granite monoliths often line these natural channels. Growing among the rocks one will find a surprising oasis of *Quercus turbinella*, *Acer negundo*, *Cercocarpus montanus*, *Nolina*, *Vitis arizonica*, *Rosa woodsii*, *Robinia neomexicana*, *Mahonia repens*, *Parthenocissus quinquefolia*, and a loud assortment of wildflowers. Sometimes a perennial stream not much wider than two feet will snake its way above grade, only to disappear twenty paces ahead.

2.7 The granite face of the Sandia Mountains



2.6 Naturally occurring hard channel is created as water slowly carves its way through a granite boulder.

Intact Alluvial Arroyos

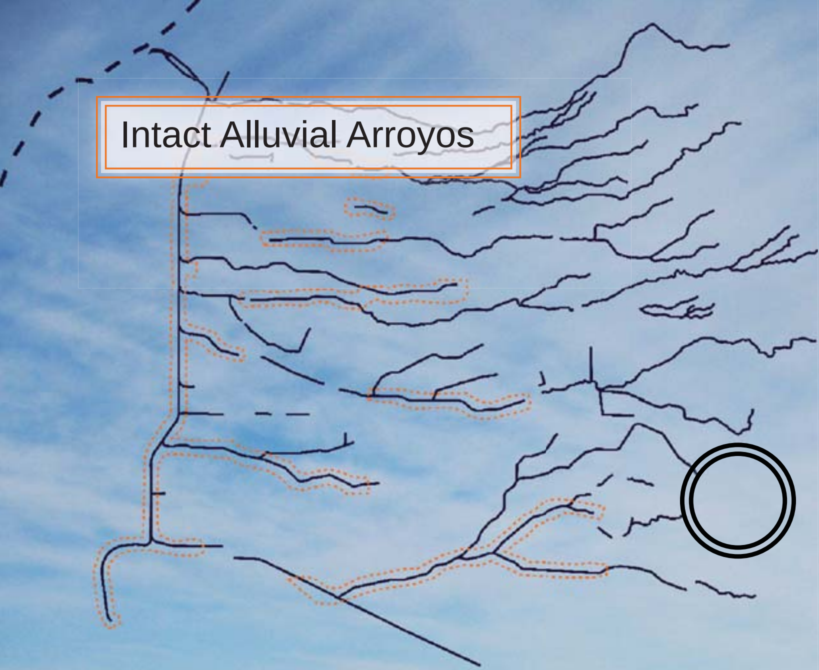


Figure 2.8 Looking downhill standing in the middle of a large drainage corridor full of vegetation.

Crossing from wilderness, to open space, to the first developments, the arroyos relax their tight topography and turn into wide swales running through the foothills. Here *Ericameria nauseosus*, *Cylindropuntia imbricata*, *Yucca glauca*, *Opuntia spp*., *Datura meteloides*, *Cucurbita foetidissima*, and the occasional *Celtis reticulata* take root in the gravelly alluvium of the Sandias. There are numerous multi-use trails that cross the foothills, some following arroyos up into the higher elevations. Hikers, bikers, dog-walkers, picnickers, and many more enjoy these rolling hills and arroyos.

Soft Channels

Background: Native earth is mixed with cement to prevent erosion and to reduce downhill sedimentation

Once the drainage corridors reach the neighborhoods, they are most often diverted into soft channels. These engineered channels are not lined with concrete, but different measures are taken to prevent erosion using methods such as gabion check dams, native dirt concrete, and native vegetation. The advantage to this kind of channel is the increased infiltration of storm water into the aquifer. Segments of soft channel are dispersed throughout the entire drainage system of Albuquerque. The soft channel is a human-stabilized arroyo meant for sustained urban drainage.

Figure 2.9 Unpaved yet altered. Gabion walls hold the slopes of this engineered soft channel.

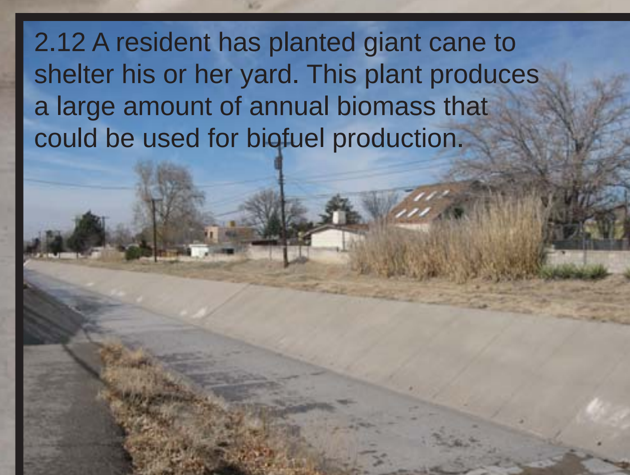
Hard Channels

2.10 Chamisa lined hard channel.

Background: Hard channel going under a residential cross street.

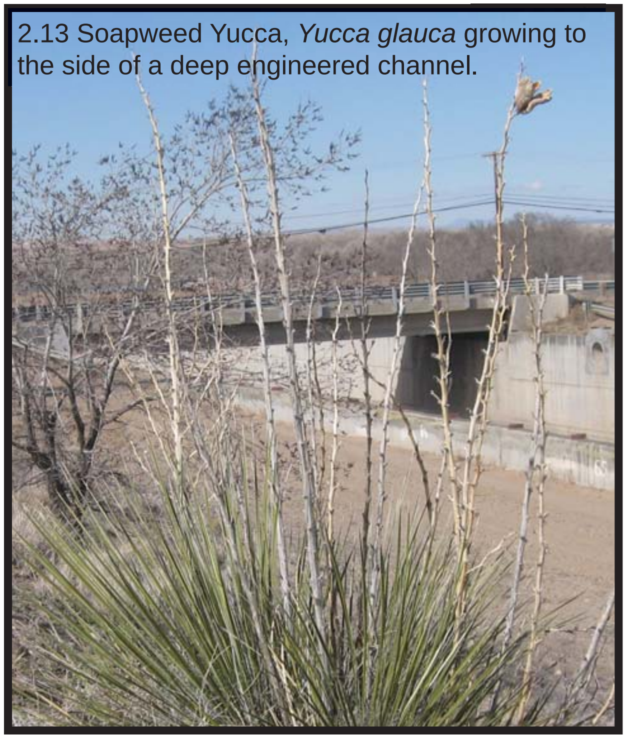
When the dendritic shape of the arroyos collects ever greater amounts of water from uphill, the channels widen and are lined with concrete. Hard channels make up the majority of the storm drainage system in Albuquerque. The hard channels vary greatly in depth and width; they grow in dimension as they merge and flow towards the river. There is always a buffer zone between the paved channel and the surrounding urban development. This drainage corridor buffer zone can vary from between 10 feet and 60 feet in width. These swaths of land, with a wall on one side and a paved watercourse on the other, are largely left unused. The addition of multi-use trails has popularized the use of Albuquerque's drainage corridors, and now these large portions of fallow land are easily accessible by a network trails that are strongly associated with the arroyos.

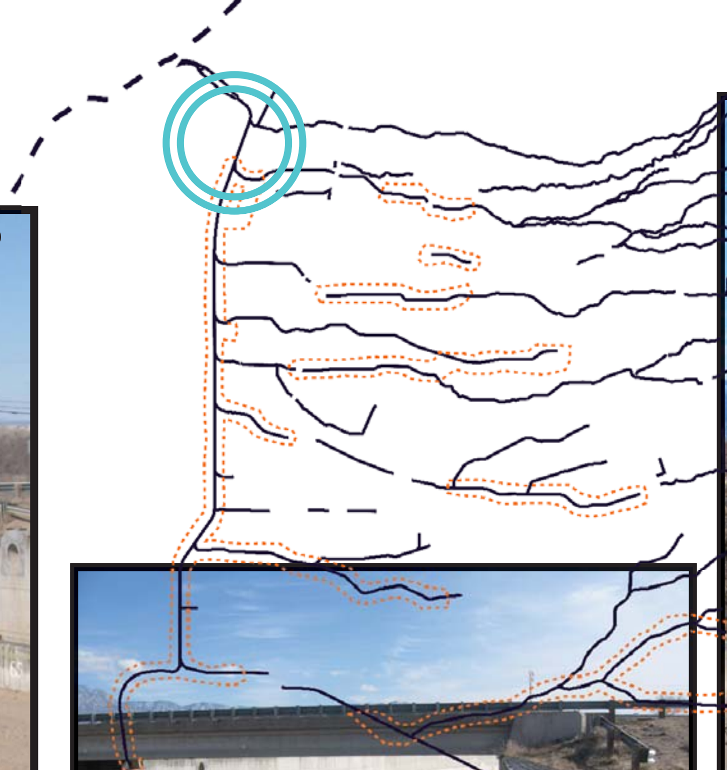
2.11 Cholla cactus thriving in full sun.



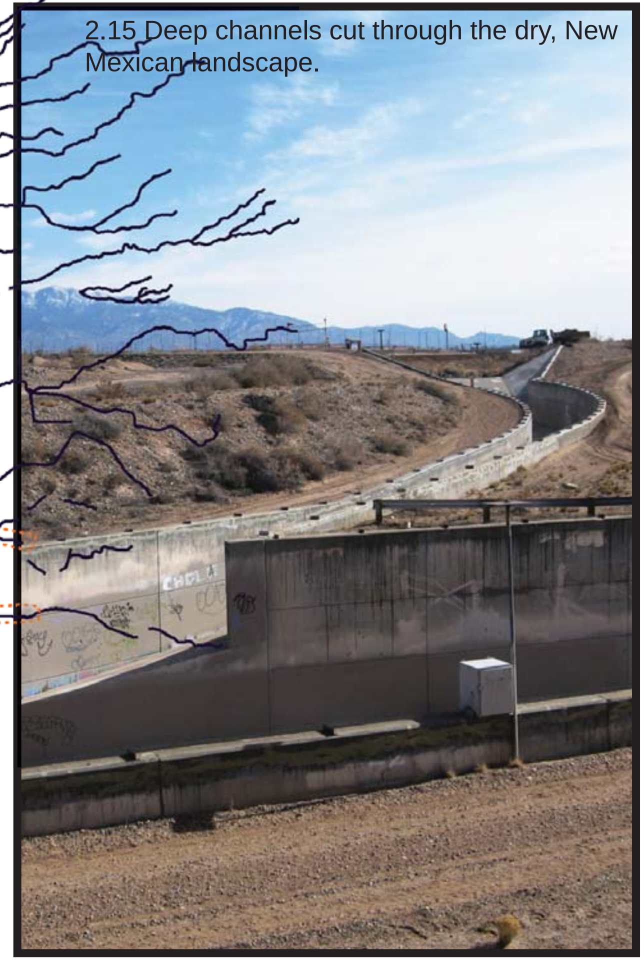
2.12 A resident has planted giant cane to shelter his or her yard. This plant produces a large amount of annual biomass that could be used for biofuel production.

Deep Collector Channels


2.13 Soapweed Yucca, *Yucca glauca* growing to the side of a deep engineered channel.



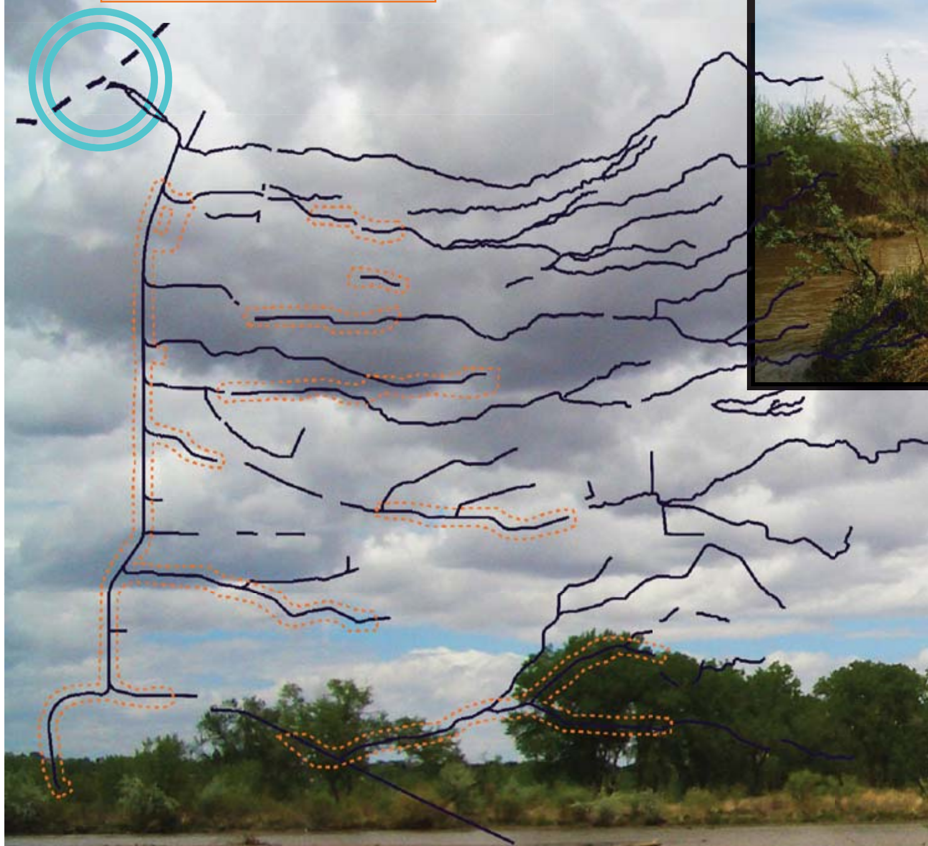

2.14 Accumulated sediment must be removed by AMAFCA's maintenance crew.


2.15 Deep channels cut through the dry, New Mexican landscape.

As the channels get closer to their outlet in the Rio Grande, they become deeper and wider to accommodate larger amounts of water. The Albuquerque Metropolitan Arroyo Flood Control Authority maintains these deep channels and is constantly removing accumulated sediment. The cut of the channel creates steep topography off to the sides. The constant supply of sediment could be used in terraced planting beds along the sections of steep topography.


2.16 A view of the Sandias from the North Diversion Channel before it pours into the Rio Grande.

Riparian Corridor



2.17 and background image: Grasses and willows colonizing islands of sediment in the Rio Grande.

Existing as a dendritic network, the water always drains into larger and larger water-courses. The terminus of the North Diversion Channel is the Rio Grande. Riparian species such as Rio Grande cottonwood, black locust, black willow, coyote willow, cattail, common reed, and the ubiquitous and invasive salt cedar, Siberian elm and Russian olive thrive wherever they can reach the water table. Harvesting invasive species could produce large amounts of biomass for alternative fuel production. Another benefit to growing biofuel crops at the North Diversion outlet is to help filter contaminants out of storm water through phyto-extraction.

2.18 4th Street as it crosses the North Diversion Outlet.

2.19 Standing water collects in a large pond before it exits in to the Rio Grande.

2.20 This is a good environment for growing certain *poaceae* species such as giant cane, common reed and switchgrasses as energy crops.

Diverse Microclimates

Figure 2.22 Vegetation attracts wildlife.

Figure 2.23 Buffalo Gourd thrives in harsh conditions.

Figure 2.24 and background image: Willow and cattail growing at least 200’ above the Rio Grande. Pockets of moisture along the drainage network promote life, even riparian species.

A number of species have colonized the otherwise vacant tracts of the drainage corridor buffer zone. Microclimates such as sunny slopes, ribbons of rock mulch, water absorbing topography, advantageous runoff from irrigated landscapes, and upland filtration ponds offer a huge range of options for colonizing plants. The improved forage and shelter encourages wildlife to use the arroyos. These landscapes host life through subtle, passive, and unintentional water harvesting techniques. Cattails, salt cedar, willow and even butterfly bush (lower left) can be found growing in wet spots and depressions along the drainage system.

These species don’t just occur naturally on the sloping alluvium of Albuquerque: they are largely riparian species. The various microclimates along the arroyos offer shelter, extra moisture and full sun to a large number of willing volunteer species. Variations in arroyo width and channel texture encourage different plants. While some look at such plants and call them ‘weeds,’ it is remarkable that a diverse amount of plant species will grow in our harsh climate without human help. These irrigation-free, self-reliant colonizers offer food, medicine, fiber, and feedstock for biofuel production.

Figure 2.21 Butterfly bush, *buddleia sp.*, volunteering in a wet spot along the North Diversion Channel.

Literature Review: A Look at the Human Interaction with the Terrain and Flora of the Middle Rio Grande Corridor

In modern human settlements, resources in the form of water, land and labor are allotted for the upkeep of planted areas. In addition to public spaces, the tending of private landscapes is widespread. So much energy is put into our green spaces, yet what dictates the selection of various species? Shade, aesthetics and screening are common factors in species selection, using plant material architectonically and ornamentally. This paradigm of using plants as an extension of the built environment simplifies the plant to nothing more than a construction material. We don't normally harvest from our buildings, nor do we harvest from the planted environment augmenting the structure of these buildings. If we are pouring so much time, space and energy into our plants, why not select ones that can provide more than just architectonic externality?

Another class of plant lurks among the planned plantings: weeds. These colonizing plants tend to thrive in areas disturbed by human activity. Anyone who has worked the land knows the battle against these voracious volunteers. Picking, spraying, burning, we put a lot of time and energy into destroying weeds. Between architectonic ornamentals and plants labeled as weeds, a good number of species are overlooked as having potential to fulfill edible, medicinal, material and biofuel needs. A number of exotic ornamentals have native counterparts that use considerably less water and contribute to the local food chain. Likewise, many of the colonizing weeds have edible and medicinal values and thrive where other plants are unable. Much energy is put into planting and maintaining thirsty exotics and to the eradication of weeds. I will demonstrate that if we embrace a holistic approach to species selection in the landscape, we can gather from our own parks and gardens while bolstering the urban ecological network. Encouraging low water natives and certain "weeds" will maximize the harvest potential of the planned landscape.

Rethinking our planting strategies as inhabitants of the semi-arid Southwest is a topic that can be approached from a number of angles. People have been interacting with this climate for many thousands of years, gathering knowledge of local growing conditions and getting to know the uses of plants that can survive on so little. The different tribes of New Mexico and the greater Southwest possess a vast knowledge of local plant species. There are numerous ethnobotanical works that focus on this region, its people, and the interactions between the human and plant worlds. This knowledge is diverse, as one plant might have varying uses among different peoples with different needs.

Science is another lens for viewing the potential of the flora in the Southwest. There are many works that sidestep ethnobotanical findings and describe instead how plants might be exploited for various substances such as oils, resins, fuel, etc. Empirical research also uncovers the climatic variability of this region. The scientific point of view paints a picture of the function of various plants and how this fits in with the regional climate. Sometimes the scientific approach overlaps with the ethnobotanical approach and both ways show a similar finding of a certain plant. Ethnobotanical research is more subjective and relies on the interaction between human and plant scientific research; however, it involves objective findings without including cultural perspectives.

There also exists a body of work surrounding the topic of weeds and wild plants. What constitutes a weed? There are many opinions, but the general consensus is that a weed is something that readily grows around human settlements without welcome. Some weeds are actually native to a given region. The amazing thing about weeds is that they grow of their own accord and can be found living around humans without their endorsement. If these vilified plants turn out to have beneficial uses, such as edibility, medicinal qualities, positive impacts on hydrology, and they grow with no effort, it would be in our best interest to develop a way to incorporate them into xeric plantings.

Dryland permaculture is another approach to growing materials in the high desert. There are ways of shaping the land, trapping soil moisture, enriching the nutrient cycle, planting allied species, using boulders to create microclimates, etc., that contribute to the longevity of sustainable low water plantings. Can landscape architects, gardeners and anyone else who works with plants in semi-arid New Mexico increase the efficiency and benefits of their designs through plant selection? Is there a way to do this without using common irrigation?

Ethnobotany and Weeds

Ethnobotanical accounts provide a human perspective of the environment, through the eyes of a specialist human, the ethnobotanist. This field encourages active participation in communities[i], and the learning can be very subjective. This practice helps with the sharing of knowledge between cultures. The ethnobotanist steps outside of his or her culture and participates in another worldview, bringing back insights and knowledge regarding plant uses. There are many semi-arid climates across the globe and lessons can be learned from horticultural practices abroad. New Mexico has its own growing volume of ethnobotanical research from the various Pueblos and other indigenous groups.

A useful and orienting publication is the *Medicinal Plants of the Acoma and Laguna Pueblos* by Shayai Lucero. In this booklet many species that grow throughout New Mexico are described and their uses explained. Lucero states that many plants in our region are dismissed as weeds, but in fact hold many valuable healing and culinary capabilities[ii]. Many of the plants in this publication are seen growing around Albuquerque with no irrigation at all. The more one can know about a plant, the more dynamic the interplay will be between human and plant communities. The knowledge is particularly rich in indigenous cultures that coevolved with certain plant species.

Eugene Hunn describes the concept of indigenous as a contrasting paradigm to the modern, global way of life. The modern way of life has only been around for a short while compared to the continuity of indigenous cultures. He posits that time and space are the fundamental elements of local knowledge and that the average citizen of the modern world understands less about the various surrounding natural systems than an average citizen of an indigenous culture[iii]. Michael Warren describes indigenous plant knowledge as having evolved in a micro-environmental context, and prone to an ever-changing set of problems[iv]. Therefore indigenous knowledge can be seen as always shifting and changing according to different experiences. Warren also posits that knowledge in an indigenous society will vary between individuals with different roles.

Knowledge to our modern way of thinking takes a different shape than the above illustration of indigenous knowledge. Where improvisation, adaptation and various gender and age roles dictated knowledge of the natural world, modern knowledge is supported by objective observation. The subjectivity of the indigenous model allows for people to take their own course of discovery with the plant world. Dictionaries and herbariums do not traditionally exist in this paradigm and knowledge is normally derived through personal experience. The objectivity of the modern model allows for a wide scope of knowledge to be incorporated through the objective observations of others, but the experience is often obscured through a lack of personal use of plants.

Robert Burgess writes on the diversity of plant uses within the indigenous Southwest. He contends that the great amount of ethnobotanical knowledge found in this region is due to four factors: the remote character, the harsh climate, the incredible diversity of flora, and the diversity of ethnic groups. These factors contribute to a set of varying conditions that inevitably produced a large amount variability in plant uses for an array of reasons[v]. The scientific world is now trying to contact this wealth of knowledge, but will the essence of improvisation be lost with the archiving of indigenous knowledge founded through subjective experience? The question raised here is whether or not our mainstream knowledge system based on science can incorporate indigenous knowledge that has been established through physical practice rather than mental visualization.

Our society is slowly waking up to the outstanding climactic considerations of the Southwest and taking measures to observe local conditions while accounting for the set of ever-changing environmental variables. The first people in the Southwest had to adapt to the local conditions in order to survive. Our society in the Southwest now faces the hard question: do we adapt and stay, continue in this manner and perish or move elsewhere? Sustainable interdependence with the environment is a relatively new topic of research. Anson Thompson writes of the detriments of farming traditional crops in Southwest soils. Emulating agricultural methods from moister climates can lead to groundwater pollution, leaching of organic materials form the soil, erosion and wasting. Anson continues on to say that food, feed and fiber can be obtained from working with native flora that are highly adapted to the high and dry local conditions[vi] . This favoring of appropriate plants not only promotes local ecosystems, but helps people in our society connect with natural systems.

Buffalo gourd (*Cucurbita foetidissima*) is most often mentioned in various sources on adaptive planting. This vine grows almost anywhere, surviving on rain alone and storing water in a large, tuberous root. Being a member of the cucumber family, buffalo gourd trails along the ground and produces baseball-sized gourds. This plant has been looked at as a novel energy crop for cultivation in the Southwest. Buffalo gourd's starchy root has potential for ethanol production and its seeds can be used for edible oil[vii]. Buffalo gourd has also been used traditionally as a food crop among indigenous groups in Arizona[viii] . The seeds and fruit can be cooked until palatable.

There are many other plants that are well adapted to the Southwest. Texts that identify useful desert plants include but are not limited to, *Wild Plants of the Pueblo Province* (Dunmire and Tierney, 1995), *Native Plants and Animals as Resources in Arid Lands of the Southwestern United States*, (Gardner, 1965), *Medicinal Plants of the Acoma and Laguna Pueblos* (Lucero, 1997), *Ethnobotany of the Tewa Indians* (Robbins et al., 1916), and *The Uses of Wild Plants* (Tozer, 2007.) This is a growing list, but these books have supplied many accounts of useful native plants such as buffalo gourd, common reed, cactus, chamisa, etc.

Some sources talk about plants as existing on a spectrum between wild and domesticated. Weeds fit into the picture somewhere along the gradient. There are some good sources that touch on the topic of weeds and some of their uses and benefits. *Eating on the Wildside* (Etkin, 1994) contains volumes about how we might use noncultigens, a fancy word for weeds. The concept of *quelites*, or edible wild plants, is a fantastic topic and a common institution in Mexico. *Quelites- Ethnoecology of Edible Greens – Past, Present,and Future* (Bye, 2000) talks about how many weeds might find their way to the dining table. The journal article "Invasive plant species as potential bioenergy producers and carbon contributors" (Young et al.) talks about the benefits of using invasive plant species to derive biofuels, and shows the diverse uses of plants that are normally seen as untouchable.

Practice: A Harsh Climate, Resilience, and Dryland Permaculture

Gerald Matlock, in *Realistic Planning for Arid Lands,* is of the opinion that drought is used as the scapegoat for poor conditions in semi-arid lands. Matlock says that attention is diverted from poor agricultural solutions, and the blame is placed on natural forces, something outside of human control[ix]. He calls for people to take more responsibility when it comes to confronting the challenging climactic conditions of the desert Southwest and begin designing for endurance and sustainability.

Judith Phillips remarks that the Rio Grande Valley is one of the driest regions of New Mexico due to mountain ranges blocking moisture. The sun and the wind have an intense drying effect on foliage, not to mention alkaline soil starved for organic material[x].

There are many accounts of indigenous people surviving off very little in the middle of this harsh climate. Climatic records indicate that drought is nothing new in the Southwest and therefore the indigenous people have had a long time to adapt to occasional food shortages[xi]. Food is available in the Southwest even during the height of a drought. Famine food is a topic that covers a diverse range of flora. Juniper bark, cactus, mistletoe, agave, beeplant, cattail, pigweed etc. are all examples of food eaten in times of scarcity[xii]. While drought and famine may seem far off to those of us engaged in modern society, it is still comforting to know that some form of sustenance can come from plants growing in and around our cities. There is an opportunity to develop these species within the urban fabric to be there as a contingency plan.

The Hopi people and their connection to dry farming corn is described in Dennis Wall and Virgil Masayesva's article "People of the Corn." The entire traditional lifestyle is based primarily on corn. For food and ritual, this plant has become integral in Hopi culture[xiii]. While mirroring the Hopi way might not be feasible on the scale of the city of Albuquerque, their story and connection with the earth is inspiring. To know that corn can be grown in the high desert with no irrigation gives hope for us currently residing in the high and dry desert Southwest.

Information on techniques for optimizing growing conditions in semi-arid conditions is becoming more widespread. Permaculture is the concept and practice of sustainable horticulture where natural systems are left intact, the lay of the land is intelligently used, and plants are intended to work together in communities. George Estabrook studied in a small village of rural Portugal, looking at the locals' use native plants to enrich their agriculture. The region studied was a dry river valley in the uplands of Portugal, distinguished by its rocky soil. The hillsides are inhabited by various shrubby species that the locals collectively call *mato*. The shrubs are harvested during the year, cut near the root to encourage regrowth, and are placed in the village's goat paddocks. After a few weeks have passed, the enriched mato from the goat paddocks is then used to build the soil in their agricultural plots[xiv]. This example of sustainable nutrient cycling can also apply to the Southwest. Our soils are often lacking organic matter and perhaps a sustainable method of harvesting brush and organic waste can help build nutrient rich soils.

Other texts that involve sustainable growing practices include *Runoff Farming* (Fink et al., 1986), *Beyond Water Harvesting: A Soil Hydrology Perspective on Traditional Southwestern Agricultural Technology* (Dominguez et al., 2005), *The Nature, History, and Distribution of Lithic Mulch Agriculture: An Ancient Technique of Dryland Agriculture* (Lightfoot, 1996), *Dryland versus Irrigated Farming* (Dhawan, 1988), and *Growing Food in the Southwest Mountains* (Rayner, 2002.) These texts cover a large variety of permaculture techniques from water harvesting to rock mulching to crop selection. Permaculture techniques, proper plant selection, respect of indigenous knowledge and a willingness to experiment are the key ingredients for a sustainable model of horticulture in the desert Southwest.

Joint fir growing wild in Albuquerque. A beautiful example of a plant that grows with no human endorsement, only rain. Needing little to no input from humans, this plant offers medicine, food and dye.

The Pilot Phase of the Xeric Biofuel Production Project

Site Selection Criteria:

Convergence of Trail and Arroyo

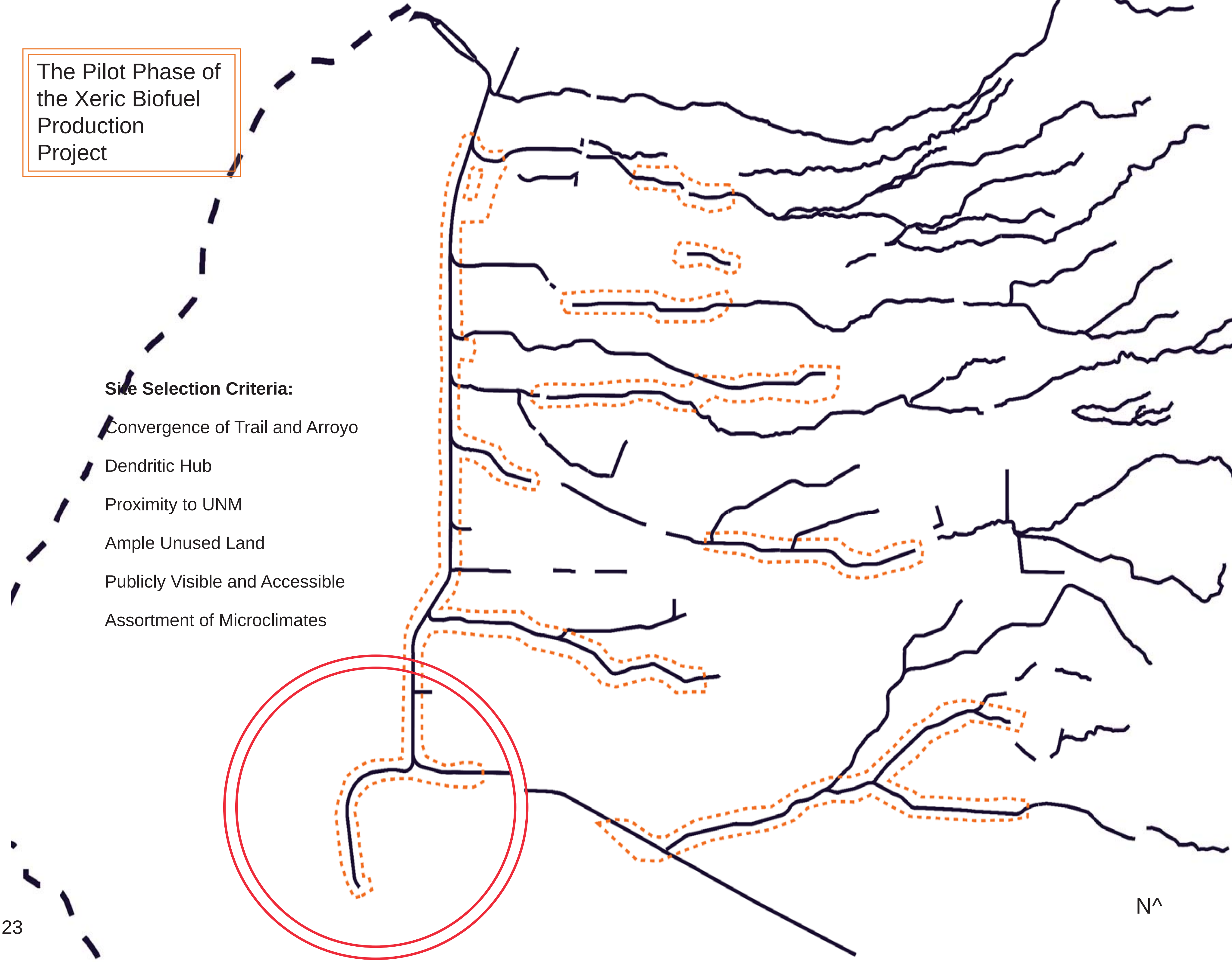
Dendritic Hub

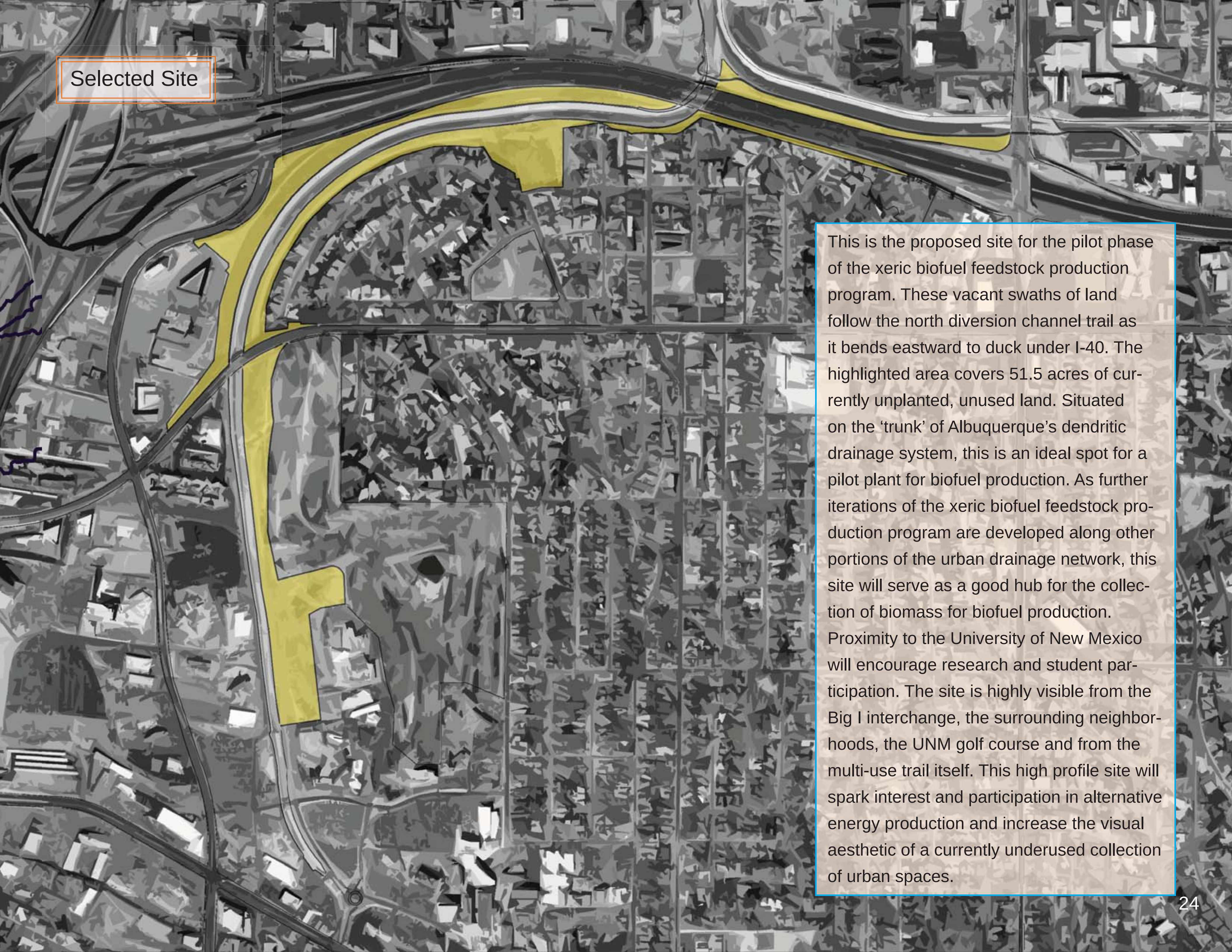
Proximity to UNM

Ample Unused Land

Publicly Visible and Accessible

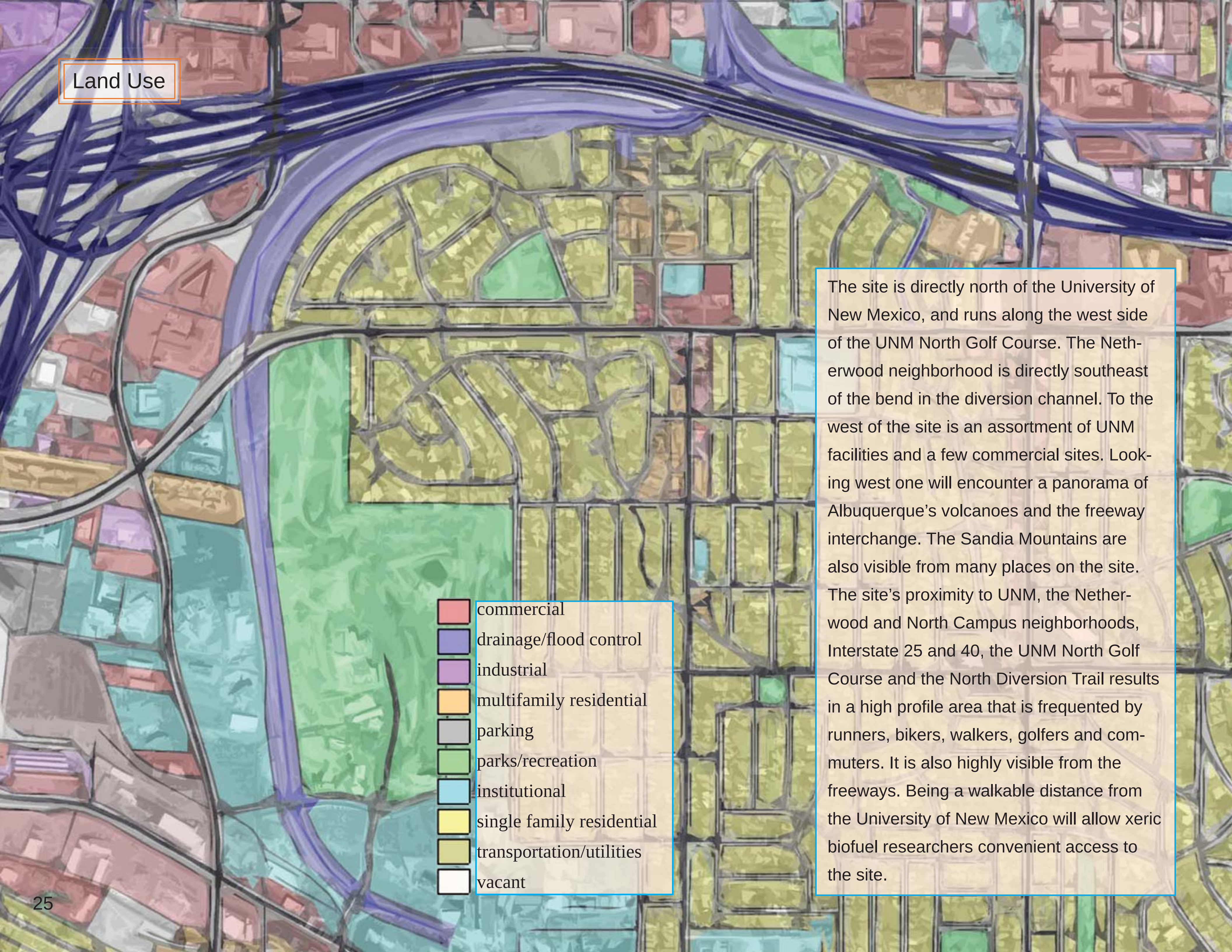
Assortment of Microclimates





This is the proposed site for the pilot phase of the xeric biofuel feedstock production program. These vacant swaths of land follow the north diversion channel trail as it bends eastward to duck under I-40. The highlighted area covers 51.5 acres of currently unplanted, unused land. Situated on the 'trunk' of Albuquerque's dendritic drainage system, this is an ideal spot for a pilot plant for biofuel production. As further iterations of the xeric biofuel feedstock production program are developed along other portions of the urban drainage network, this site will serve as a good hub for the collection of biomass for biofuel production. Proximity to the University of New Mexico will encourage research and student participation. The site is highly visible from the Big I interchange, the surrounding neighborhoods, the UNM golf course and from the multi-use trail itself. This high profile site will spark interest and participation in alternative energy production and increase the visual aesthetic of a currently underused collection of urban spaces.

Land Use



The site is directly north of the University of New Mexico, and runs along the west side of the UNM North Golf Course. The Netherwood neighborhood is directly southeast of the bend in the diversion channel. To the west of the site is an assortment of UNM facilities and a few commercial sites. Looking west one will encounter a panorama of Albuquerque's volcanoes and the freeway interchange. The Sandia Mountains are also visible from many places on the site. The site's proximity to UNM, the Netherwood and North Campus neighborhoods, Interstate 25 and 40, the UNM North Golf Course and the North Diversion Trail results in a high profile area that is frequented by runners, bikers, walkers, golfers and commuters. It is also highly visible from the freeways. Being a walkable distance from the University of New Mexico will allow xeric biofuel researchers convenient access to the site.

AMAFCA History

In order to control flooding in the greater Albuquerque area, AMAFCA (Albuquerque Metropolitan Arroyo Flood Control Authority) was formed in 1963 through a movement in the state legislature. Two kinds of floods naturally take place in this region: the flooding of the Rio Grande and flash floods in arroyos above the floodplain. AMAFCA and the Army Corps of Engineers' first project was the North and South Diversion Channels. These massive engineered drainage ways divert water from the floodplain below, safely depositing it in the Rio Grande where it travels on to the Gulf of Mexico. The resulting flood control infrastructure in Albuquerque is a powerful element in the landscape, invoking the power of high desert storms and tumbling walls of water. AMAFCA maintains its channels, dams and storm drains in Albuquerque with a small crew of workers and a variety of trucks and heavy equipment. Their entire fleet could be run on fuel derived from energy crops grown along the channels. Not only would fuel be produced, but the drainage corridors would become a fascinating low water garden, softening the edges of a pragmatic piece of infrastructure.

Figure 3.5 The AMAFCA logo stamped into the John B. Robert dam.

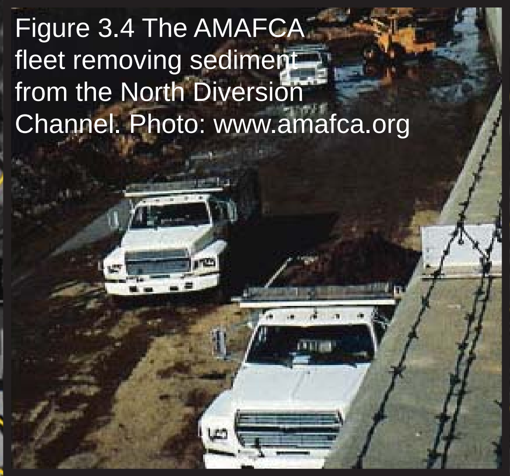
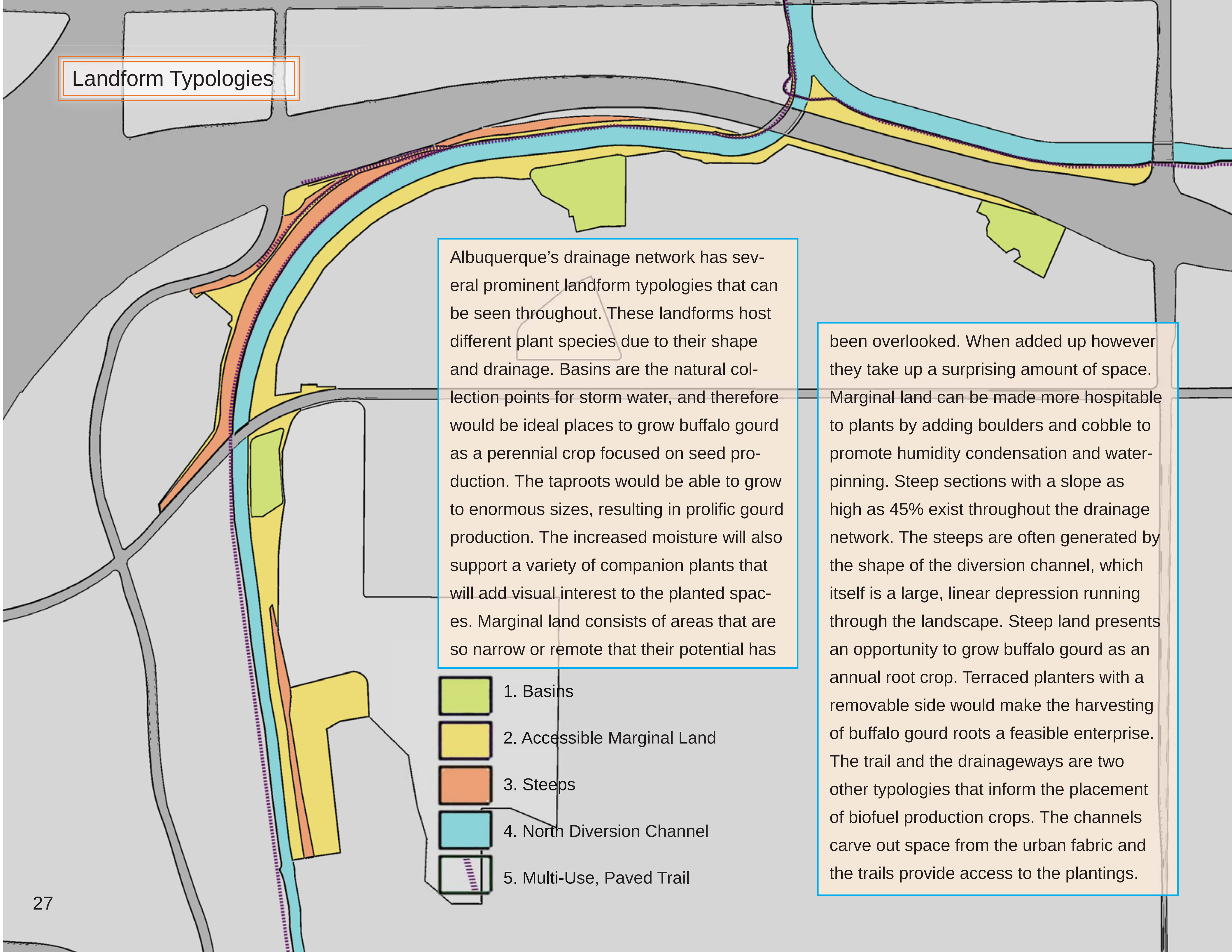


Figure 3.4 The AMAFCA fleet removing sediment from the North Diversion Channel. Photo: www.amafca.org

Landform Typologies



Albuquerque's drainage network has several prominent landform typologies that can be seen throughout. These landforms host different plant species due to their shape and drainage. Basins are the natural collection points for storm water, and therefore would be ideal places to grow buffalo gourd as a perennial crop focused on seed production. The taproots would be able to grow to enormous sizes, resulting in prolific gourd production. The increased moisture will also support a variety of companion plants that will add visual interest to the planted spaces. Marginal land consists of areas that are so narrow or remote that their potential has been overlooked. When added up however they take up a surprising amount of space. Marginal land can be made more hospitable to plants by adding boulders and cobble to promote humidity condensation and water-pinning. Steep sections with a slope as high as 45% exist throughout the drainage network. The steeps are often generated by the shape of the diversion channel, which itself is a large, linear depression running through the landscape. Steep land presents an opportunity to grow buffalo gourd as an annual root crop. Terraced planters with a removable side would make the harvesting of buffalo gourd roots a feasible enterprise. The trail and the drainageways are two other typologies that inform the placement of biofuel production crops. The channels carve out space from the urban fabric and the trails provide access to the plantings.

Storm Water Collection Sites

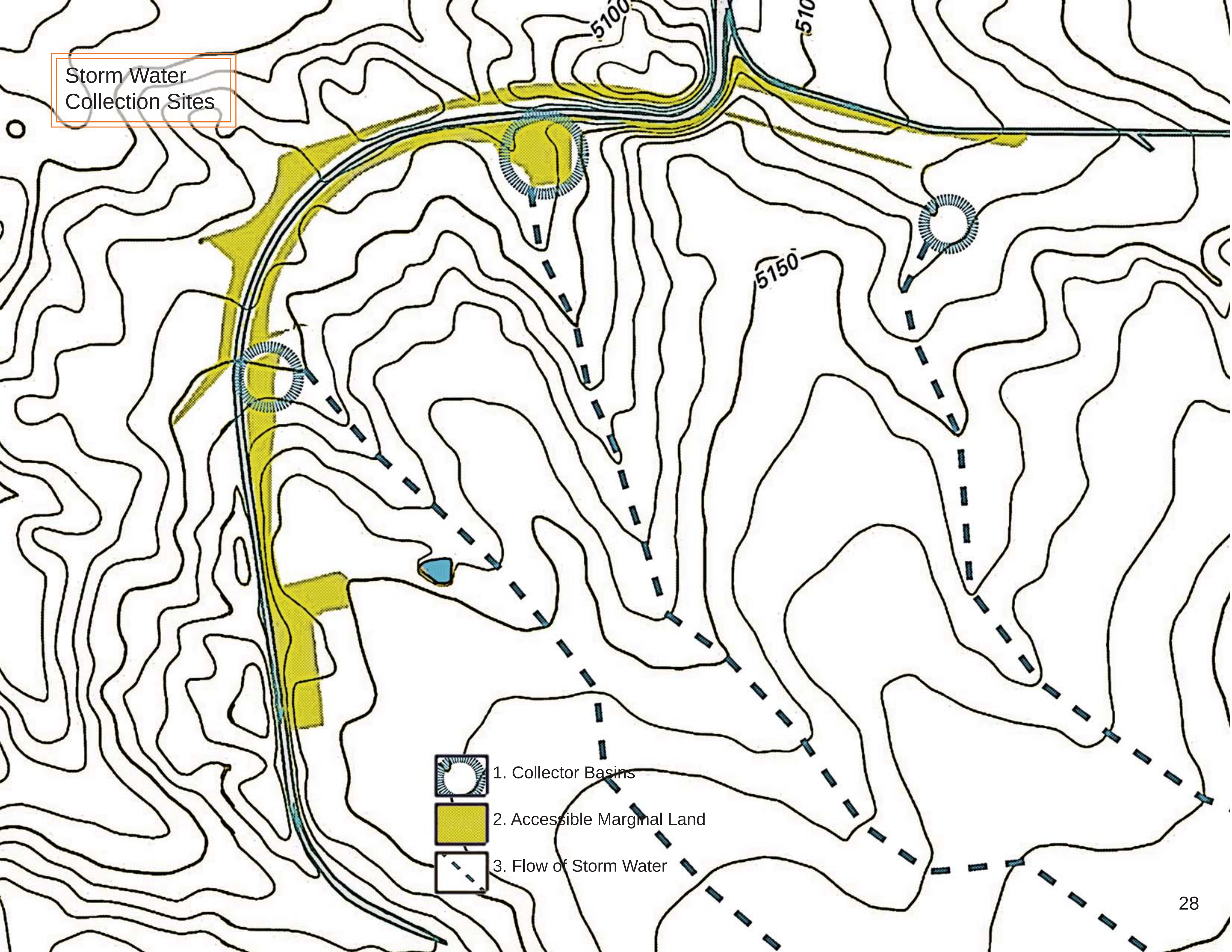


Figure 3.8 The Princeton Detention Basin.

Figure 3.9 Volunteer Siberian elm, *Ulmus pumila*

On this portion of the north diversion channel, flow lines in the topography gather in man-made retention basins. These large depressions are intended to catch sediment and reduce the amount of water spilling into the concrete lined drainage network. Prickly pear cactus, Siberian elm, saltbush, scorpion weed and sand sage dot this landscape. Shin-high boulders invite plant life. This lithic humidity-condensing technology (Santistevan) can be used to establish enough soil moisture to produce biofuel crops. Buffalo gourd can be established with very little water and can be grown in these basins as a perennial energy crop, producing seed oil.

Figures 3.10 and 3.11 The so called “Barren Fairways” adjacent to the UNM North Golf Course. Little grows here, but this harsh environment could support a thriving population of buffalo gourd.

Figure 3.11

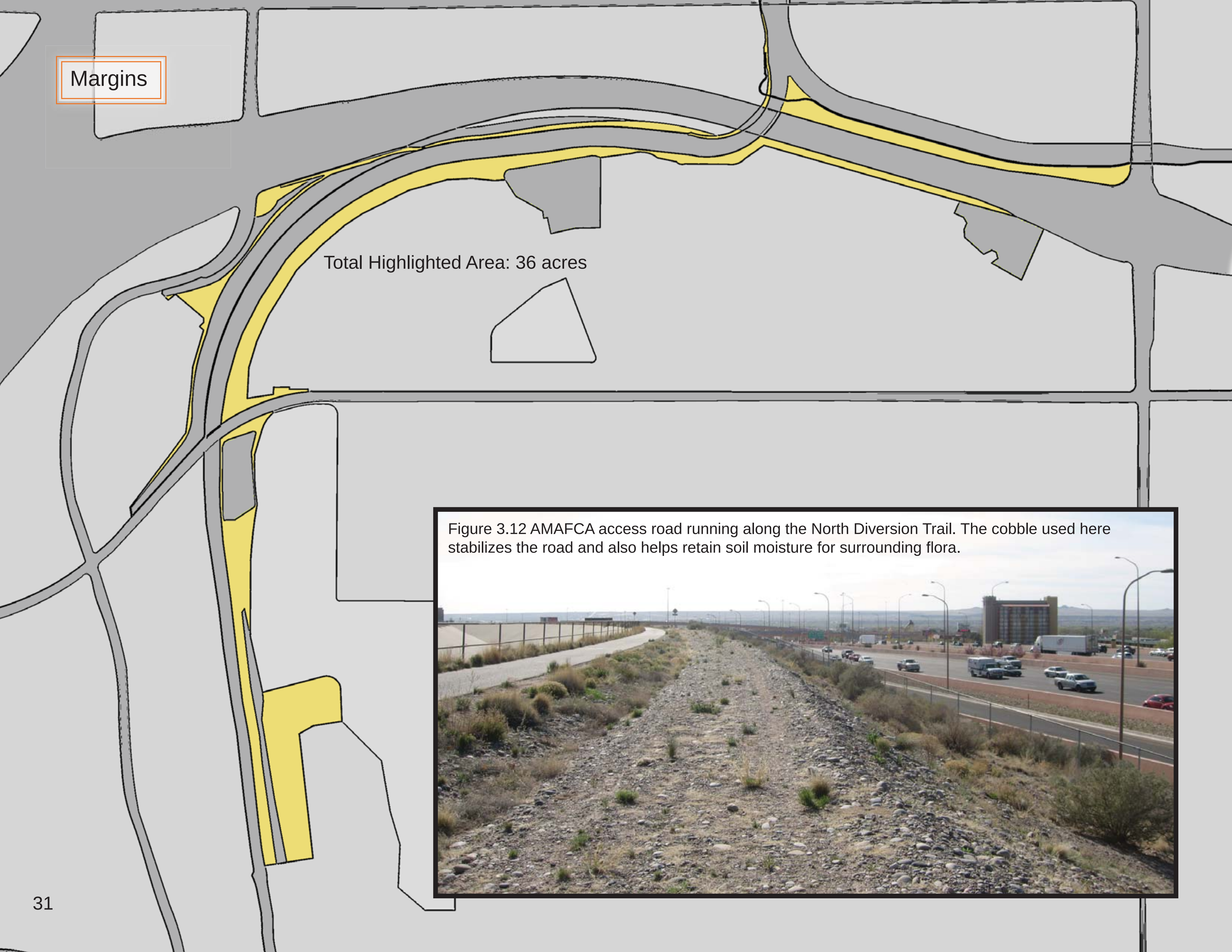


Figure 3.12 AMAFCA access road running along the North Diversion Trail. The cobble used here stabilizes the road and also helps retain soil moisture for surrounding flora.

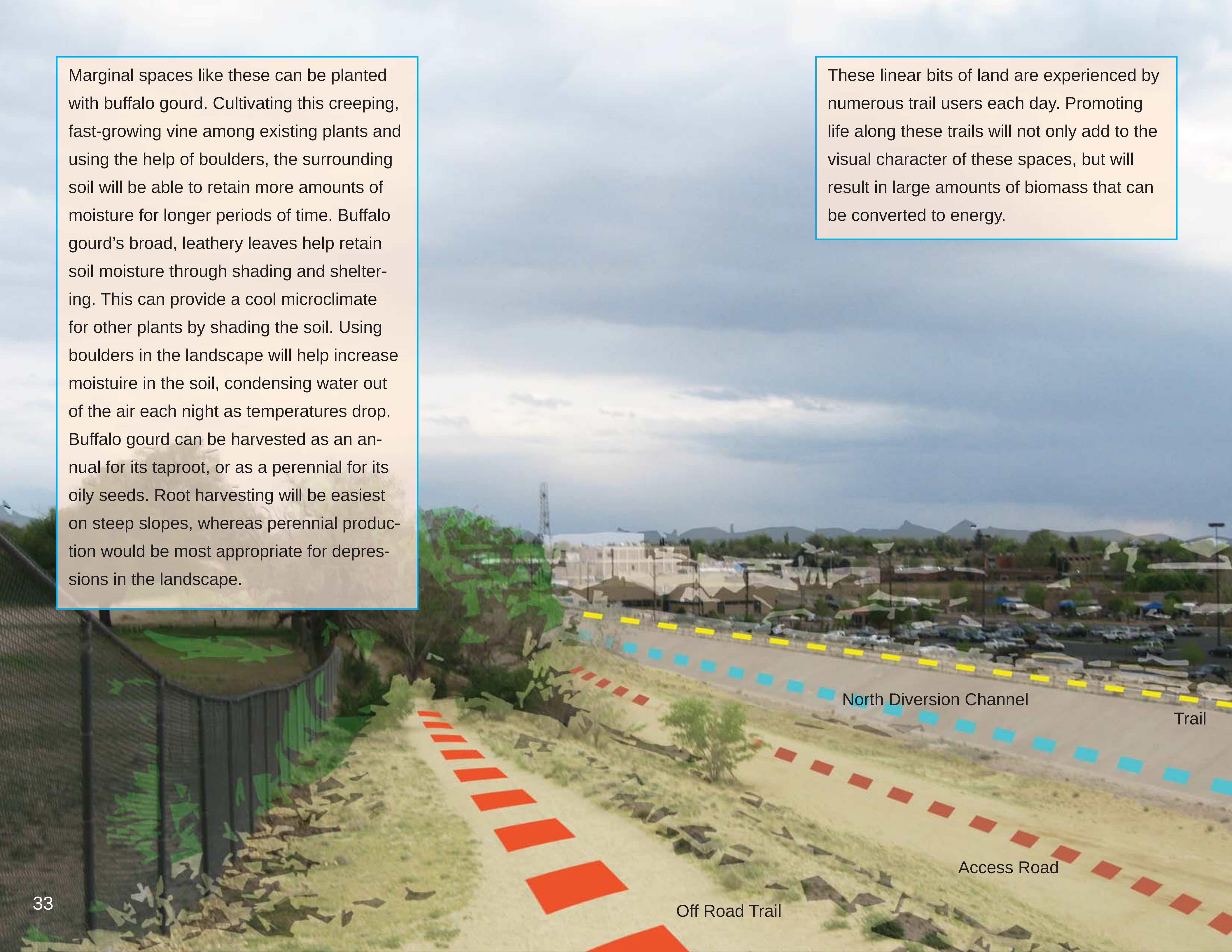
The bike path is situated on top of the ridge that supports the diversion channel. An AMAFCA access road runs parallel to the multi-use trail. The access road is comprised of graded cobble and sand. Cobble is an effective soil moisture retention tool. It could be used to establish buffalo gourd. Using the existing grade of the access road, buffalo gourd can be grown in its annual mode for root starch as a feedstock for ethanol production. Its large, starchy roots can be harvested with a modified harvester attachment. Both sides of the north diversion channel have flat, graded, linear swaths of land intended for maintenance access and buffer. There is enough room to grow linear crops of buffalo gourd, while preserving AMAFCA's required access routes.

Figures 3.13 and 3.14 Much of the marginal land is easily accessible from the trail.

Figure 3.14

Marginal spaces like these can be planted with buffalo gourd. Cultivating this creeping, fast-growing vine among existing plants and using the help of boulders, the surrounding soil will be able to retain more amounts of moisture for longer periods of time. Buffalo gourd's broad, leathery leaves help retain soil moisture through shading and sheltering. This can provide a cool microclimate for other plants by shading the soil. Using boulders in the landscape will help increase moistuire in the soil, condensing water out of the air each night as temperatures drop. Buffalo gourd can be harvested as an annual for its taproot, or as a perennial for its oily seeds. Root harvesting will be easiest on steep slopes, whereas perennial production would be most appropriate for depressions in the landscape.

These linear bits of land are experienced by numerous trail users each day. Promoting life along these trails will not only add to the visual character of these spaces, but will result in large amounts of biomass that can be converted to energy.



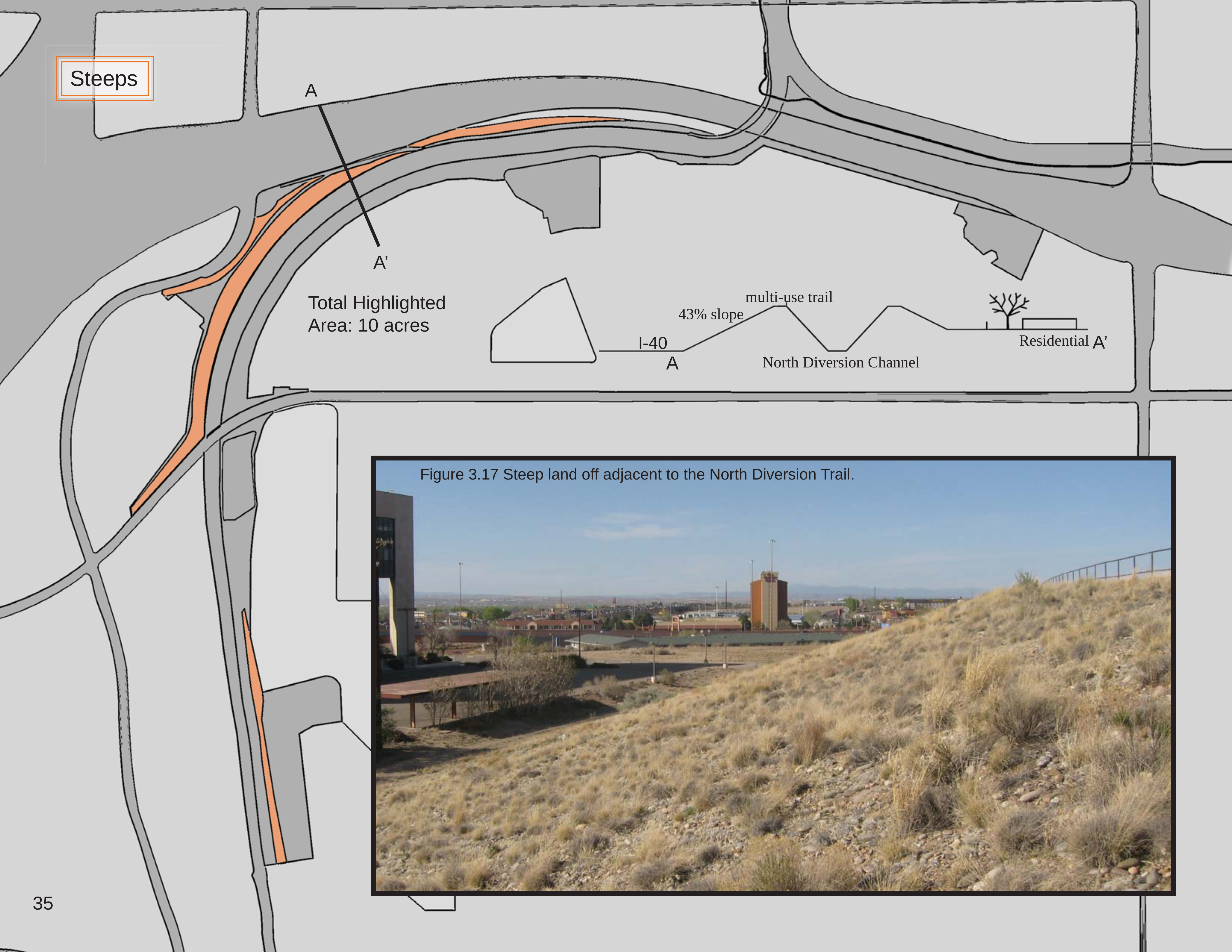


Figure 3.17 Steep land off adjacent to the North Diversion Trail.

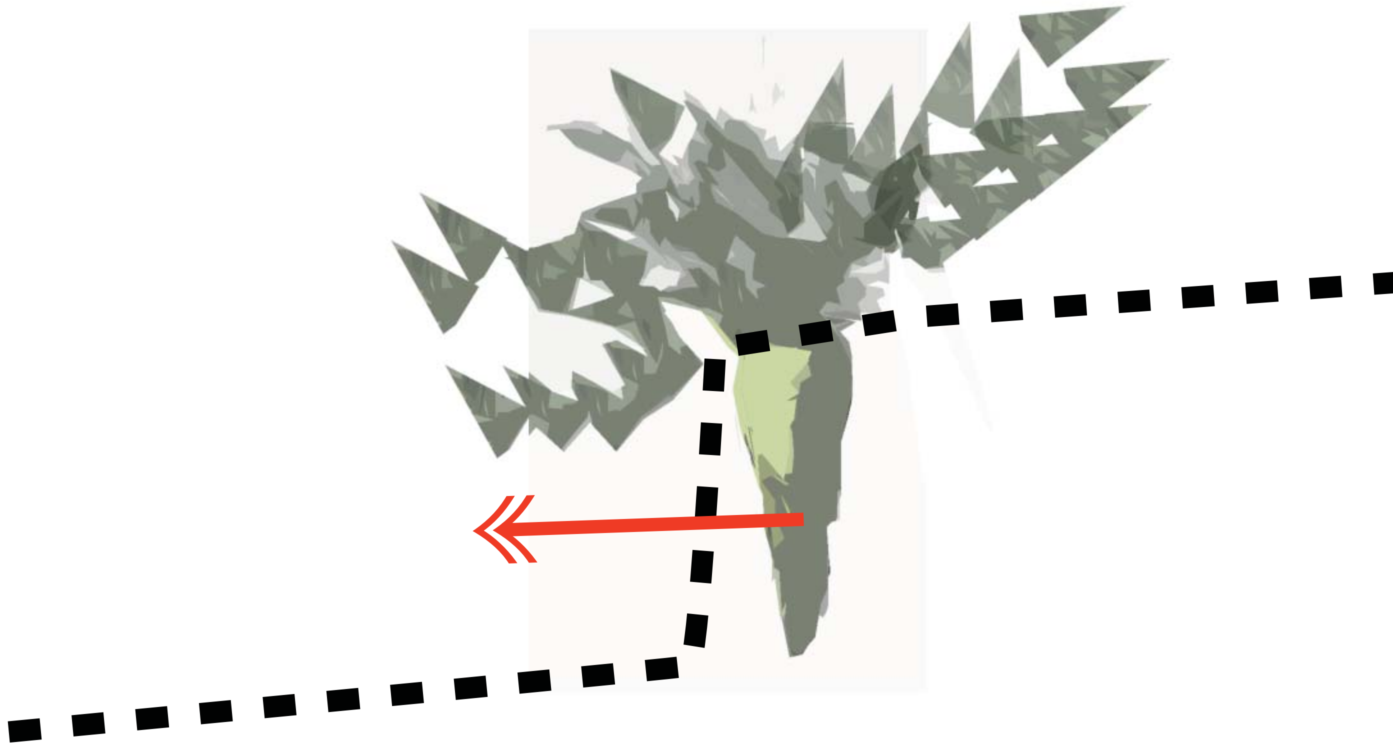
Figures 3.18, 19 and 20 Images of steep, unused land of 40% grade and above.

Portions of the site are incredibly steep due to the topographic imprint of the north diversion channel. The hill underneath the bike path, for example, averages around 43% slope. These slopes are covered in cobble and a variety of native species that are doing an important job of holding the soil with their roots. Scorpion weed, chamisa, sand sage, an assortment of colonizing grasses, globemallow, Apache plume, snakeweed, Mormon tea, gaura, spectacle-pod, four wing saltbush, and the occasional desert willow define this landscape. The following section shows the distinct footprint of the channel, and the relationship between the steeps and the flats.

Figure 3.19

Figure 3.20

Terraced plantings of annual root crops such as buffalo gourd and bush morning glory will be easier to harvest, as less digging will be required to unearth the root. Terraced planting boxes that have a removable side would make the job even easier. The only question is how to reassemble the growing box after harvest. The physical design of the terraces will evolve as the project matures. Some research has been conducted on the annual production of root crops such as buffalo gourd, but no research has yet looked into the feasibilty of harvesting these kinds of crops on slopes as steep as 45%. Buffalo gourd has been known to hold soil on steep slopes. When a vine gets covered in soil, it will begin to root out, as this network expands, more soil is locked into place. Root closets could be built in to the hills with removable sides. Only experimentation will show how buffalo gourd and bush morning glory tolerate these kinds of growing conditions.



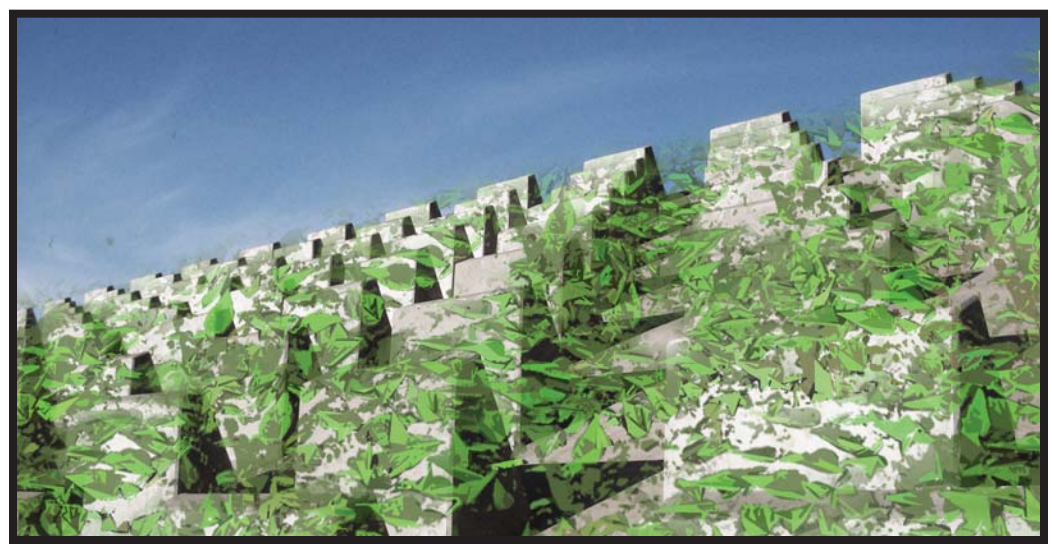
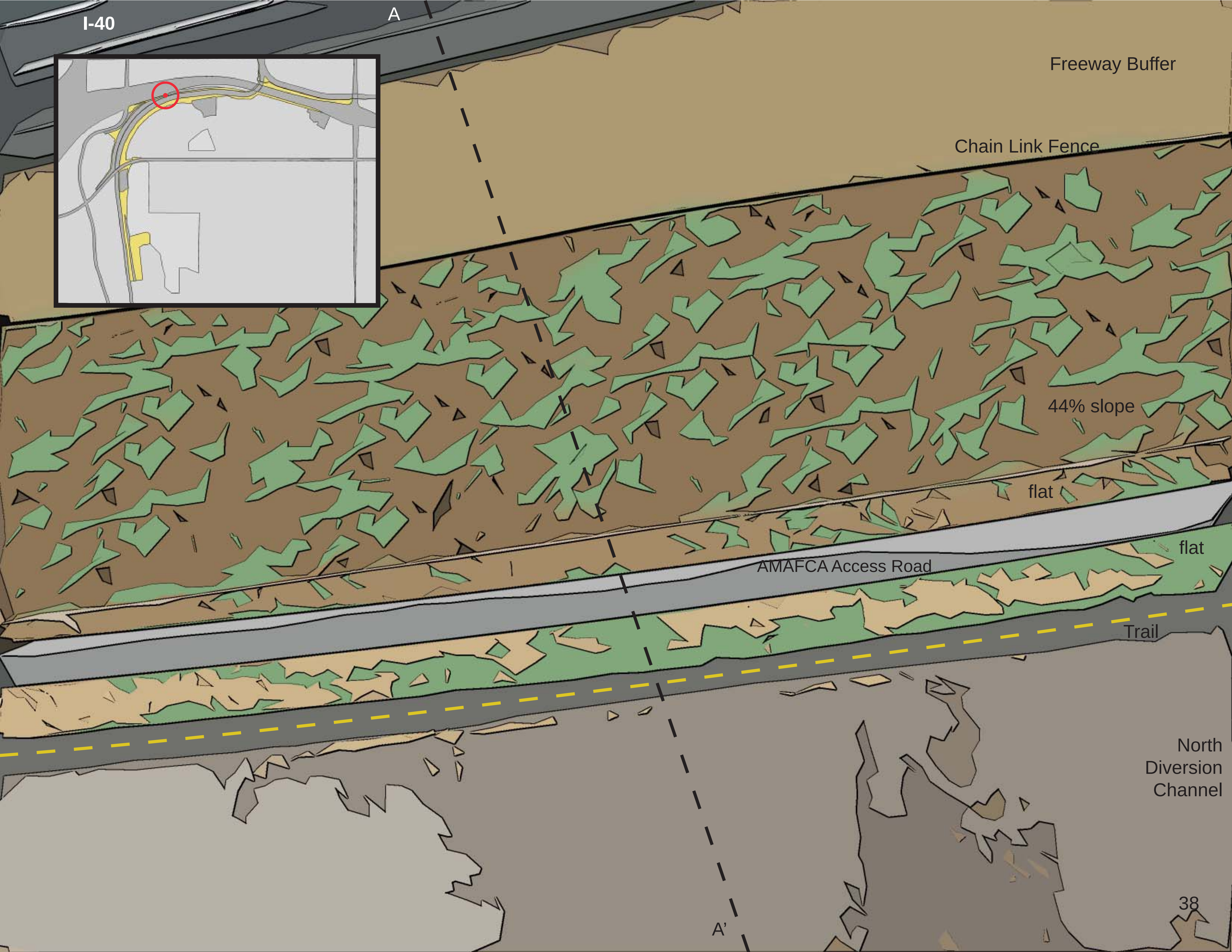


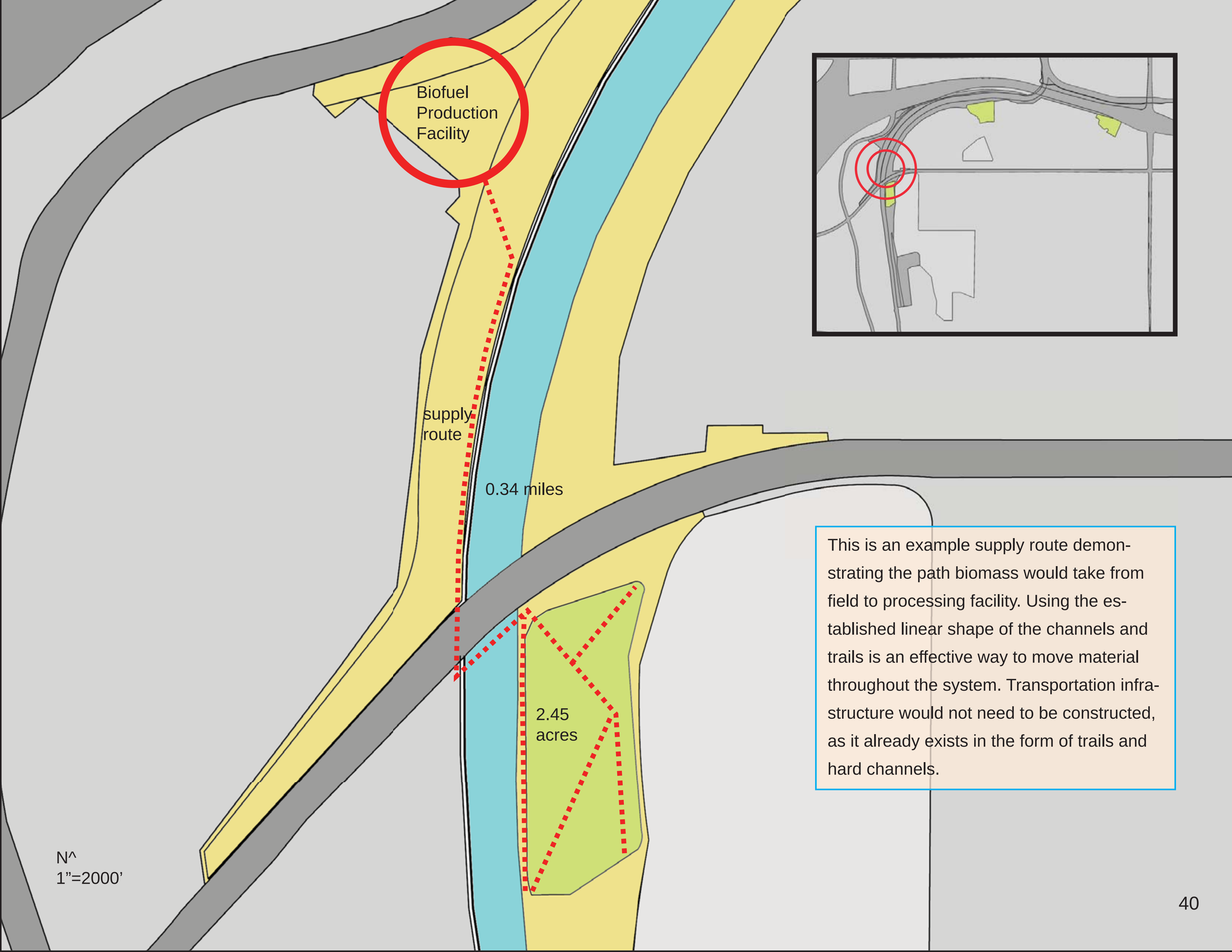
Figure 3.21 The AMAFCA baffle dam as a form generator for terraced root planters.



I-40
A
Freeway Buffer
Chain Link Fence
44% slope
flat
flat
AMAFCA Access Road
Trail
North
Diversion
Channel
A'

Transportation

The arroyos are avenues that transport water, people, animals, sediment, and debris. Using these corridors to transport biomass for fuel production expands the original function of the arroyos. Bike harvesting is a way to engage biofuel coop volunteers. The AMAFCA drainage infrastructure is engineered to be driven on and biofuel-powered collector vehicles could augment the operation. Whether through biofuel-powered vehicles or human-powered bicycles, the opportunity to use alternative energy to create alternative energy is powerful.

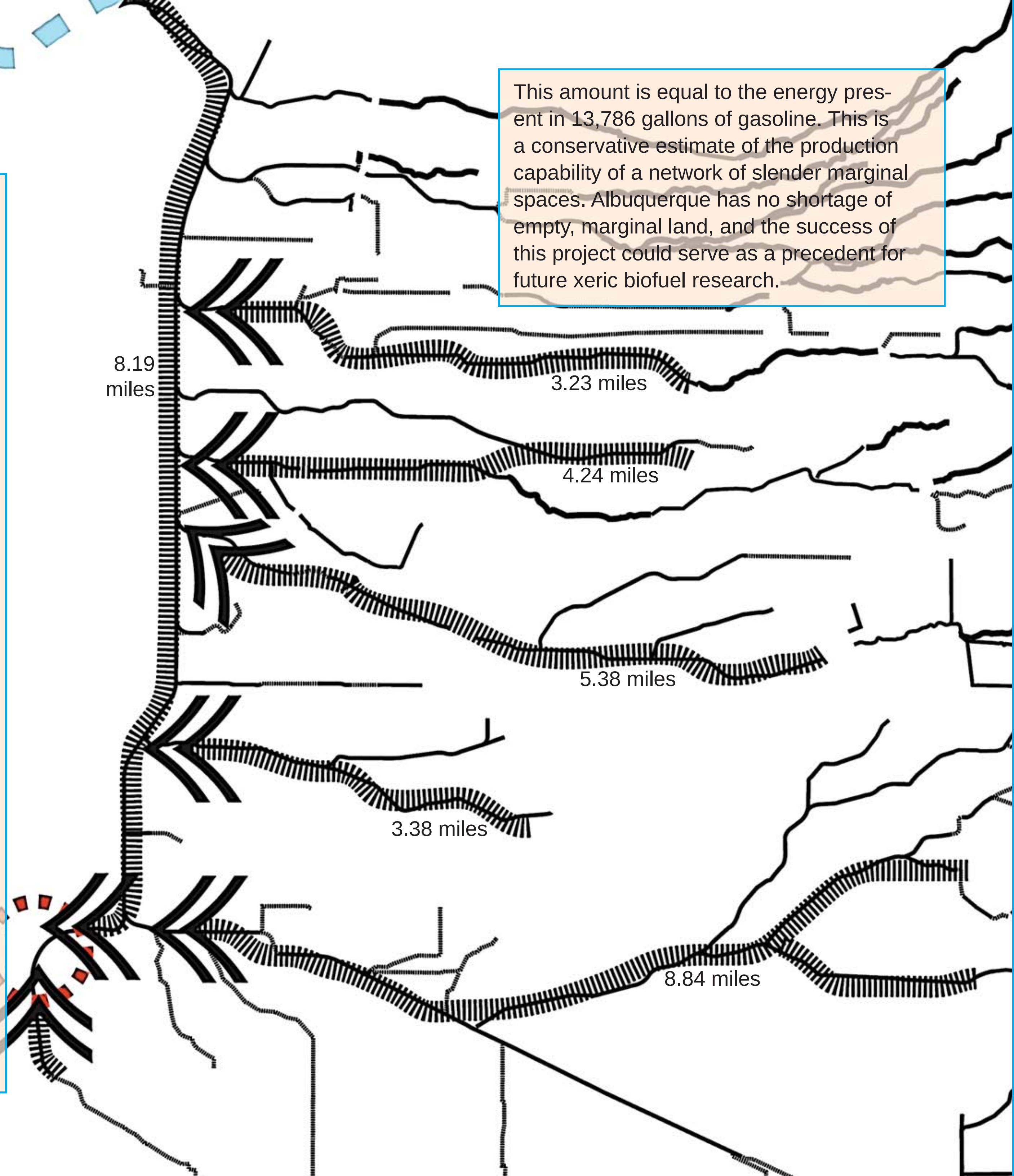


This is an example supply route demonstrating the path biomass would take from field to processing facility. Using the established linear shape of the channels and trails is an effective way to move material throughout the system. Transportation infrastructure would not need to be constructed, as it already exists in the form of trails and hard channels.

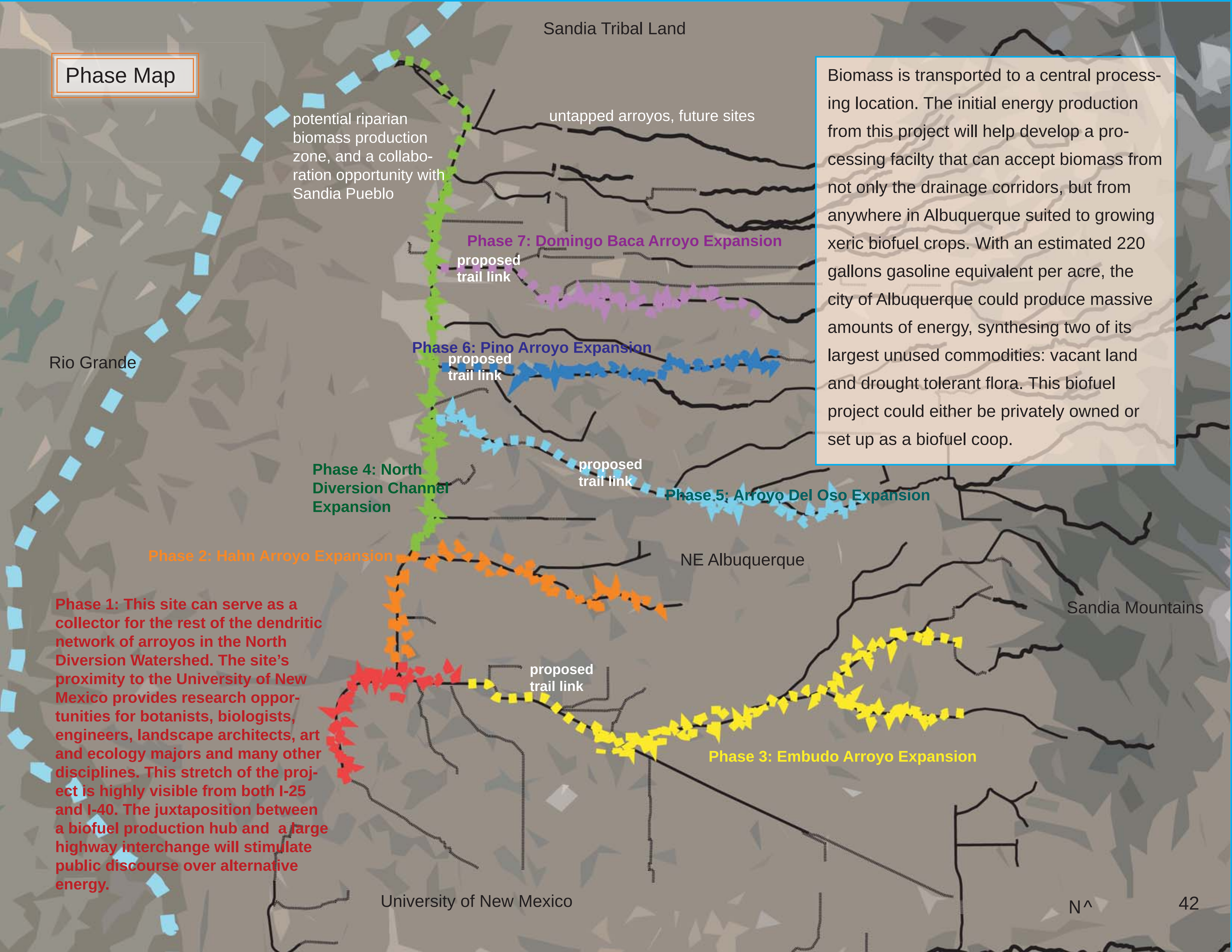
Production Estimate

The total mileage, including proposed trail links, of the entire project is 33.26 miles. Estimating that at any given point on this network there is a space at least 15 feet wide available for energy crop cultivation, this conservative figure adds up to 60.475 acres of available land. Research at NMSU has demonstrated that buffalo gourd, when grown intensively as an annual energy crop, can produce up to 400 gallons/acre or 34 million Btu/acre. When grown as a perennial energy crop the total energy output in the form of seed oil and root alcohol is 18 million Btu/acre. Different landforms are good for different energy crop growing methods. Steep hillsides for instance are best for annual root production. Terraced root boxes with a removable side will make harvesting massive roots a quick job. Planting on steep slopes will also prevent erosion and downhill sedimentation. Large, shallow depressions in the landscape are best for perennial energy crops. Basins are collection points for water and these depressions encourage life. Buffalo gourd would do well in the basin topography, and if allowed to grow for several years, will become a prolific producer of gourds whose seeds are full of oil. Assuming that the space along these paths is an even mix of land suitable for annual production and land suitable for perennial production, approximately 1,027,651,000 Btus could be produced annually.

This amount is equal to the energy present in 13,786 gallons of gasoline. This is a conservative estimate of the production capability of a network of slender marginal spaces. Albuquerque has no shortage of empty, marginal land, and the success of this project could serve as a precedent for future xeric biofuel research.



Phase Map



Biomass is transported to a central processing location. The initial energy production from this project will help develop a processing facilty that can accept biomass from not only the drainage corridors, but from anywhere in Albuquerque suited to growing xeric biofuel crops. With an estimated 220 gallons gasoline equivalent per acre, the city of Albuquerque could produce massive amounts of energy, synthesing two of its largest unused commodities: vacant land and drought tolerant flora. This biofuel project could either be privately owned or set up as a biofuel coop.

Conclusion:

This patterning of landform typologies is apparent throughout the drainage system of Albuquerque. From the riparian corridor of the Rio Grande to the granite-lined arroyos of the Sandias, there are unique landforms that harbor life. Where water collects, plants colonize. Using topography to maximize soil moisture and a palette of durable and prolific desert plants, this system of biofuel production has potential to spread throughout the entire dendritic shape of Albuquerque's arroyo network, collecting into a single biomass processing plant. While the beginning phase of this project uses mostly buffalo gourd as a feedstock for biofuel production, other biomes along the drainage corridors host different plant communities that support other kinds of crops. Some of these plants are native and some are invasive. Giant cane, salt cedar, and switch grass among many are plants that have colonized large poritons of the riparian corridor. Through eradication or control these plants provide ample biomass that can be used for biofuel production. Using diverse species for biofuel production will ensure a continual flow of biomass. Albuquerque is full of vacant land, and to find large amounts of this land linked together by drainage and transportation infrastructure presents an opportuntiy to combine these overlooked resources into an integrated alternative energy production project.

Appendix: A Closer Look at Buffalo Gourd

Botanical binomial: *Cucurbita foetidissima*

Synonyms: *C. perennis*

Common name(s): Buffalo Gourd, Calabazilla, Chilicote

Plant family: *Cucurbitaceae*

PHYSICAL CHARACTERISTICS

Growth rate: Fast

Form: Ground-covering vine.

Mature height and spread: No more than 2’ tall and can spread to over 40’ in width

Notable stem/bark characteristics: Tender stems die back to the ground at the end of every growing season.

Notable leaf characteristics

Evergreen/deciduous: Deciduous

Size: 4” wide by 8” long at maturity

Color: Green, almost blue

Texture: Like sandpaper, rough and slightly aromatic

Canopy density: Forms a dense mat, good haven for small “critters.”

Notable flower characteristics

Size and shape: Large tubular squash flower, roughly 4” in diameter.

Position on stem: Growing out of nodes throughout entire vine.

Color/fragrance: Orange/yellow with a distinct cucurbit aroma.

Season/duration: Summer

Pollinator(s): Bee, certain beetles

Notable fruit characteristics

Type: Gourd

Size: 4” diameter

Color: striped dark and light green, fading to yellow as it dries

Season: Summer.

Notable root characteristics: Large, starchy taproot. A mature root that has been growing for several seasons can weigh over 100 pounds.

Lifespan and contributing factors: Roots out at nodes. A certain biome that hosts buffalo gourd can have buffalo gourd cloning itself in the same area for decades.

NATIVE OCCURRENCE

Range: Southwestern United States, but seen as far east as Missouri

Elevation: 1000 to 7000’

Average annual precipitation: 10”

Cold hardiness: Dies back at first frost, but roots can survive temperatures as low as -15° F.

Heat tolerance: Heat is not a problem for this plant.

Exposure: Full sun

Soil type(s): Likes disturbed soil, sandy loam, and decomposed granite

Drought response: Buffalo gourd’s taproot is one of its main defenses against drought. Its rough, slightly fuzzy leaves also slow the process of evapo-transpiration.

Habitat value: Provides shelter for rabbits, mice etc.

LANDSCAPE QUALITIES AND USES

Compatible trees: *Chilopsis linearis*

Companion shrubs/vines: *Ericameria nauseosus*

Succulents: *Opuntia spp., Cylindropuntia spp.*

Herbaceous perennials: *Verbena bipinnatifida, Oenothera spp., Berlandiera lyrata*

Bulbs/corms/rhizomes: *Iris missouriensis*

Grasses: *Bouteloua dactyloides, Bouteloua gracilis, Oryzopsis hymenoides*

Method of propagation: Easy to propagate from cuttings. Roots at nodes. Seeds, if properly matured, are also a good way to start C. foetidissima.

Management recommendations

Watering schedule after well-established: One deep drink a month.

Fertilizing: Not necessary

Pruning (season/purpose): Cut back dead stems and leaves late fall, early winter.

Susceptibility to pests/diseases and controls: Amazingly resistant to problems like root rot and squash bugs.

Competitiveness: Needs space.

REFERENCES

Books: Barry Goldstein, *Technical and Economical Feasibility of Buffalo Gourd as a Novel Energy Crop.*

Websites: http://www.pfaf.org/user/Plant.aspx?LatinName=*Cucurbita+foetidissima*

Anecdotal information:

In *Wild Plants of the Pueblo Province* by Dunmire, Tierney and Nabhan, a man from Santo Domingo Pueblo is said to have claimed that the mashed up fruit of the buffalo gourd, mixed with water provides a decoction that will stave off squash bugs if applied to the leaves and stems of the squash plants.

I tried it and still had an amazing swarm of squash bugs. I also read that *C. foetidissima* attracts cucumber beetles and is actually used from time to time as a trap crop, redirecting swarms of pests to a less palatable species. This cucurbit's strongly concentrated cucurbitacins and saponins certainly interact with the surrounding flora and fauna, but I have yet to understand the full picture of beetle repulsion and attraction.

Buffalo gourd has a long history of use with the Pueblo Indians of New Mexico. The root has numerous medicinal benefits. The fruits can be used to wash clothes. The seeds and flesh of the gourds can be eaten with thorough removal of the bitter cucurbitacins and saponins present in the fruit. Cooking or soaking in flowing water helps decrease undesirable chemical compounds. Buffalo gourd is very bitter. I was hiking in the foothills of the Sandias with a friend, picking currants up in the boulders when we found some buffalo gourd and picked a few fruits to take home. After handling the bitter gourds, I could no longer eat handfuls of currants, as my hands were covered in the bitter cucurbitacins. I could only taste bitter.

References

1. Michael J. Balick and Paul Alan Cox, Plants, People, and Culture: The Science of Ethnobotany (New York: Scientific American Library, 1996.), 21-22.

2. Shayai Lucero, Medicinal Plants of the Acoma and Laguna Pueblos (Shayai Lucero, 1997.)

3. Eugene Hunn, “ Meeting of Minds: how do we share our appreciation of traditional environmental knowledge?” in Ethnobiology and the Science of Humankind, ed. Roy Ellen (United Kingdom: Blackwell Publishing, 2004), 178.

4. Michael Warren, “The Role of Indigenous Knowledge Systems in Facilitating Sustainable Approaches to Development: an Annotated Bibiography,” in Nature Knowledge: Ethnoscience, Cognition, and Utility, ed. Glauco Sanga and Gherardo Ortalli (New York: Berghahn Books), 317-318.

5. Robert L. Burgess, “Utilization of Desert Plants by Native Peoples: An Overview of Southwestern North America,” in Native Plants and Animals as Resources in Arid Lands of the Southwestern United States, ed J.Linton Gardner (Flagstaff: Arizona State College.)

6. Anson E. Thompson, “New Native Crops for the Arid Southwest,” Economic Botany 39, no. 4 (October 1985): 437.

7. Barry Goldstein, Technical and Economical Feasibility of Buffalo Gourd as a Novel Energy Crop (NMRDI no. 2-72-4213, February 1988,) 146-147.

8. Jack Johnson, “ Plants as Potential Economic Resources in Arid Lands,” in Alternative Strategies for Desert Development and Management vol. 2, ed Margaret R. Biswas and Asit. K. Biswas (New York: Pergamon Press,) 355.

9. Gerald Matlock, Realistic Planning for Arid Lands: Natural Resource Limitations to Agricultural Development (New York: Harwood Academic Publishers, 1981,) 36.

10. Judith Phillips, Southwestern Landscaping with Native Plants (Santa Fe: Museum of New Mexico Press, 1987,) 3.

11. Paul E. Minnis. “Famine Foods of the North American Desert Borderlands in Historical Context,” in Ethnobotany: A Reader, ed. Paul E. Minnis (Norman: University of Oklahoma Press, 2000), 219-220.

12. Rebecca Huss-Ashmore and Susan Johnston, “Cultural Adaptations to Food Stress,” in Eating on the Wild Side, ed. Nina Etkin (Tucson: University of Arizona Press: 1994,) 69-70.

13. Dennis Wall and Virgil Masayesva, “People of the Corn: Teachings in Hopi Traditional Agriculture, Spirituality, and Sustainability,” American Indian Quarterly 28, no. 3/4 (Summer-Autumn, 2004).

14. George Estabrook, “Fuel for Bagaço in Portuguese Agriculture,” in Ethnobotany: A Reader, ed. Paul E. Minnis (Norman: University of Oklahoma Press, 2000), 307-311.