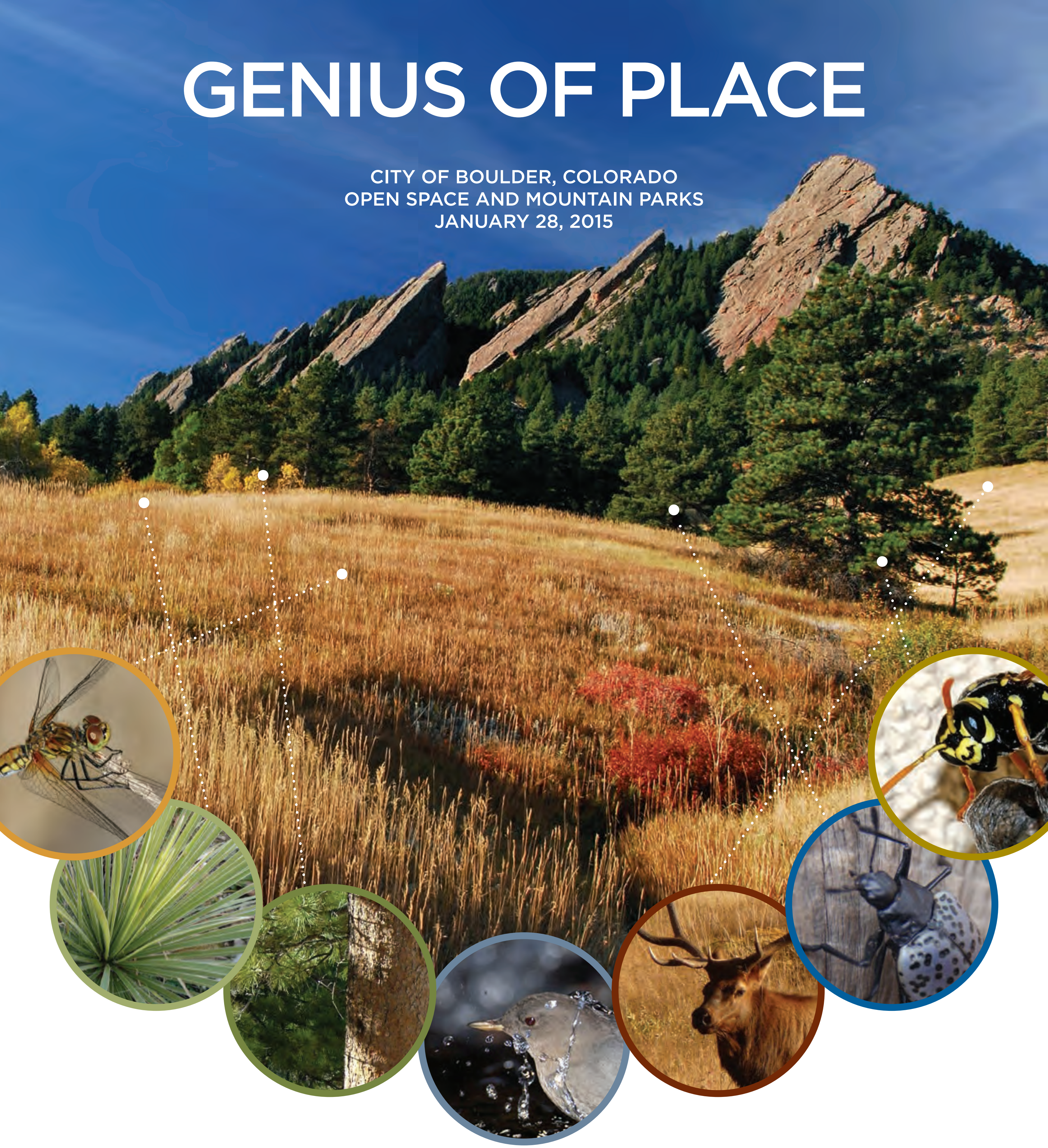
GENIUS OF PLACE

CITY OF BOULDER, COLORADO
OPEN SPACE AND MOUNTAIN PARKS
JANUARY 28, 2015



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Cover photo of Flatirons © Ann Duncun; South Boulder Creek © Josh Couts

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EXECUTIVE SUMMARY

In early 2014, the City of Boulder Open Space and Mountain Parks Department (OSMP) embarked on a Genius of Place Project and Biomimicry trainings with two Certified Biomimicry Professionals, consultant Karen Allen, Aequinox and Marie Zanowick Bourgeois, U.S. EPA.

There were two goals for the project. The first was to use a biomimetic systems approach to find locally-attuned solutions to a design challenge faced by OSMP in their management of the City's open space lands. The second was to educate OSMP staff about the Biomimicry process, through training and as much direct participation as possible to help embed the process into the organization's way of functioning for future projects.

The project focused on the need to find a solution to the deteriorating asphalt surface of Bluebell Road. The two most important functions the road must perform include maintaining shape under forces of shear and compression and shedding water. OSMP also wants to enhance infiltration in the ditch, and possibly in the middle of the road, while protecting the side of the road exposed to the ditch from infiltration. The practice of Biomimicry teaches us to ask, "What would nature do?"

In the research phase of the project we asked, "How would nature maintain shape, shed water, and enhance infiltration?" Our research led to the translation of seventy-five ways nature prevents deformation, sixty ways life creates a waterproof barrier, and fifty ways nature enhances infiltration. We chose seven organisms from OSMP ecosystems for further research and created detailed biology stories, design principles and illustrations for the Local Genius Stories used in the design charrette as inspiration for design concepts.

Forty-four OSMP staff, students, design, engineering and biology professionals participated in a design charrette in late 2014. The workshop was designed to share the Genius of Place process, create design concepts for the project, and to advance understanding of Biomimicry as an innovation approach. The group brainstormed application ideas and refined eleven design concepts for the redesign of Bluebell Road.

Throughout the process, approximately 70 OSMP staff received basic education in Biomimicry. Many participated in the Genius of Place process and trainings, and 21 staff were integral participants in the charrette, contributing to the creative solutions.

By 2016 OSMP hopes to incorporate Biomimicry language and concepts into the Request for Proposals for the target challenge, re-designing the former road into a trail and roadway with designs inspired by concepts from the charrette. The year 2017 is a potential target date for OSMP to engage a contractor to build this Biomimicry inspired trail/road. Simultaneously, OSMP will tell the story of the Genius of Place process, the 7 species studied for design inspiration, and the Biomimicry process in general to locals and visitors to OSMP lands.

Two project goals included using Biomimicry to find a locally-attuned solution to a design challenge and to train staff in this innovative problem solving process.

OSMP's Stormy Ecotone

Photo © Gary Stevens

Photo © Ann Duncun

Top to Bottom — Achemon Sphinx *(Eumorpha achemon),* Fox Hills Sand Stone at White Rocks, Various Lichen, Visitors on a Prairie Trail

INTRODUCTION

WHAT IS BIOMIMICRY

Biomimicry is the practice of emulating nature's design principles to help bring about a more sustainable world. Self-cleaning paint modeled after micro bumps on a lotus leaf, recyclable plastics inspired by the process of photosynthesis, industrial systems that emulate natural ecosystems, all are examples of mimicking nature's genius. The practice of Biomimicry connects us to the systems that support us, to the habitats we call home, and deepens our thinking and practice of living sustainably on earth.

Biomimicry is the practice of emulating life's time-tested strategies and deep patterns to generate sustainable designs.

WHAT IS A GENIUS OF PLACE PROJECT?

A Genius of Place study looks to nature in a particular place to provide guidance on locally-attuned design strategies. By asking, "How have organisms and ecosystems solved this challenge *here*?" we discover a suite of design strategies that are well-adapted to place. The practice of looking to the locals for guidance on how to live is an ancient one, practiced by indigenous cultures the world over. More and more, biomimics today are seeking the wisdom of other organisms who share our home habitat for models of locally-attuned sustainable designs. The practice of Biomimicry and the Genius of Place process were developed by Biomimicry 3.8 (B3.8), a consultancy based in Montana, and are being practiced by the Certified Biomimicry Professionals (CBP) and others trained to bring Biomimicry into the world.

The goal of the City of Boulder Open Space and Mountain Parks (OSMP) Genius of Place project was to use a biomimetic systems approach to find locally-attuned solutions to a design challenge faced by OSMP in their management of the City's open space lands. To engage OSMP staff and deepen their understanding of Biomimicry, trainings were offered throughout the process.

PROJECT TEAM

The project team consisted of the following individuals:

- Lynne Sullivan, OSMP Interpretive Naturalist, Biomimicry Practitioner
- Karen Allen, Certified Biomimicry Professional, Biologist & Restoration Ecologist at Aequinox
- Marie Zanowick Bourgeois, Certified Biomimicry Professional, Engineer at U.S. EPA, Region 8
- Mary Wagner, Founder and Creative Director at M.A. Studio, Inc.

To learn more about Biomimicry, visit Biomimicry 3.8's website: Biomimicry.net.

METHODS

Boulder Genius of Place Timeline

TIMELINE

The general timeline for the Project is shown above and is described in subsequent sections. Prior to 2014, Lynne had multiple conversations with upper management introducing them to the concepts of Biomimicry and securing their support to schedule and fund the project for the 2014 work plan. Throughout early 2014, Lynne held extensive trainings throughout the organization to introduce as many staff as possible to the process and enable them to begin speculating about potential challenges for the process.

THE PLACE

The City of Boulder's OSMP lands encompass 45,000 acres where the Great Plains meet the Rocky Mountains (Figure 1). This diverse landscape is an integral part of the community and receives 5.3 million visits per year, more than any national park in the United States. Holding many embedded microhabitats and having been protected for more than a century, these lands lie in the heart of the most biologically diverse region in the U.S. interior.

Large Marble Butterfly *(Euchloe ausonides)*

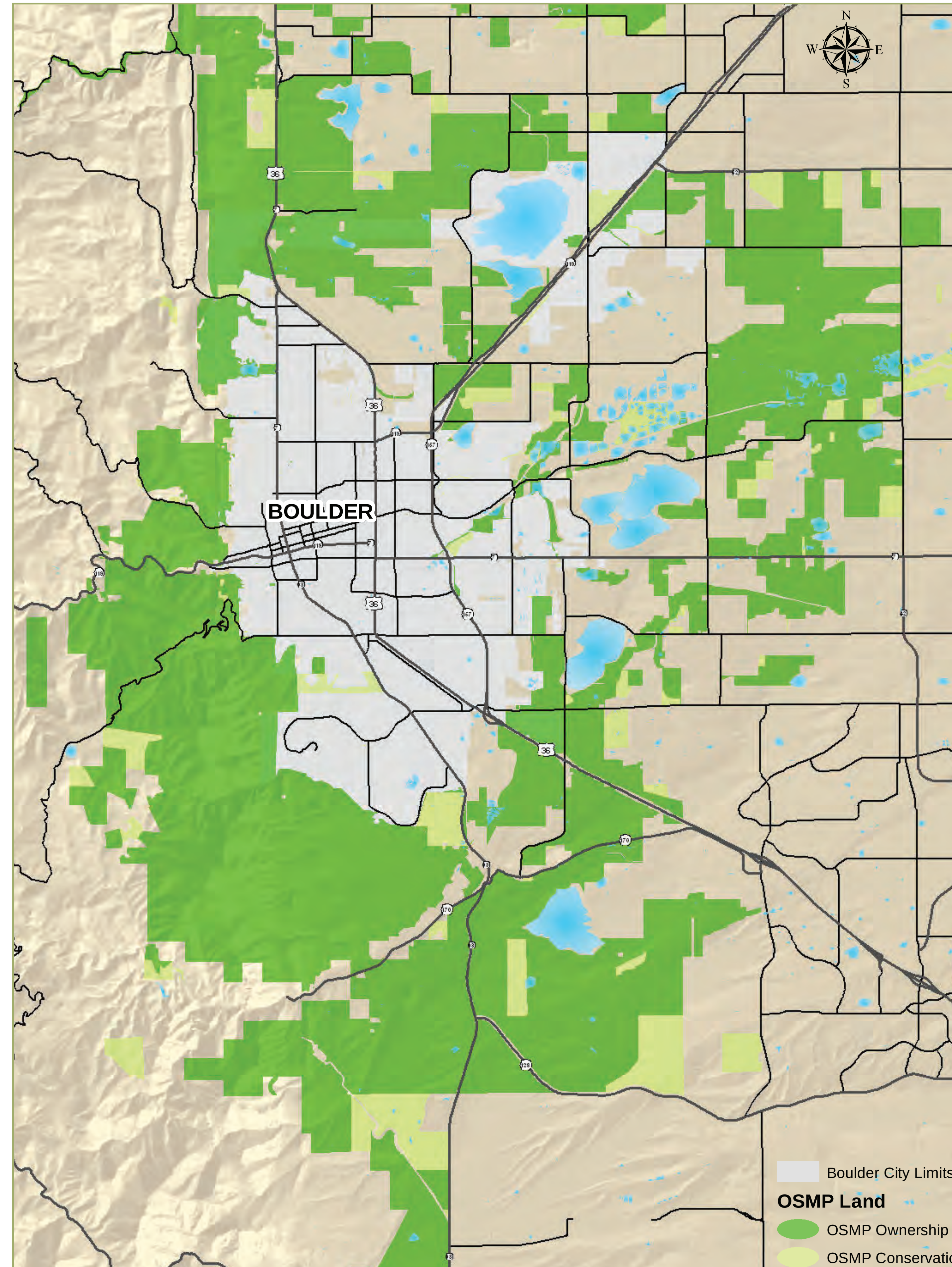
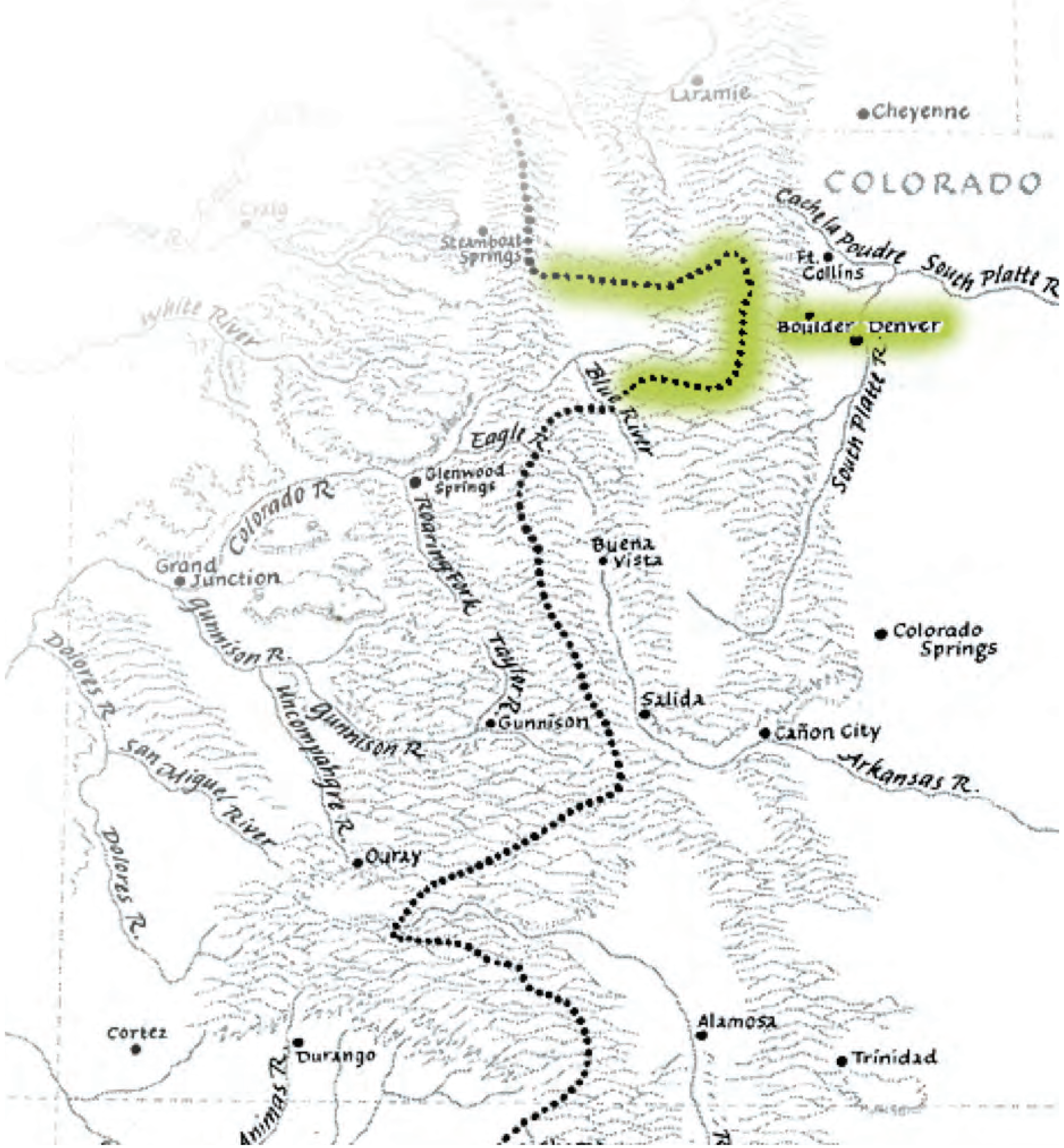


Figure 1 - Open Space & Mountain Parks Lands

There are four primary reasons for the high biodiversity. First, these lands have been protected from development for over a century. Second, OSMP lands encompass the ecotone where the prairie and foothills ecosystems meet. Ecotonal regions have higher biodiversity because each ecosystem contains specialists, and generalists move back and forth between the two. Third, smaller scale biodiversity abounds in multiple microhabitats found within this landscape, including steep east-west running canyons. The bottoms are shady, wet, and cool, supporting moisture-loving vegetation and animals such as black bears. The sun-parched wind-blasted rocks rimming the tops of the canyon host drought tolerant lichen and cactus. The hotter, drier south facing slopes support species such as ponderosa pines and yucca originating from southern regions, while the north facing slopes host species such as Douglas fir and chicory squirrels, originating from cooler moister more northern climates.

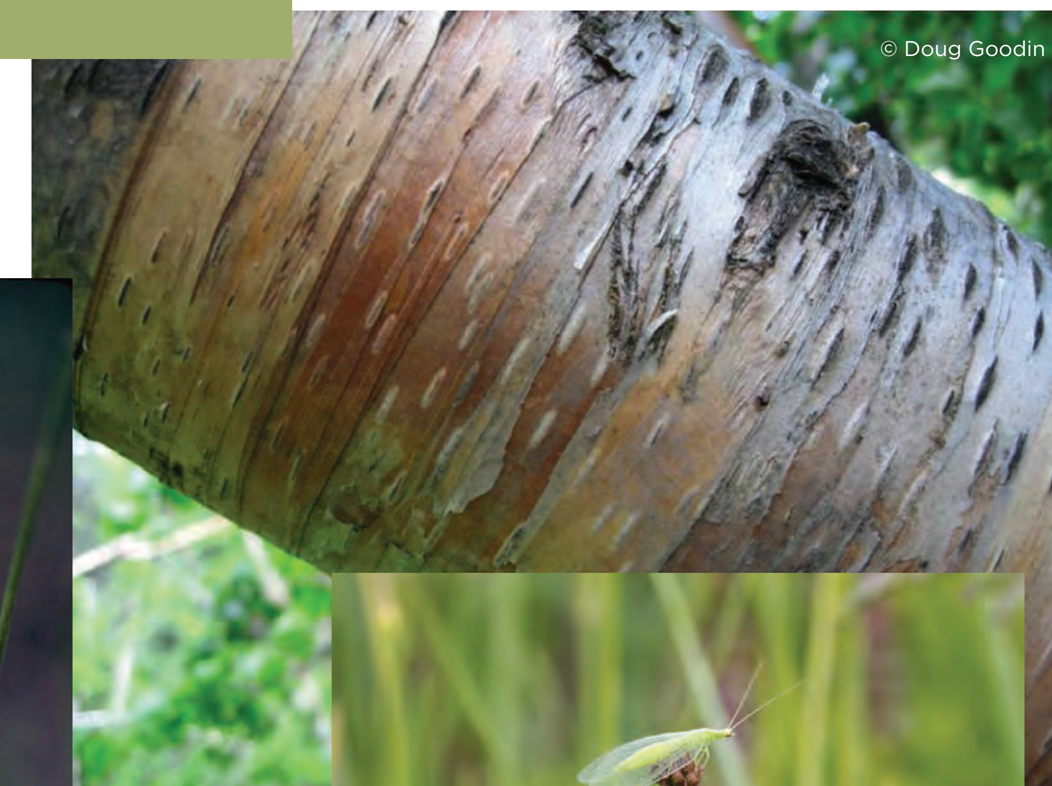
The fourth reason for high biodiversity on OSMP lands is due to the concentration of life zones from prairie to montane due to local steep vertical rise over a short horizontal distance. The closely compacted life zones allow for unusually low elevation occurrences of species such as aspen, lodgepole pine, and marmots on OSMP mountain slopes. High-quality montane forests support species such as flammulated owls that prefer old growth or near old growth forests. The proximity of the continental divide as it swings sharply eastward towards Boulder, and the steeply rising foothills, increases this semi-arid region's average annual precipitation (17 inches) by a few inches per year over surrounding areas, supporting plant species that are not found in similar habitats to the north, south or east of OSMP.

OSMP is host to two plant communities that are relicts of the Pleistocene era, snapshots of the region's habitat 10,000 years ago. As the Earth's climate warmed and dried over the last 9,000 years, these habitats died out locally, except in microhabitats that remained cooler and moister, such as in the bottom of Long Canyon and along the western edge of the Great Plains tucked against the steeply rising foothills. Here we find a relict eastern woodland paper birch and beaked hazelnut forest community, and a relict tall grass prairie, respectively. Tall grass prairie is one of the most endangered habitat types in the world, with only 2-4% of the original habitat remaining. OSMP's tall grass prairie is also globally unique due to the mountain species that have embedded into the prairie over thousands of years.



The continental divide swings sharply eastward towards Boulder. Source: Benedict. 2008

Myriad endangered, rare and sensitive species are dependent on the protection and sound management of OSMP ecosystems for viable habitat in which to thrive. OSMP strives to foster appreciation and use that sustains the rich biological diversity and natural values of the land for current and future generations.


© Doug Goodin


© Bill May

Rare and Sensitive Species (top to bottom) — Paper Birch *(Betula papyrifera)* is critically imperiled in Colorado. Bird's Foot Violet *(Viola pedatifida)* and Dwarf Lead Plant *(Amorpha nana)* are both imperiled in Colorado.

CHALLENGE SELECTION PROCESS

An in-depth scoping process in the first half of 2014 led to the selection of a challenge for the Genius of Place Project. The goals of the scoping phase were multi-faceted and included:

- educate OSMP employees about the Biomimicry and Genius of Place processes
- garner interest, involvement, and investment from within all levels of the organization
- work with the staff to identify potential challenges for the process
- explore the contextual issues surrounding each challenge
- conduct a site visit with the consulting team to become familiar with the local ecosystems
- choose a challenge supported by OSMP staff

Throughout early 2014 Lynne delivered introductory Biomimicry presentations to all interested work groups within OSMP in order to educate staff about Biomimicry, to garner support for the Genius of Place process, and to solicit staff involvement in the process, including speculating about potential challenges for the process. Lynne and Marie led a brainstorming session with staff, collectively generating a list of twenty-five potential challenges to run through the Genius of Place process. Through a series of scoping meetings and by applying selection criteria, the surfacing of Bluebell Road became the selected challenge (for more information on the Scoping Phase, please see the Project Scoping Report).

THE CHALLENGE

Bluebell Road is owned by OSMP, is approximately 0.9 miles long and 20 feet wide, and rises approximately 430 feet from Baseline Road at 5,662 feet elevation to the Bluebell shelter at 6,089 feet elevation (Figure 2). The road is a primary access route to a network of trails, including the Mesa and Royal Arch trails, used extensively by hikers and runners. It is also open to equestrians. The road is also used by emergency vehicles for rescues and by OSMP staff to service the outhouse and Bluebell shelter, and to maintain local trails. There is no public vehicle access.

Portions of Bluebell Road are surfaced with deteriorating asphalt. During the September 2013 flood, large portions of the road sustained flood damage including gullying and undermining of the asphalt surface. Due to the deteriorating asphalt, the road did not properly drain water into the ditch and water was absorbed by the road, leading to freeze/thaw action that further degraded the road surface. Early planning to repair Bluebell Road included recognition that the surface structure of the road is important to be maintained in order for the road to effectively shed water. Temporary repairs were made, and a long term solution will be developed in the next year or two, making the exploration of a biomimetic solution to the road surface and ditch a viable project. A suite of design parameters were identified for the Bluebell Road challenge (Appendix A).

The challenge chosen was the resurfacing and transition of Bluebell Road into a sustainable trail, able to handle emergency vehicles as necessary, using earth-friendly materials.

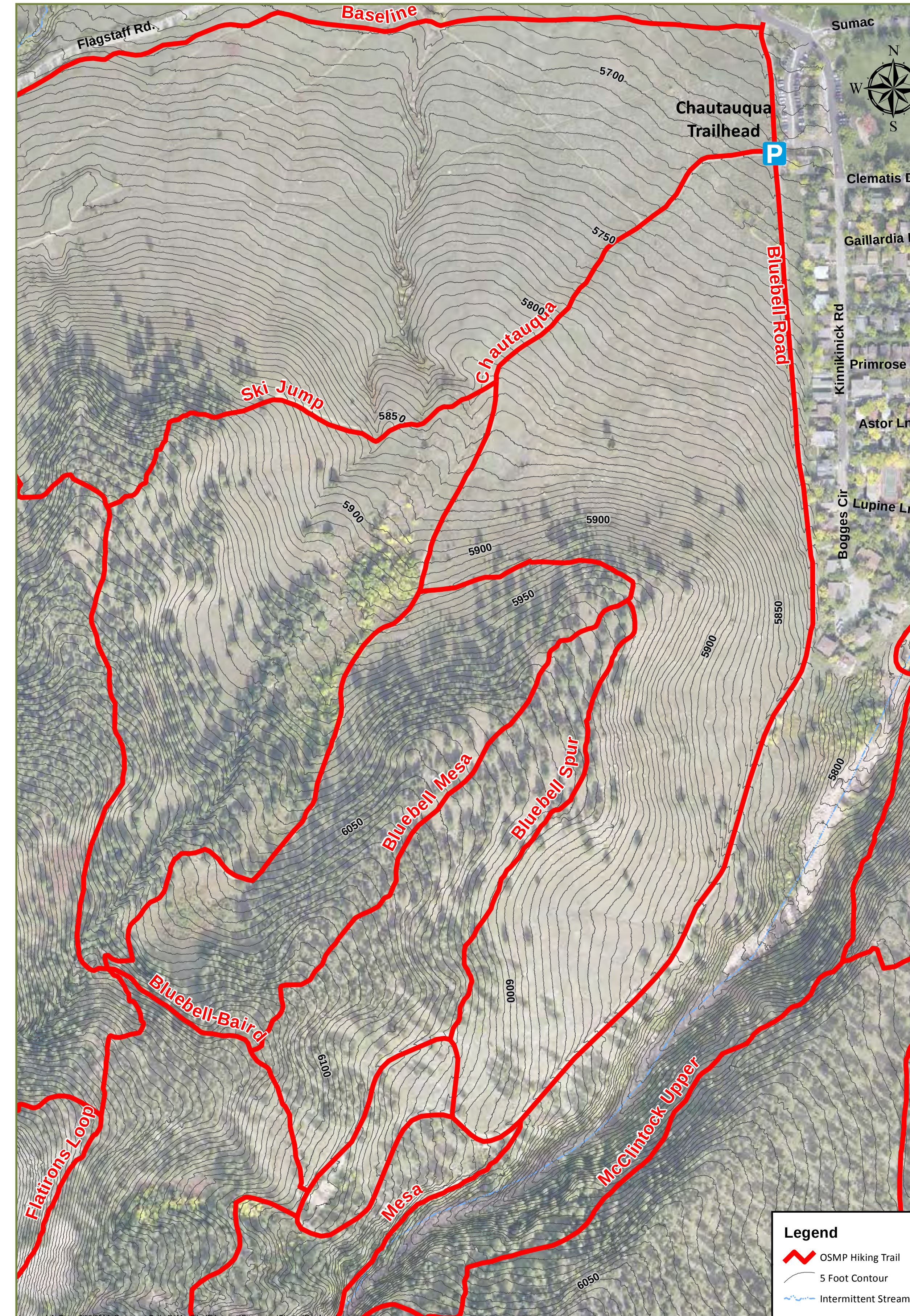


Figure 2 — Bluebell Road Biomimicry Project Area

Deteriorating Asphalt on Bluebell Road

Flood Damage to Bluebell Road

The novelty of the Biomimicry approach is in asking, "What should the design solution do? What are its most important functions?" We then turn to nature for examples of time-tested strategies that accomplish these functions.

Photo by Chris Brown
www.ChrisBrownPhotography.com

FUNCTIONS SELECTED

One of the ways Biomimicry differs from other design approaches is a focus on asking "What do we want the design to do?" rather than, "What do we want the design to be?" By asking this question, we identify the functions the design needs to perform. Given the considerations noted above, the two most important functions the road must perform include *maintaining shape under forces of shear and compression, and shedding water.* The ditch lies on the cut (upslope) side of the road, conveying water during runoff events northward onto Baseline Road. Historically the ditch has been vegetated and OSMP prefers to revegetate the ditch to help slow flows during surface runoff events. OSMP also wants to *enhance infiltration* in the ditch, and possibly in the middle of the road, while protecting the side of the road exposed to the ditch from infiltration.

Three functions the new trail/road and ditch design will do:

- maintain shape
- shed water
- enhance infiltration

BIOLOGICAL RESEARCH

Based on the functions most important for the road and ditch to perform, the biological research phase focused on these questions:

- *How does nature maintain shape and prevent deformation under shear and compression forces?*
- *How does nature shed water?*
- *How does nature increase infiltration?*

The Research Phase of the Project started with Karen, the biology research lead, facilitating two brainstorming sessions with interested OSMP staff biologists to generate a list of as many local organisms, processes, or ecosystem patterns as possible that perform the identified functions. This was followed by research into the biological literature to learn and translate nature's strategies.

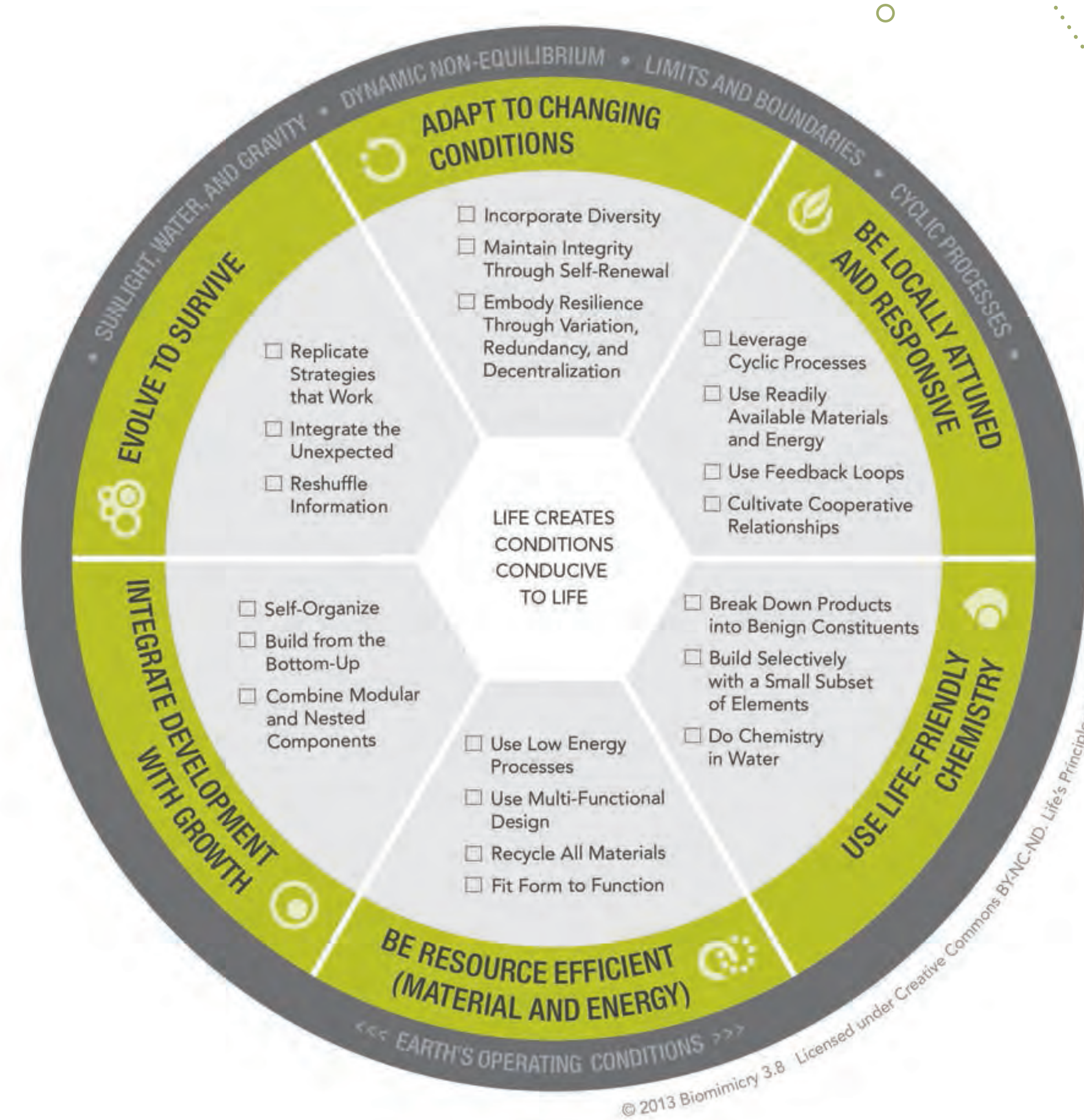
Karen led a training for interested OSMP staff on how to conduct biology research for Biomimicry and the unique lens one must bring to that research to uncover life's most interesting and well-adapted strategies. Once the research was complete, the research table consisted of seventy-five ways nature prevents deformation, sixty ways life creates a waterproof barrier, and fifty ways nature enhances infiltration. Karen vetted the research table for patterns, and grouped like strategies together. Then the project team and self-selected OSMP staff voted on their top strategies per function for further research.

Prior to this voting, the team eliminated *enhance infiltration* as a function to move into the next phase since OSMP prefers to use vegetation to enhance infiltration and the team wanted to dive deeper into the research on more strategies for the other two functions. The team selected four strategies for *prevent deformation* and three for *shed water* to move into the next project phase.

DEEP RESEARCH & WORKSHOP PREP

Karen conducted deeper research into seven local organisms and strategies. Information gathered during this research includes organism, function, the biology strategy story, mechanism, design principles, application idea, key Life's Principles, and references. Descriptions of each of these terms can be found on the first page of Appendix B, a template for How to Read a Local Genius Story (Appendix B). Karen and Mary then worked together to translate this biology into visuals. Mary created strategy and design principle illustrations, and developed worksheets for the Local Genius Stories to use in the design charrette as inspiration for design concepts (Appendix B).

Seven local species were studied in-depth to understand how they performed the three functions needed to inform the design solution.



LIFE'S PRINCIPLES

LIFE'S PRINCIPLES

Life's Principles represent the overarching deep patterns found among species surviving and thriving on earth. They are an important part of any Biomimicry project, used to set aspirational goals at the onset, as design principles to inspire sustainable innovations, and to evaluate the appropriateness of human-created designs. Because most other species embody all of these principles, they provide a lens into what the other 30 million species have in common and guidance on how we might better fit in.

To learn more about Life's Principles, visit B3.8's website: Biomimicry.net.

TRAININGS

Throughout the Boulder Genius of Place process, numerous opportunities were created for staff to engage in and understand the process to help advance the practice of Biomimicry within the organization. As described above, in late 2013 and early 2014, Lynne gave Biomimicry presentations to all interested OSMP work groups in order to educate staff about Biomimicry and to garner support for and involvement in the Genius of Place process. Through interviews and scoping meetings, OSMP staff were instrumental in the challenge selection and context definition process.

During the research phase, staff scientists participated in two brainstorming sessions and training in how to conduct biological research for Biomimicry. Some participated in the biology research itself. Finally, for anyone who planned to attend the design charrette (participants came from both within and outside of the organization), Lynne offered a one-hour Introduction to Biomimicry class and Marie taught a 2-day Life's Principles course that consisted of 3 class hours each day. Marie and Lynne offered each course three different times. The collective result of these trainings was that most design charrette participants had a solid introduction to Biomimicry and Life's Principles prior to the workshop. Additionally OSMP staff were able to identify how many local organisms embodied the various Life's Principles.

The patterns that emerged in design concepts during the workshop will guide the design of the new trail/road surface.

Design Charrette Participants Sharing Ideas

DESIGN CHARRETTE

On November 4, 2014, the project team led a full-day design charrette in Boulder, Colorado at the OSMP Annex. The purpose of the workshop was to share the Genius of Place process, create design concepts for the project, and to advance understanding of Biomimicry as an innovation approach. Forty-four designers, engineers, architects, trails specialists, educators, students and biologists attended the workshop.

Prior to the design charrette, Lynne divided the 44 attendees into 11 groups of 4 to distribute the disciplines and strengths represented. Five groups were tasked with generating biomimetic design concepts for a future road, three groups with generating concepts for a trail that would experience equestrian and pedestrian use, and three groups with generating concepts for a trail that would experience pedestrians and equestrian use and be wheelchair accessible (with some limitations). Each group was given a list of relevant design parameters (Appendix A).

RESULTS

DESIGN CHARRETTE OUTCOMES

Of the forty-four workshop participants, approximately two-thirds were OSMP staff, while the other one-third were primarily design professionals from outside of the organization. The mix of expertise from both inside and outside the organization led to fruitful cross-pollination of ideas and challenged the current paradigm in road and trail design. Involving so many OSMP staff in the process proved valuable, especially for those who would not otherwise be involved in a Biomimicry project.

The project team introduced the Genius of Place process, the challenge selected and design parameters, the story of Place, and shared the seven Local Genius Stories. This set the stage for participants to brainstorm design concepts inspired by nature, report out on their suite of application ideas, then further refine one design concept that incorporated at least one (but typically more than one) design principle and several Life's Principles. The OSMP videographer captured the design ideas presented by each group.

The final eleven design concepts were summarized (Appendix C) and the following patterns emerged:

- Combine modular and nested components by using modular designs that can be adjusted as necessary instead of monolithic surface applications
- Use hexagonal shapes to provide structure as a method of fitting form to function
- Discover "What does the water want to do?" as a way to direct flows using low energy processes. These included:
  - V-shaped channels to disperse water
  - Creation of a "stream bed" aside or within the path that acts as a ditch to direct flow
- Meander the trail to mimic natural flows and direct visitors and equipment along non-linear pathways
- Be locally attuned and responsive by using native plants with strong root structures to hold soil and enhance infiltration
- Be resource efficient by recycling all materials and reusing readily available local materials
- Use 'life-friendly' materials that result in no harmful by-products
- Use multi-functional design, meeting multiple needs with one elegant solution
- Cultivate cooperative relationships with visitors by inviting users to participate in road/trail upkeep and maintenance as a way to integrate development with growth as the trail/road use and needs evolve

NEXT STEPS

By 2016 OSMP hopes to incorporate Biomimicry language and concepts into the Request for Proposals for the target challenge, re-designing the former road into a trail and roadway with designs inspired by concepts from the charrette. The year 2017 is a potential target date for OSMP to engage a contractor to build this Biomimicry inspired trail/road. Simultaneously, OSMP will tell the story of the Genus of Place process, the 7 species studied for design inspiration, and the Biomimicry process in general to locals and visitors to OSMP lands.

American Black Bear *(Ursus americanus)* © Tevis Morrow

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ACKNOWLEDGEMENTS

Thank you to Mike Patton, Jim Reeder, Dave Kuntz and Lisa Dierauf for being OSMP visionaries who championed this innovative project from the beginning.

Without the dedicated involvement and encouragement from OSMP staff across the organization this project would not have succeeded. Their excitement, creativity and desire to be innovative were truly inspirational. Many brainstormed potential challenges then narrowed the list and helped with the detailed and complicated task of defining the context to make the final challenge choice. Others contributed to the bio-brainstorms and the species selection process for the Genius of Place study. Many brought their expertise to the design charrette, bringing critical information to the table and rounding out our dynamic teams, and others helped to manage the event logistics and record the results of the charrette.

We would like to thank all of the people who joined us from the larger Biomimicry inspired professional community, as their fresh perspectives and expertise were vital to the creative process.

Local scientists from University of Colorado and CSU graciously supplied answers and research documents about the species we studied, significantly contributing to the Genius of Place work.

This was truly a collaborative, community-wide team effort and our deep thanks go out to all who contributed to and inspired this process.

CONTACTS

If you'd like to learn more about the Boulder Genius of Place or have questions about how to do a Biomimicry project of your own, please feel free to contact one of us:

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Dwarf Lead Plant *(Amorpha nana)* © Bill May

APPENDIX A

DESIGN PARAMETERS

DESIGN PARAMETERS

The following design parameters were identified for the Bluebell Road challenge:

- The original road geometry does not need to be maintained, as long as the road surface supports all functions of the road
- The geometry of adjacent ditches will be determined by the road geometry
- Must use current location, length, and grade
- Depth of substrate can be altered
- Drainage
  - should be directed onto the upslope side of the road
  - into the road bed, or
  - down slope, only if design includes a fail-safe catchment (given private property situated down slope)
- Aesthetic considerations affecting materials choices
  - The materials and design should complement and not compete with the natural features surrounding the facility
  - Consider color and texture of materials
  - Native materials are ideal
  - The solution will not include asphalt or concrete
- Maintenance: goal is to minimize
- Current road is 20 feet wide, newer surface will be narrower leaving room for more sinuosity if desired
- No vehicle pull offs to maintain the trail-like feel
- Designs need not be uniform throughout
- The road can be built with different design parameters, such as:
  - Porous interior vs. hardened tracks for tires
  - Different portions of the road can have different solutions to deal with problems as they vary from place to place on the road
- Ability to accommodate 2-axle vehicle use (i.e. ambulance):
  - Typical 2-axle vehicle has wheel base: 8.5 feet
  - Weigh up to 36,000 pounds
  - Consider narrowest road base feasible with single lane, no pull offs: 9 feet
  - Shoulders on both sides of road: 2 feet each

Prior to the design charrette, the project had evolved to the point of considering design concepts for 1) a trail for pedestrian and equestrian use, and 2) a trail for pedestrian, equestrian, and wheelchair-accessible use. The following design parameters were identified for each:

1) Trail for pedestrian and equestrian use:

- Appropriate trail surfacing and durability for equestrian use
- Fit aesthetically with environment
- Minimum width: 3 feet

2) Trail for pedestrian, equestrian, and wheelchair-accessible use

- Trail surfacing smooth, firm and stable to accommodate wheelchairs and appropriate for horses
- Fit aesthetically with environment
- Minimum width: 5 feet

APPENDIX B

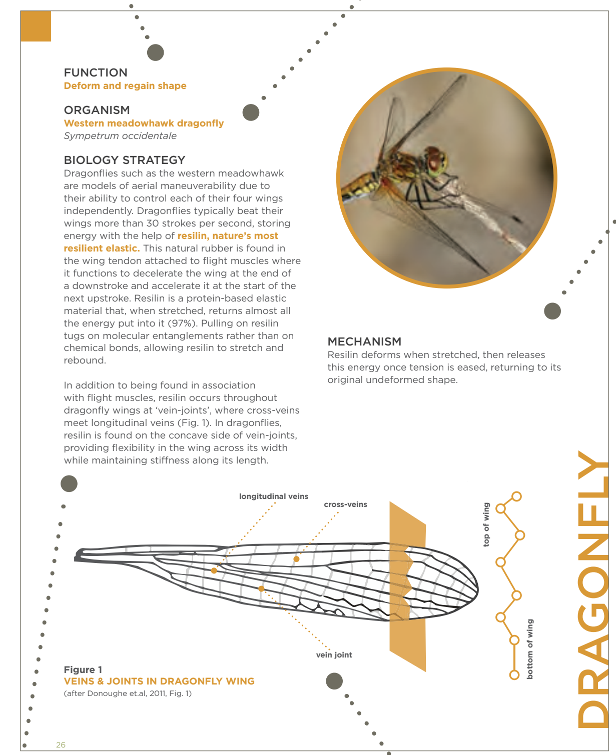
LOCAL GENIUS STORIES

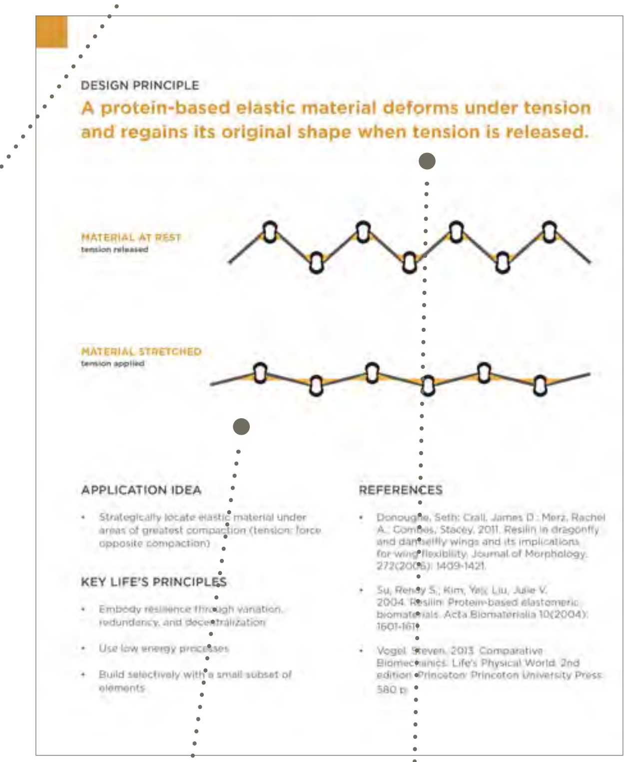
HOW TO READ A LOCAL GENIUS STORY

Function
Function describes what the organism or ecosystem does and what we want our design to do. Function is the bridge between biology and design.

Organism
The common and scientific name of the local genius.

Mechanism
How the strategy works, specifically. Mechanism is usually written as just 1-2 sentences.





Biology Strategy
This section tells the story of the biology strategy or adaptation used by the organism to achieve the function. The story is a translation of biological research, often times as reported in the primary literature, into words that can be understood by a non-biologist.

Strategy Illustration
A diagram or illustration to support the Biology Strategy.

Design Principle Illustration
The illustration supports the written design principle and facilitates application of it in design.

Design Principle
The idea or underlying principle of the biology strategy, stated without reference to the biology. The design principle is succinct, usually written as just one sentence, and is what we emulate in design, what we use to generate biomimetic design concepts.

FUNCTION
Deform and regain shape

ORGANISM
Western meadowhawk dragonfly
Sympetrum occidentale

BIOLOGY STRATEGY

Dragonflies such as the western meadowhawk are models of aerial maneuverability due to their ability to control each of their four wings independently. Dragonflies typically beat their wings more than 30 strokes per second, storing energy with the help of **resilin, nature's most resilient elastic.** This natural rubber is found in the wing tendon attached to flight muscles where it functions to decelerate the wing at the end of a downstroke and accelerate it at the start of the next upstroke. Resilin is a protein-based elastic material that, when stretched, returns almost all the energy put into it (97%). Pulling on resilin tugs on molecular entanglements rather than on chemical bonds, allowing resilin to stretch and rebound.

In addition to being found in association with flight muscles, resilin occurs throughout dragonfly wings at 'vein-joints', where cross-veins meet longitudinal veins (Fig. 1). In dragonflies, resilin is found on the concave side of vein-joints, providing flexibility in the wing across its width while maintaining stiffness along its length.

MECHANISM

Resilin deforms when stretched, then releases this energy once tension is eased, returning to its original undeformed shape.

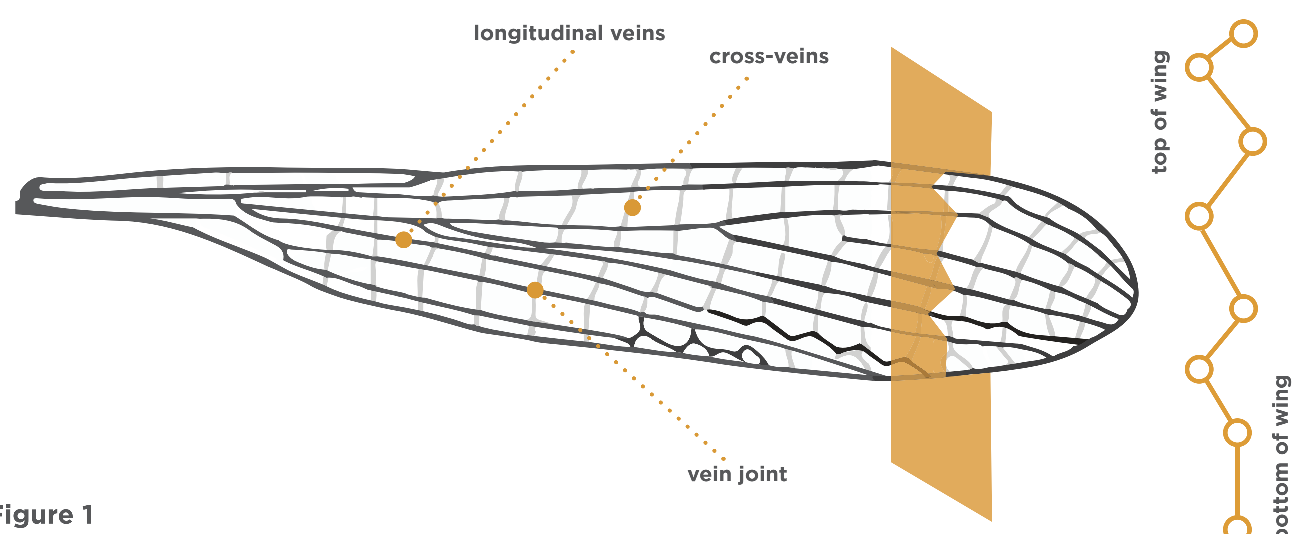
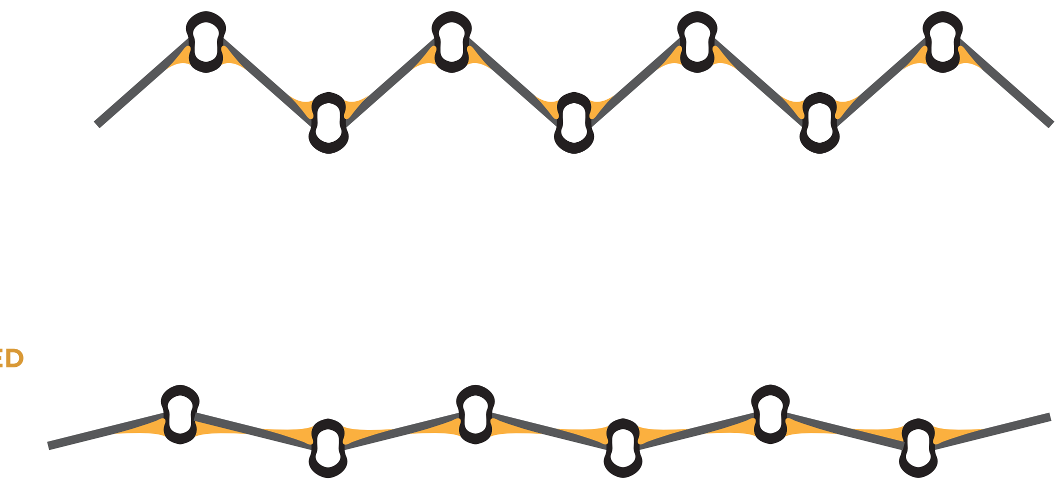


Figure 1
VEINS & JOINTS IN DRAGONFLY WING
(after Donoughe et.al, 2011, Fig. 1)

DRAGONFLY

DESIGN PRINCIPLE

A protein-based elastic material deforms under tension and regains its original shape when tension is released.



APPLICATION IDEA

- Strategically locate elastic material under areas of greatest compaction (tension: force opposite compaction)

KEY LIFE'S PRINCIPLES

- Embody resilience through variation, redundancy, and decentralization
- Use low energy processes
- Build selectively with a small subset of elements

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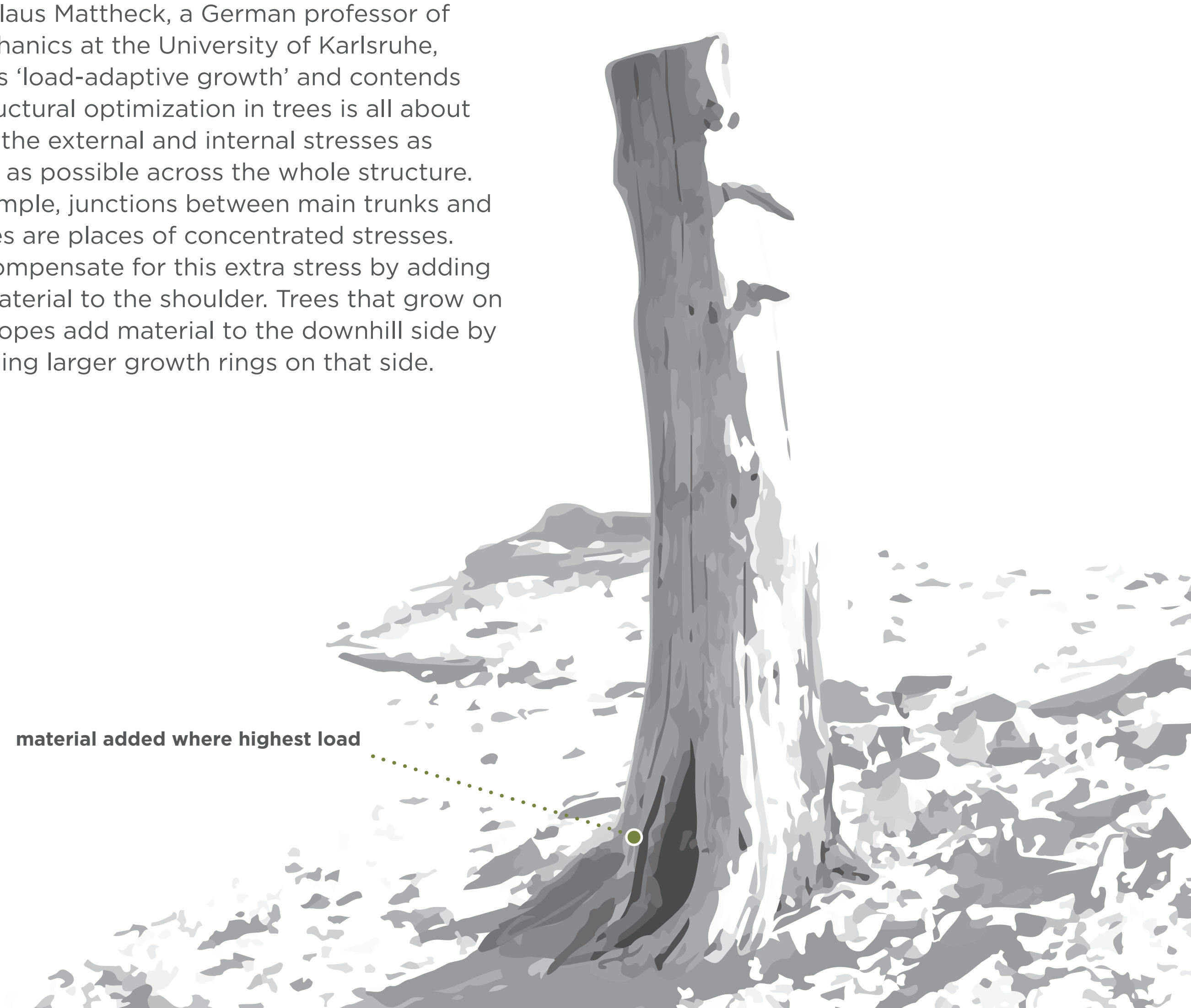
FUNCTION
Uniformly distribute stress

ORGANISM
Ponderosa pine
Pinus ponderosa var. scopulorum

BIOLOGY STRATEGY
Ponderosa pine trees grow throughout the Colorado Front Range from the border of the prairie and foothills, up to 10,000 ft elevation, depending on topography. Along the Front, 300-500 year old trees are frequent, a testament to their ability to withstand many forces, including those generated by fire, wind, snow loading, and steep slopes. Trees react to these external stresses and internal damage by adding wood at mechanically weak points.

To distribute stress uniformly, trees such as ponderosa pine add wood at points of greatest mechanical load. **The biological method of shape optimization is simple: at places of higher load, extra material is grown, i.e. thicker tree rings.** Claus Mattheck, a German professor of Biomechanics at the University of Karlsruhe, calls this 'load-adaptive growth' and contends that structural optimization in trees is all about making the external and internal stresses as uniform as possible across the whole structure. For example, junctions between main trunks and branches are places of concentrated stresses. Trees compensate for this extra stress by adding more material to the shoulder. Trees that grow on steep slopes add material to the downhill side by developing larger growth rings on that side.

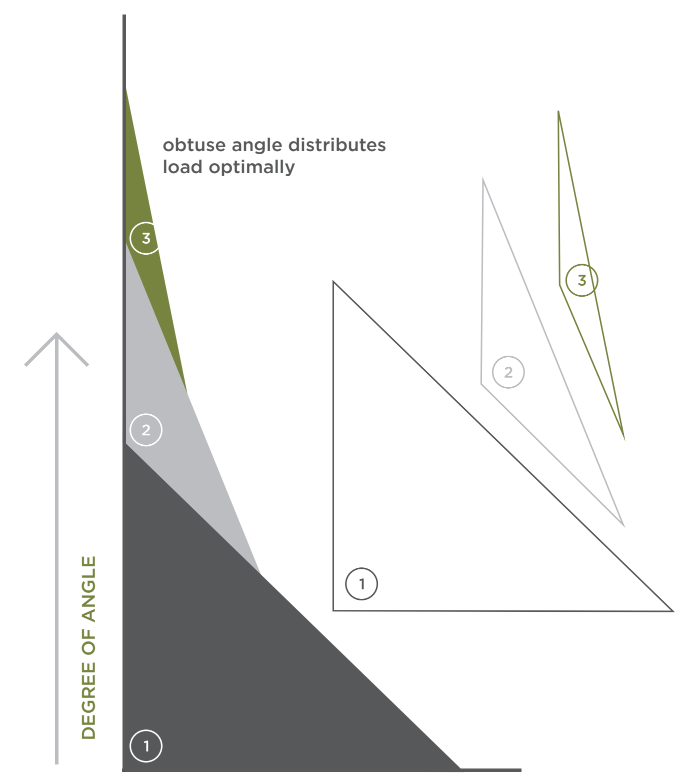
MECHANISM
To distribute stress uniformly, trees add wood (grow thicker rings) at points of greatest mechanical load.



PONDEROSA PINE

DESIGN PRINCIPLE
Add material at points of greatest mechanical load to uniformly distribute stress.

APPLICATION IDEA
- If there is compression on road and tension on road edge, obtuse angle from road to ditch optimally distributes load (after Mattheck, 2006, Figures 5-7).



KEY LIFE'S PRINCIPLES
- Be resource efficient
- Use life-friendly chemistry
- Be locally attuned and responsive

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FUNCTION
Waterproof

ORGANISM
American dipper
Cinclus mexicanus

BIOLOGY STRATEGY

Lured by an abundance of aquatic insects, the American dipper (water ouzel) has developed the amazing ability to walk underwater as it forages among the rocks in search of food. This ability to dive underwater in streams is unique among songbirds and is thanks to the dipper's compact bones that are not hollow like most other birds, the ability to close ear and nose openings, and a rich production of 'preen waxes' from a well-developed preen gland to shed water off their feathers.

Surface coatings of wax to achieve water repellency are a deep pattern seen across many species, from plants and beaver, to amphibians and birds. Dippers are equipped with large preen glands (at least ten times larger than those found in other songbirds) that produce the wax needed for frequent rewaterproofing. A study of the wax composition found it to be unusually homogeneous, consisting of only two components comprised purely of carbon, hydrogen, and oxygen.

Preen waxes are a multi-functional design. Besides waterproofing, they keep feathers flexible and moist to prevent them from drying out and becoming brittle, deter bacteria and fungi, moisturize the bird's bill, and in the presence of sunlight turn into Vitamin D!

Photo © Bill Schmoker

MECHANISM

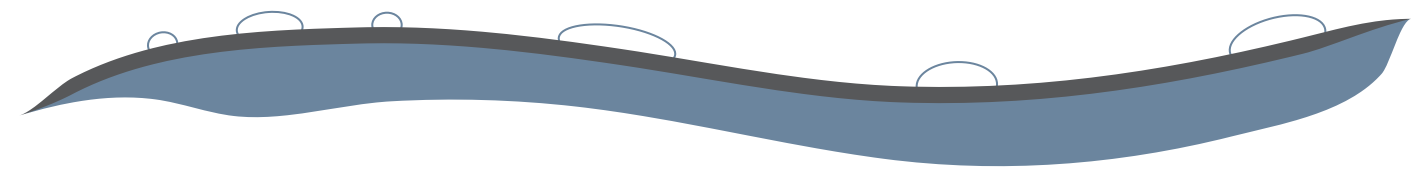
Dippers waterproof feathers by applying a surface coating of preen waxes from a well-developed preen gland.

surface coating of wax waterproofs feathers

AMERICAN DIPPER

DESIGN PRINCIPLE

A surface coating of wax sheds water.



APPLICATION IDEA

- Apply surface coating of life-friendly wax to parts of road where waterproofing desirable.
- Vary location of shedding water (into ditch or other desired location) and allow for infiltration in the road itself to reduce the volume of water ditch must convey and to restore part of function lost by presence of road that is found in surrounding landscape.

KEY LIFE'S PRINCIPLES

- Life-friendly chemistry
- Multi-functional design
- Use feedback loops

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SOAPWEED YUCCA

FUNCTION
Direct water

ORGANISM
Soapweed yucca
Yucca glauca

BIOLOGY STRATEGY
Soapweed yucca is a native perennial plant in the Agave family found throughout the Great Plains and central United States, mainly on dry soils. For more than 40 million years yucca plants and yucca moths have had a cooperative relationship, so important that neither can survive without the other. The moth's larvae depend on yucca seeds for food, and the yucca plant can only be pollinated by the yucca moth.

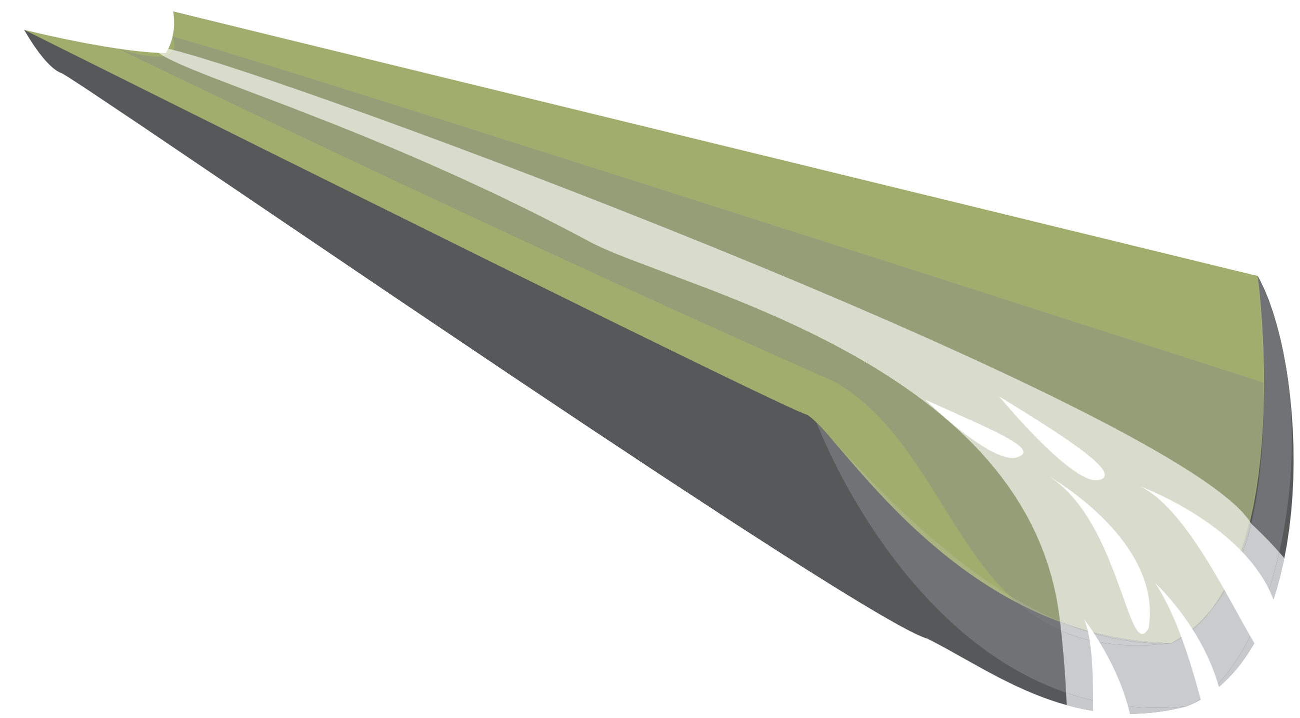
Collectively, the leaves on an individual plant form a rosette, a circular arrangement of leaves that meet in the middle. Yucca leaves are stiff, one to three feet long, and approximately ½ inch wide, tapering toward the tip to a sharp point. When viewed in cross-section (Fig 1), each leaf is shaped like a crescent moon creating a concave channel.

The combination of leaf shape and rosette morphology allow yucca to collect water during a rainstorm and divert it to its base. This water interception across a broad area also reduces runoff. The root system, including a deep taproot, is well-adapted to store water, quickly consuming the rainfall that the leaf structure directs toward the center of the rosette. Although the concave channel shape and circular arrangement of leaves in yuccas is used to collect water, this shape-based principle can also be used to divert or direct water where desired.

MECHANISM
Yuccas are adapted to collect water using leaves shaped in concave channels and a circular arrangement of these leaves that divert water to their bases.

Figure 1
YUCCA LEAF CROSS-SECTION

DESIGN PRINCIPLE
Rounded concave channel directs water where needed.



APPLICATION IDEA
- Divert water from road using shape: dispersed interception channels funnel water into ditch or other desired location

KEY LIFE'S PRINCIPLES
- Fit form to function
- Leverage Cyclic Processes
- Cultivate cooperative relationships

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PLEASING FUNGUS BEETLE

FUNCTION
Repel water

ORGANISM
Pleasing fungus beetle (chitin)
Gibbifer californicus

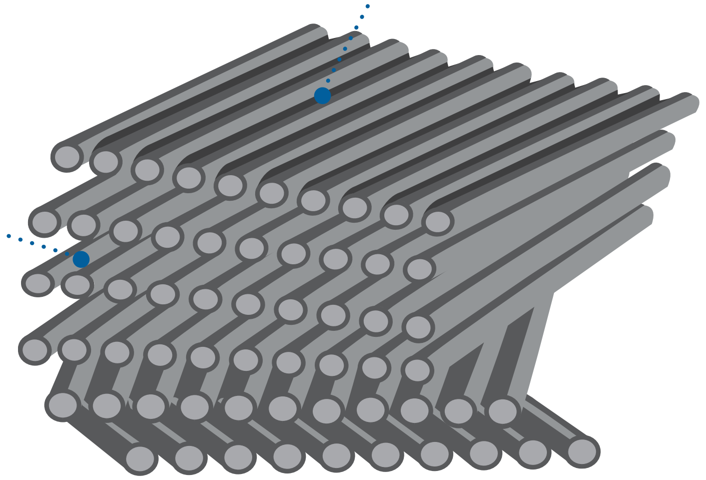
BIOLOGY STRATEGY
The pleasing fungus beetle is found locally in stands of ponderosa pine and aspen, especially near bracket fungi that grow on rotting logs. Here, adult beetles lay their eggs and once hatched, the larvae feast on the bracket fungi. Adult beetles are shiny black with blue or purple elytra (hardened wing covers) with black dots. This shiny cuticle or exoskeleton is waterproof thanks to the components of this natural composite.

In beetles, chitin is a tough, flexible component of a complex matrix of materials that create a passive physical surface barrier to water. As such, insects rely on their chitinous cuticle to resist desiccation. Chitin is composed primarily of polysaccharide fibers (bonded sugar molecules much like cellulose in wood) in a protein matrix. These fibers are stacked, with each layer slightly rotated relative to the orientation of the underlying layer, much like plywood (Fig 1). This fiber-protein complex holds a very thin waterproofing waxy lipid layer, less than 0.2 microns thick, that is secreted onto and integrated with the complex to ensure a water balance is achieved.

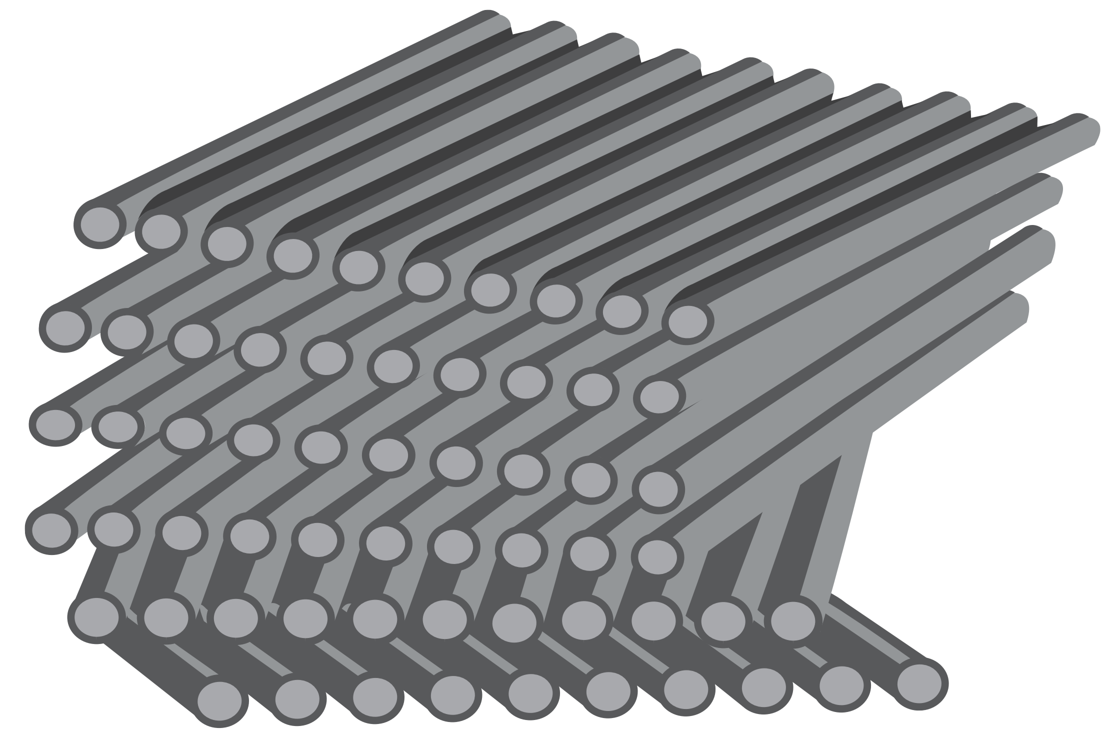
Photo: Kati Fleming, 2009 | Wikipedia Commons

MECHANISM
Stacked chitin fibers, each layer slightly rotated relative to the underlying layer, in a protein matrix holds a thin waterproof waxy lipid layer, less than 0.2 microns thick, to achieve an effective water balance within the insect.

Figure 1
FIBER ORIENTATION & WAX LOCATION IN CHITIN



DESIGN PRINCIPLE
Layers of fibers oriented at slightly different angles in a protein matrix hold a thin waxy lipid layer that collectively creates a physical surface barrier to water.



APPLICATION IDEA

- Explore creation of 'complexes' with fiber orientation into which waterproofing lipid layer might be integrated.

KEY LIFE'S PRINCIPLES

- Use readily available materials and energy
- Build selectively with a small subset of elements
- Fit form to function

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NORTHERN PAPER WASP

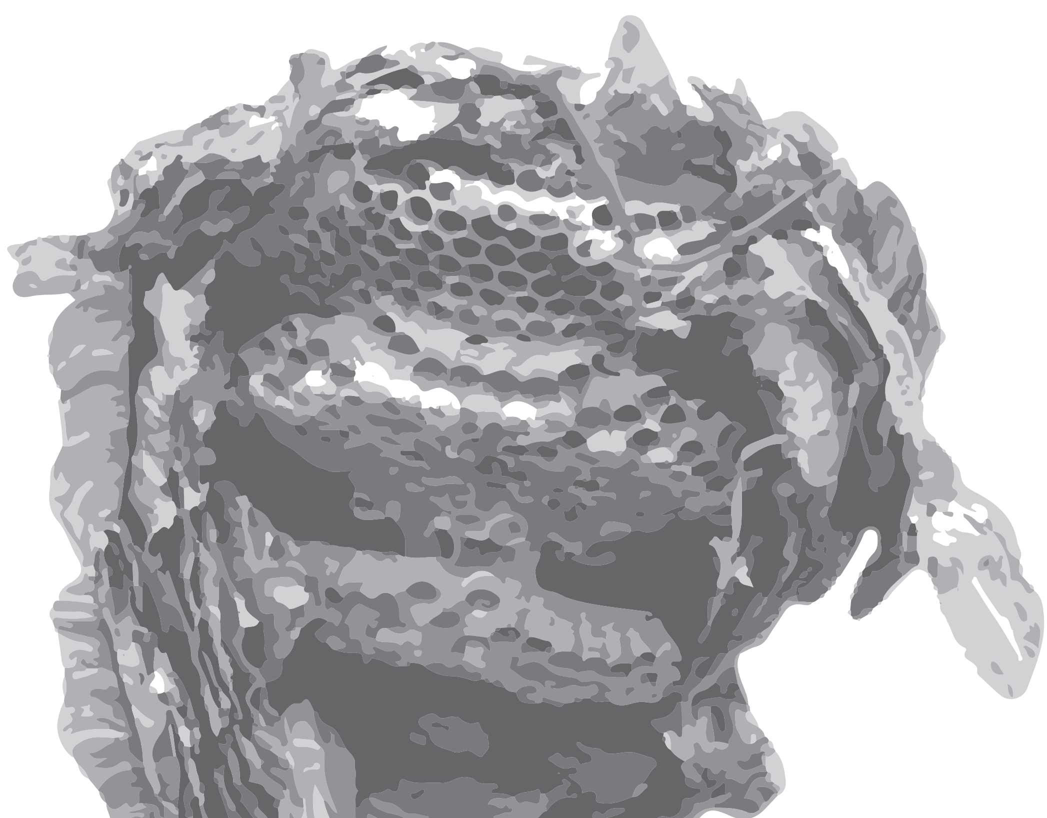
FUNCTION
Provide strength

ORGANISM
Northern paper wasp
Polistes fuscatus

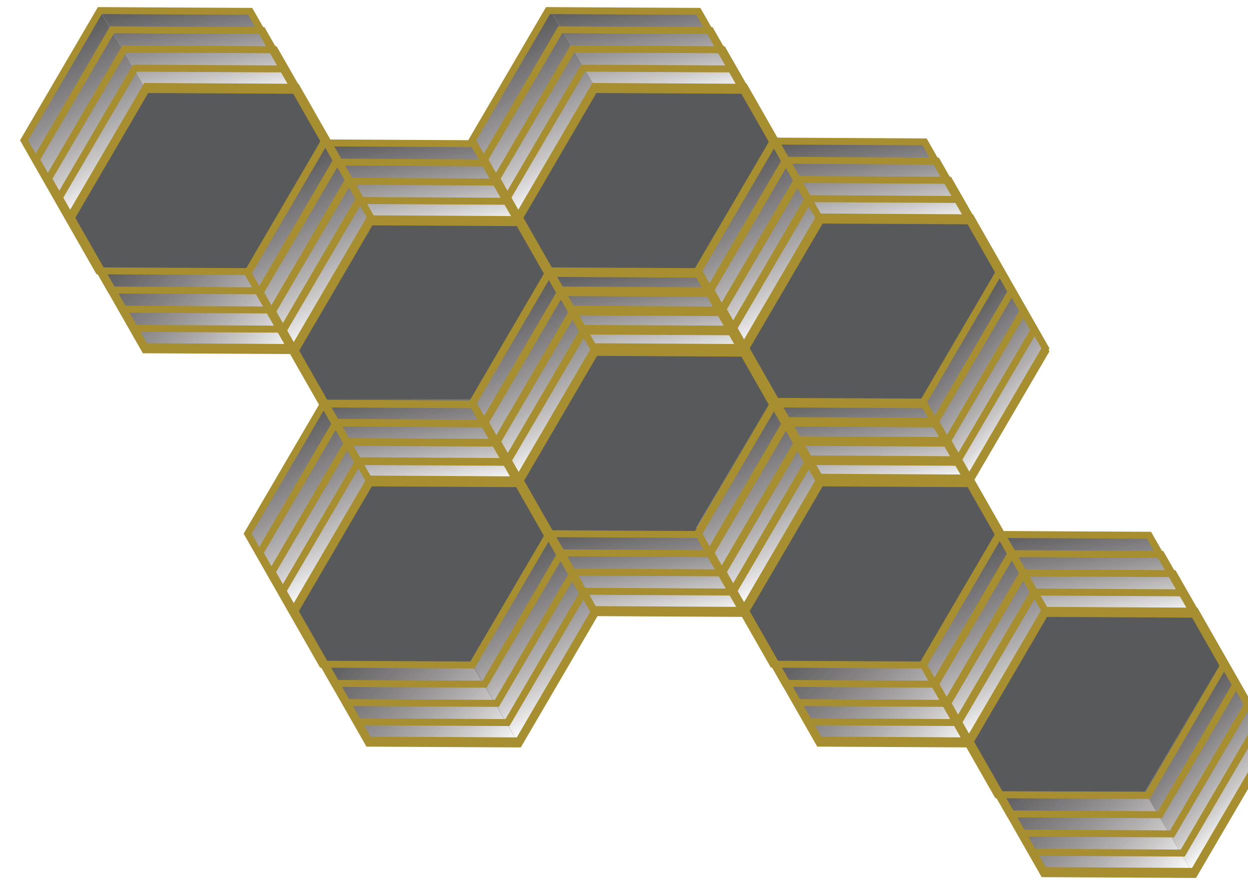
BIOLOGY STRATEGY
Wasps of the genus *Polistes* are the most common type of paper wasp in North America, known for their hanging nests. By scraping and chewing wood into a pasty pulp, wasps build paper-like nests which they hang in protected places. The recycled cellulose is mixed with sticky saliva that is water-proof, making the nest water repellent and strong. But a large part of the nest's strength is attributed to the use of hexagons and parallel fibers.

Inside the drooping dome of the nest, paper wasps create hexagonal cells in which eggs, and later pupae, mature. **The hexagonal tubes are surprisingly strong since the fibers are arranged in a parallel pattern. In addition, the modular hexagonal comb shape utilizes 120° angles, creating an extremely strong structure while minimizing material use (high strength-to-weight ratio).** Honeybees take this a step further in the structure of their vertical combs: two cell layers back-to-back with a half cell width shift in the position create a three-dimensional pyramidal structure with extraordinary strength.

MECHANISM
The hexagonal shape of honeycombs uses 120° angles that minimize material use while providing exceptional strength. Fibers oriented parallel to each other enhances this strength.



DESIGN PRINCIPLE
Hexagonal shape and parallel material orientation provide strength and minimize material use.



APPLICATION IDEA

- Utilize hexagonal pattern with parallel layers of material making up the frame for strength and to minimize material use. Could be applied to frame/structure for areas of infiltration or compaction.

KEY LIFE'S PRINCIPLES

- Combine modular and nested
- Use readily available materials and energy
- Build from the bottom up

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ROCKY MOUNTAIN ELK

FUNCTION
Minimize deformation under stress; regain original shape

ORGANISM
Rocky Mountain Elk (bone)
Cervus canadensis nelsoni

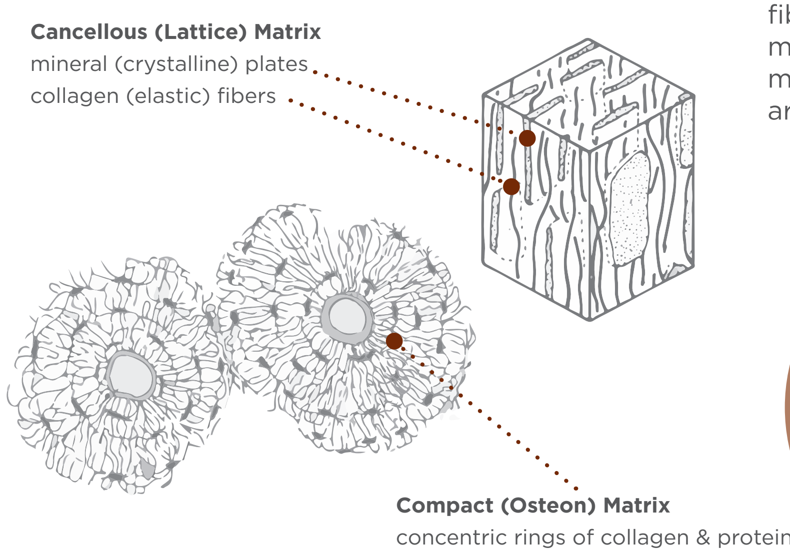
BIOLOGY STRATEGY
Bone is a strong ‘rigid material’, a composite that responds to stresses with only minimal deformation. Bone has greater compressive strength and higher work of fracture (resistance to cracking) than concrete. Evolutionarily, the invention of bone provided fitness for large body size, as found in large mammals such as the Rocky Mountain Elk. Within a single long bone such as a femur, there are two types of bone tissue: cancellous and compact bone. The complex structure of these two types of bone give them strength, light weight, and some flexibility.

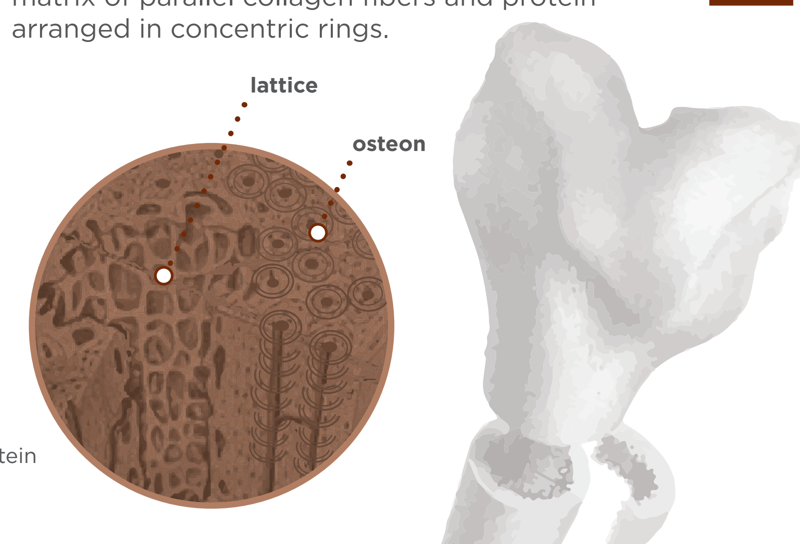
Cancellous bone is a **spongy composite lattice material** known as trabeculae (“little beams”) that makes up 80% of mammalian bone. It is typically found at the ends and in the core of long bones, and has two main constituents. **Small inorganic crystals of phosphate, calcium, and hydroxyl ions make up ~50% of the volume. These tiny, brittle crystals are interspersed with neat layers of elastic collagen fibers, the other ~50%, in a protein matrix.** The continuous alternation between brittle and elastic material makes it fracture resistant. Studies of the latticework geometry in terrestrial mammals and birds have found that bone volume does not scale with size, but trabeculae in larger animals’ femurs are thicker, further apart and fewer per unit volume than in smaller animals, increasing the larger animals’ ability to withstand loads.

Photo: Daniel Mayer, 2011 | Wikipedia Commons

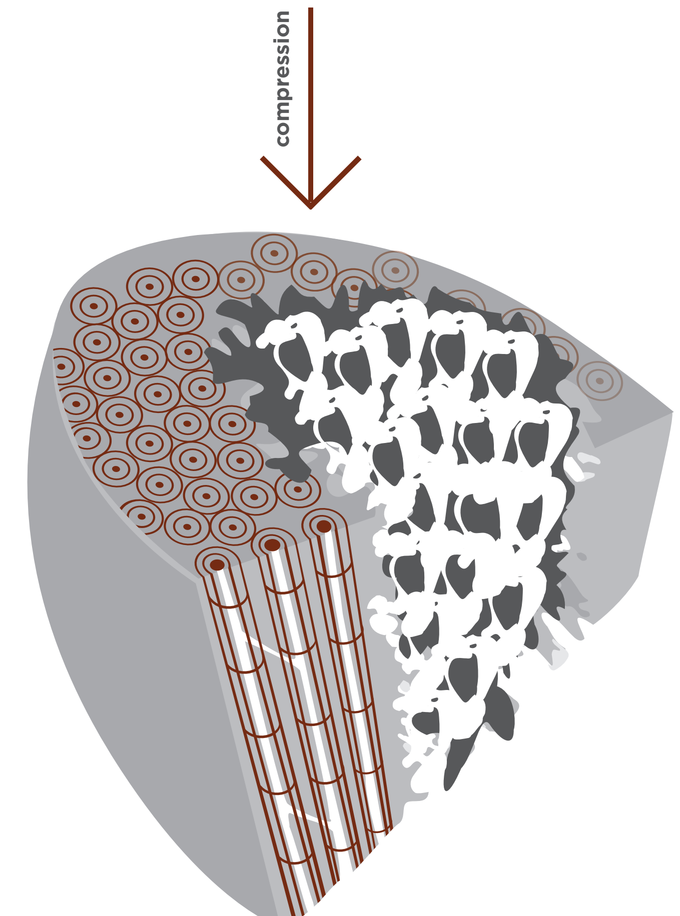
Compact bone forms the outer shell of most bones, is harder, stronger and stiffer than cancellous bone, and makes up 20% of the skeleton, but 80% of its weight. As such, it is much denser than cancellous bone and performs the key function of mechanical support. The structural unit of compact bone is the osteon. **Each osteon consists of a calcified matrix of parallel collagen fibers and protein arranged in concentric rings, typically several millimeters long and ~0.2mm in diameter, surrounding an open canal where blood vessels and nerves pass.**

MECHANISM
Outer layer of compact bone and inner layer of cancellous bone experiences minimal deformation under loads then regains its shape. Cancellous bone is a spongy composite lattice material made of parallel layers of elastic collagen fibers and brittle inorganic crystals in a protein matrix. Compact bone consists of a calcified matrix of parallel collagen fibers and protein arranged in concentric rings.





DESIGN PRINCIPLE
Composite lattice material (made of alternating crystalline and elastic components) surrounded by a harder material (composed of concentric rings of a calcified matrix of parallel elastic fibers) resists compression.



APPLICATION IDEA
- Mineralized fibers as construction element for road that handles shear and compressional stresses.

KEY LIFE’S PRINCIPLES
- Use life-friendly chemistry
- Fit form to function
- Replicate strategies that work

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APPENDIX C

DESIGN CONCEPTS FROM DESIGN CHARRETTE GROUPS

DESIGN CONCEPTS FOR A PEDESTRIAN/ EQUESTRIAN TRAIL AND ROAD

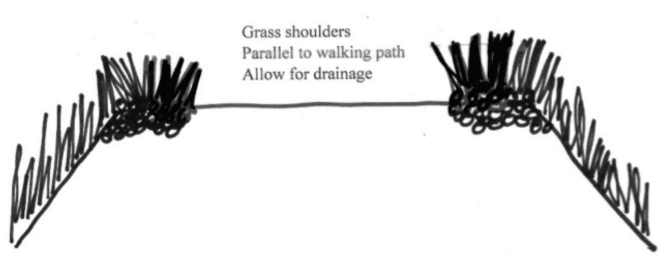
TEAM 1

Team Participants
Kelly Wasserbach, OSMP Engineering Manager
Kaitlyn Merriman, OSMP Educator
Lynn Riedel, OSMP Prairie Ecologist
Greg Varhola, Graphic Designer

Team Task
Design concepts for a trail that will experience equestrian and pedestrian use, and allow for the passage of a double axel vehicle.

Inspiration
Our team began by thinking about an elephant walking along the path because this was comparable to a vehicle. When something large goes through nature, natural vegetation is maintained around the path that the animal travels down.

Design Idea, Road Area
Try to maintain a grassy area for as much of the road surface as possible. Create grass-lined shoulders that come into the road area, with necessary areas of drainage underneath. Allow for a wide enough area so that the slope maintains stability. Drive a vehicle on the grass areas and place a pedestrian trail in the middle. Inspired by how the yucca sheds water, build a U-shaped wheel track to channel the flow and keep the tires on this area and not on the pathway. Could use wax on the surface to direct water, but this has potential to affect grass growth and lower drainage. Deter water below the surface.



Meander the road within the 20' existing surface to slow water flows and provide a more interesting walking experience. Start off with a seed mixture that will grow quickly (Gum Weed for early succession) mixed with a strong root system plant for long term stability. The reason why some grasses can survive within the operating conditions of this ecosystem is there is a clay layer below that slows infiltration, and creates a higher water table so the plants have access to more water. So lower the "waxy layer" and direct water below the surface.

Drainage: With thoughts of the recent flood, drainage is on our minds. Beefing up the sides of the road using design ideas from the tree (place more material in areas of increased stress). The area right around the loop is where the road needs the most stabilization. Beef this up with both extra material and drainage via check dams.

Additional thoughts: Are we really trying to fit in with nature? Have we really taken the time to understand how organisms use this place, where they are traveling? If we want to selectively seed a trail, identify the organisms' travel paths first so that migration routes are preserved.

Pedestrian Path Design Ideas
Inspiration: A lot of structures in the ecosystem have a lattice design, providing strength within a minimal structure.

For the pedestrian walking area use a lattice sub base with finer substrate. Slow down and drain water flow and use different substrates to drain at different rates. Use a honeycomb design so that it will still drain and retain strength. Use bark mixed with gravel in this area so it would have the springiness of bark, but also the drainage of rock. Since bark does not last long, it might be better to find an alternative (something that is life-friendly chemistry).

TEAM 2

Team Participants
Doug Beal, Architect
Laurel Reisman, OSMP Trails
Chris Wanner, OSMP Forest Ecologist
Dustin Allard, OSMP Graphics

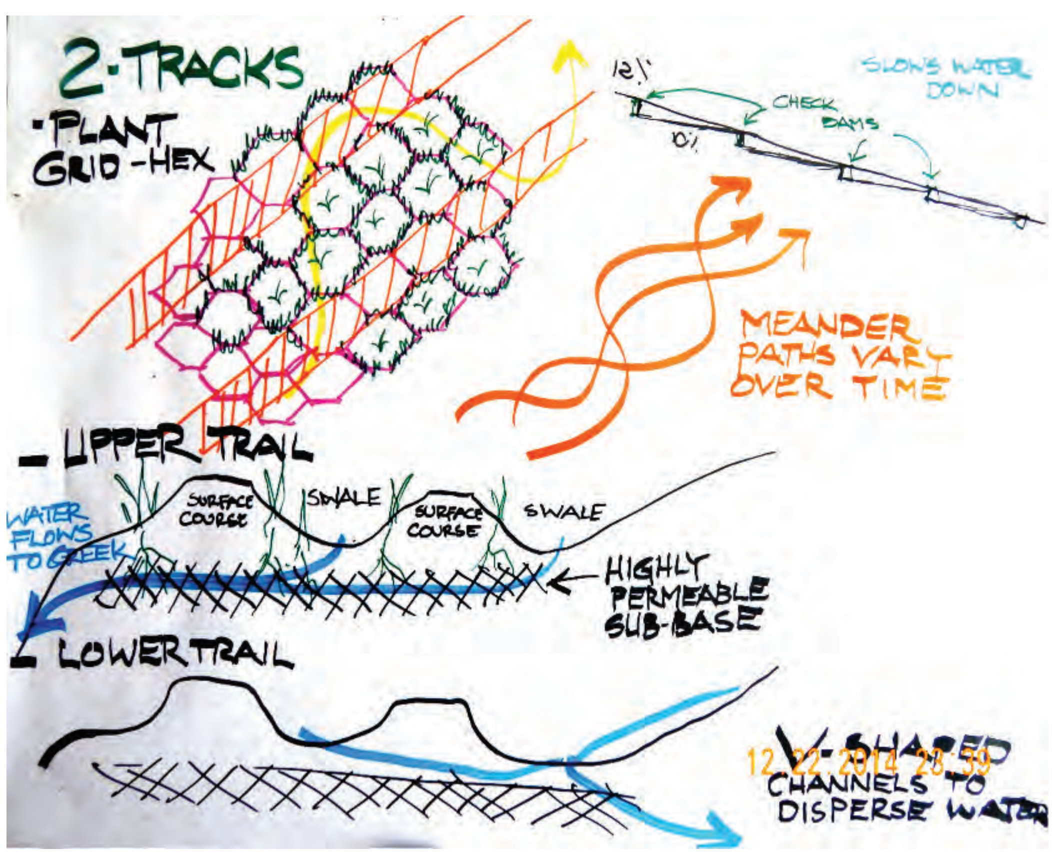
Team Task
Design concepts for a trail that will experience equestrian and pedestrian use, and allow for the passage of a double axel vehicle.

Vehicle Track
The two vehicle tracks are placed along the sides of the existing road and are U-shaped to allow for water drainage. With this structure, the water would come down the road, and be channeled to underneath the U-shaped vehicle tracks. Swales in the road are constructed with a higher surface course with a highly permeable sub-base to allow for infiltration of water. Check dams down the center of the swale would continually slow down the water and allow for infiltration.

Near the cottage area recreate the ditch following the lines of topography and direct this water to the meadow area.

Pedestrian Walkway
This walkway is placed in the center of the pathway and meanders so that the path varies over time. This design allows for human foot traffic to create social trails within a set boundary. To stabilize the area, use biodegradable hexagon shaped structures and selectively seed these areas to allow for native vegetation to form within and overtime self-organize into a shape that allows for water catchment in the center.

Use local materials for this project, including native vegetation and root structure for stabilization.



TEAM 3

Team Participants
Heather Boaz, US Forest Service, Engineer
Chelsea Taylor, OSMP Trails
Greg Hill, CU Student
Dave Sutherland, OSMP Education

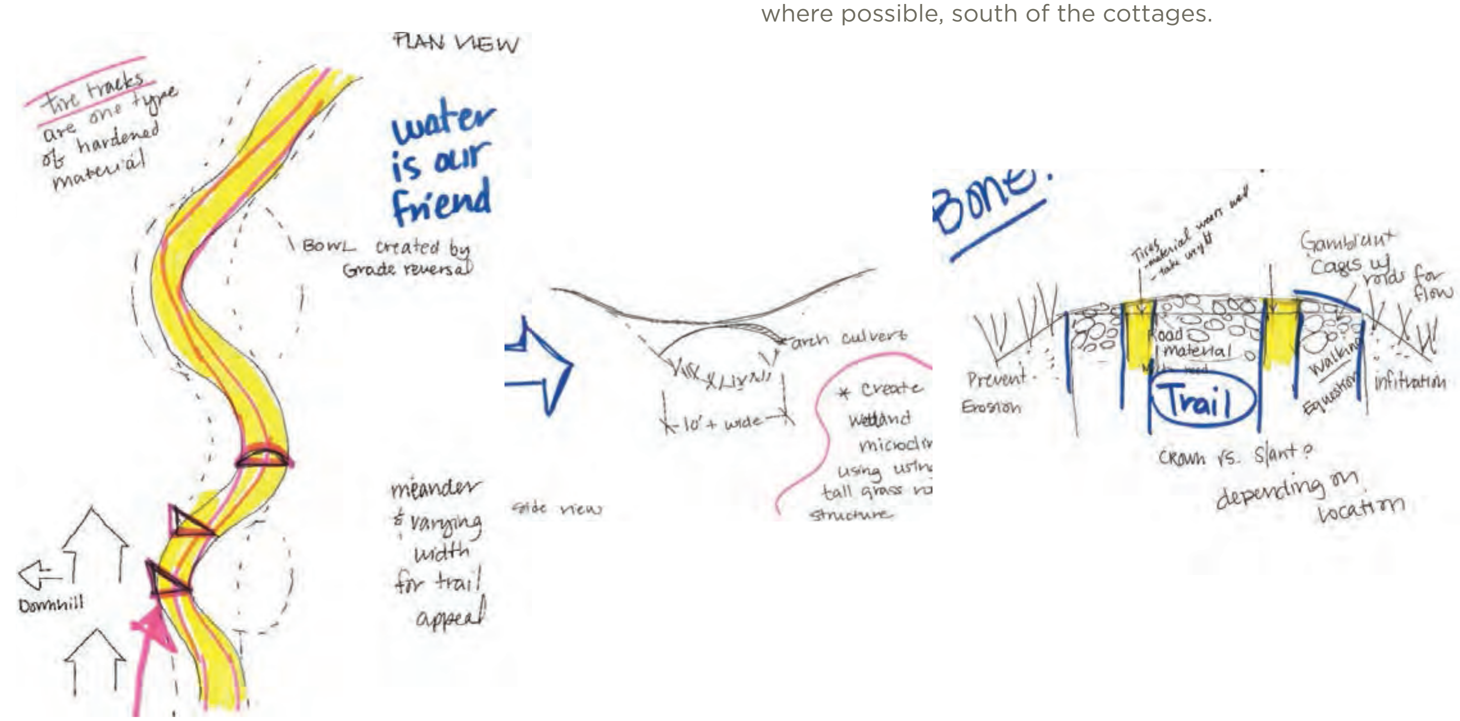
Team Task
Design concepts for a trail that will experience equestrian and pedestrian use, and allow for the passage of a double axel vehicle.

Inspiration
Water is our friend, let's embrace it. How does nature prepare pathways? What kind of natural pathways exist? In nature, roads don't exist and organisms use micro-pathways between areas, not highways. We got inspiration from a river: it meanders as it travels through the ecosystem and varies its width depending upon conditions.

Design Ideas
Meandering trail/road as seen in the plan view, but also grade reversal areas that create a wetlands micro-climate to infiltrate water and soak up large rain events. Tall grasses create dense root structure and create strength. There were areas during the 2013 flood where asphalt was washed away and plant roots were able to keep soil structures in place.

Hardened surface designed for the tire tracks, with the rest using gabion cages which allow for structure, flexibility and space for roots to form within the spaces. These cages also provide a strong surface that can accept a lot of stress from vehicle traffic. Build out of chain-link and fill with rocks. Use different road materials for different uses, vehicle, pedestrian, and infiltration.

Slope of road area: Some parts of the road will have traditional surface slopes. For the roadway adjacent to the cottages use the trail shape to direct water flow towards the meadow. Upslope, develop a small ditch to intercept water before it gets to the road. Direct runoff from the road into Bluebell Creek where possible, south of the cottages.



TEAM 4

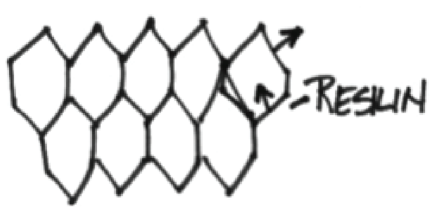
Team Participants
Jake Cseke, OSMP GIS
Ryan Grabowski, OSMP Trails
Mary Wagner, Graphic Designer

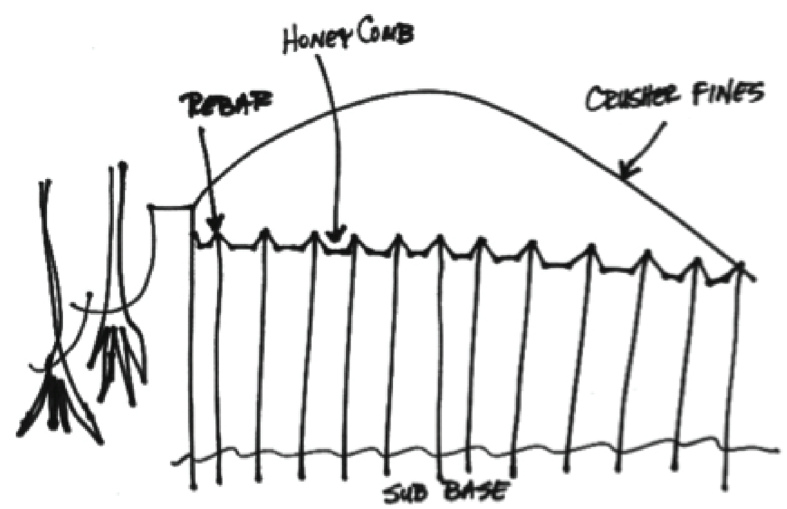
Team Task
Design concepts for a trail that will experience equestrian and pedestrian use, and allow for the passage of a double axel vehicle.

Design Ideas
Use crusher fines for the top layer of the road surface. The sub-layer would be excavated down 2 feet and consist of a sub-base constructed of rebar (vertical lines on drawing) or other strong material. A layer of honeycomb structure is placed on top of the sub-base and filled with crusher fines. This material allows for flexibility. The honey comb is both rigid and strong, like resilin and will allow water to pass through. This sub- base also serves as a stabilizing layer to hold the road in place. If a large amount of water hits the road surface, the crusher fines may be washed away, but can be easily replaced.

Additional drainage is designed into the side of the road area. Especially near the cottages. A multi-tiered drainage system is developed through a series of swales. If one swale fails, there are others to perform the function of slowing the water down to allow it to infiltrate. Plant shrubs, trees and grasses in these channels to assist with infiltration and to provide privacy for the cottage residents.

The road width would remain at 20 feet in front of the cottages and tapper to 15 feet as it goes up the hill. This will allow more of a trail feel.





TEAM 5

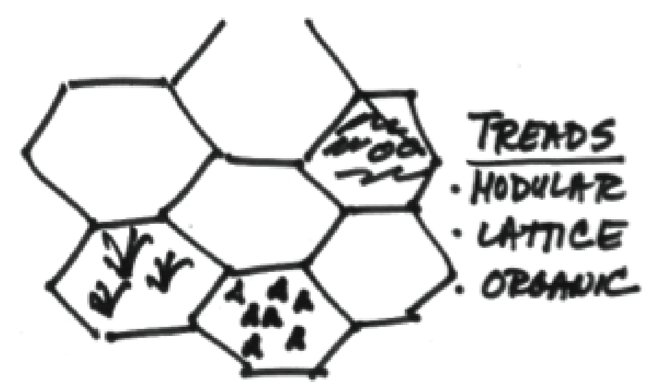
Team Participants
Neal Dawes, Trails Designer
Kelly Simmons, CU Permaculture
Heather Swanson, OSMP Wildlife Ecologist
Taylor Embury, Clean Energy Analyst

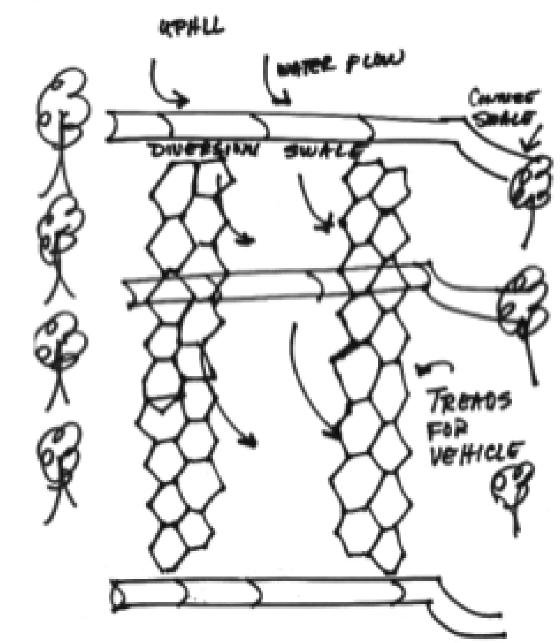
Team Task
Design concepts for a trail that will experience equestrian and pedestrian use, and allow for the passage of a double axel vehicle.

Top Recommendation
Minimize use of road or rehabilitate into a trail only, removing the road structure altogether. To do so, switch to composting toilets, remove trash cans and designate ambulance parking behind Chautauqua as alternatives to the existing road uses.

Design Ideas for Road/Trail
Narrow the trail from 20 feet to 12 feet. Use the 8 foot buffer on the side for plants and a channel to slow water flow. Place diversion swales on the road – like a small berm that captures water as it flows down and direct this water to a contour swale in order to spread it out and soak it into the meadow area. Plant trees along this area to create habitat, provide shade and increase infiltration. Minimize the amount of embodied energy in the materials used. Beetle kill trees as diversion swales, cobblestones for the pathway.

Modular Design
The road should consist of modular units that can be replaced or repaired as needed. Keep road as two treads for the tires. Nature builds using modular and nested components, not as one monolith. Items that are repairable can be repaired routinely and the design can be replaced if one item does not work in this context. Construct these modular units out of a honeycomb design for strength and durability. Combine these components to embrace the organic side of design. When you have a diverse set of materials that can be changed over time you are able to mix and vary the trail, it becomes a living laboratory and could embrace trail users to assist with the repair. The road can be split up into different parts, field testing different types of materials and designs. Around the cottage area, place a sink to capture water. Design different infiltration conditions into different parts of the road based on need in the area.





DESIGN CONCEPTS FOR A PEDESTRIAN/ EQUESTRIAN TRAIL

TEAM 6

Team Participants
Marianne Giolitto, OSMP Wetland Ecologist
Frances Boulding, OSMP Trails
Courtney Young, CU Student
Jennifer Schill, Designer, Ask Nature.Org

Team Task
Design concepts for a trail designed for equestrian and pedestrian use.

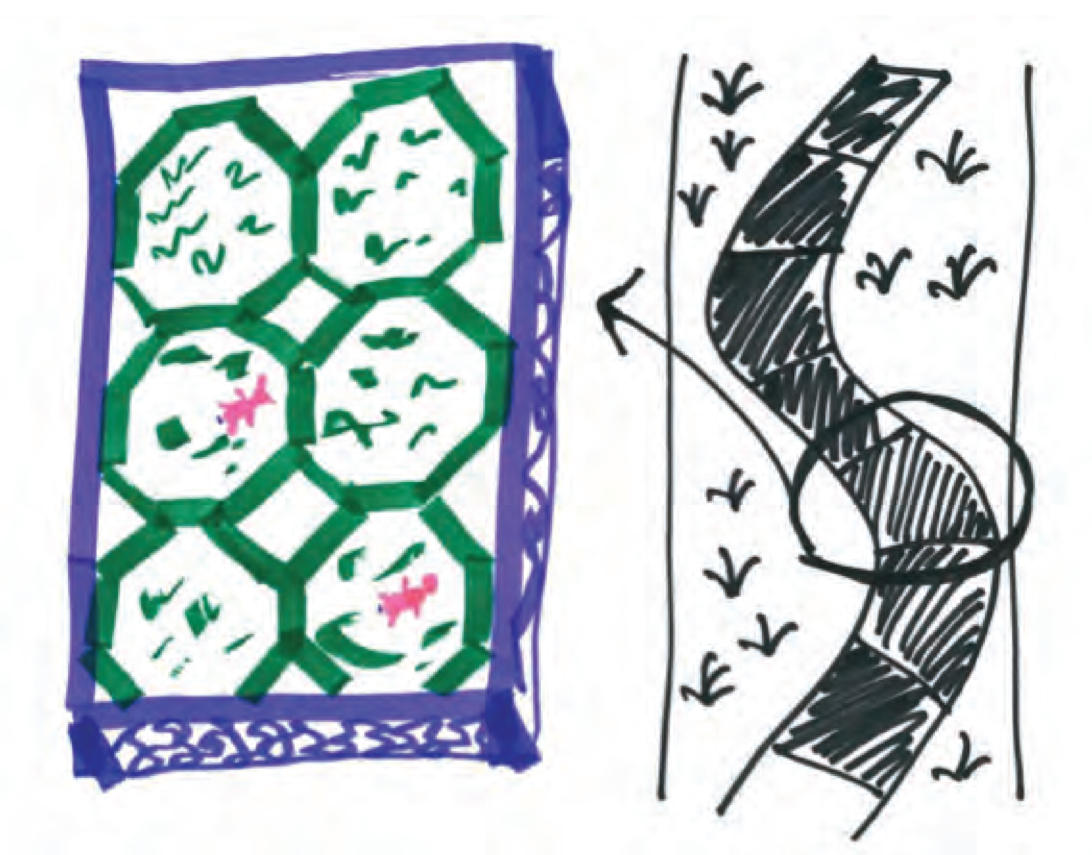
Inspiration
We don't have a problem in nature when we do not channel water due to a bare surface area.

Design Ideas
Make the surface of the trail more permeable. Use hexagon structure with plants in the middle of the trail for strength and permeability. Use some kind of resilin material across the trail surface and a bone-lattice type structure under the surface to either infiltrate water or move water away. Re-contour the existing road and ditch to go back to original contour of the hill. Bone structure is good inspiration for what we need: structure, water permeability and strength.

Add modular steps to the trail and fill spaces with buffalo grass which will withstand foot traffic.

Buffalo grass in center of water permeable, modular component.

Use bone lattice structure under the surface to either help water infiltrate or move water away.



Boulder Open Space and Mountain Parks Biomimicry Design Charrette

DESIGN CONCEPTS FOR A PEDESTRIAN/ EQUESTRIAN TRAIL

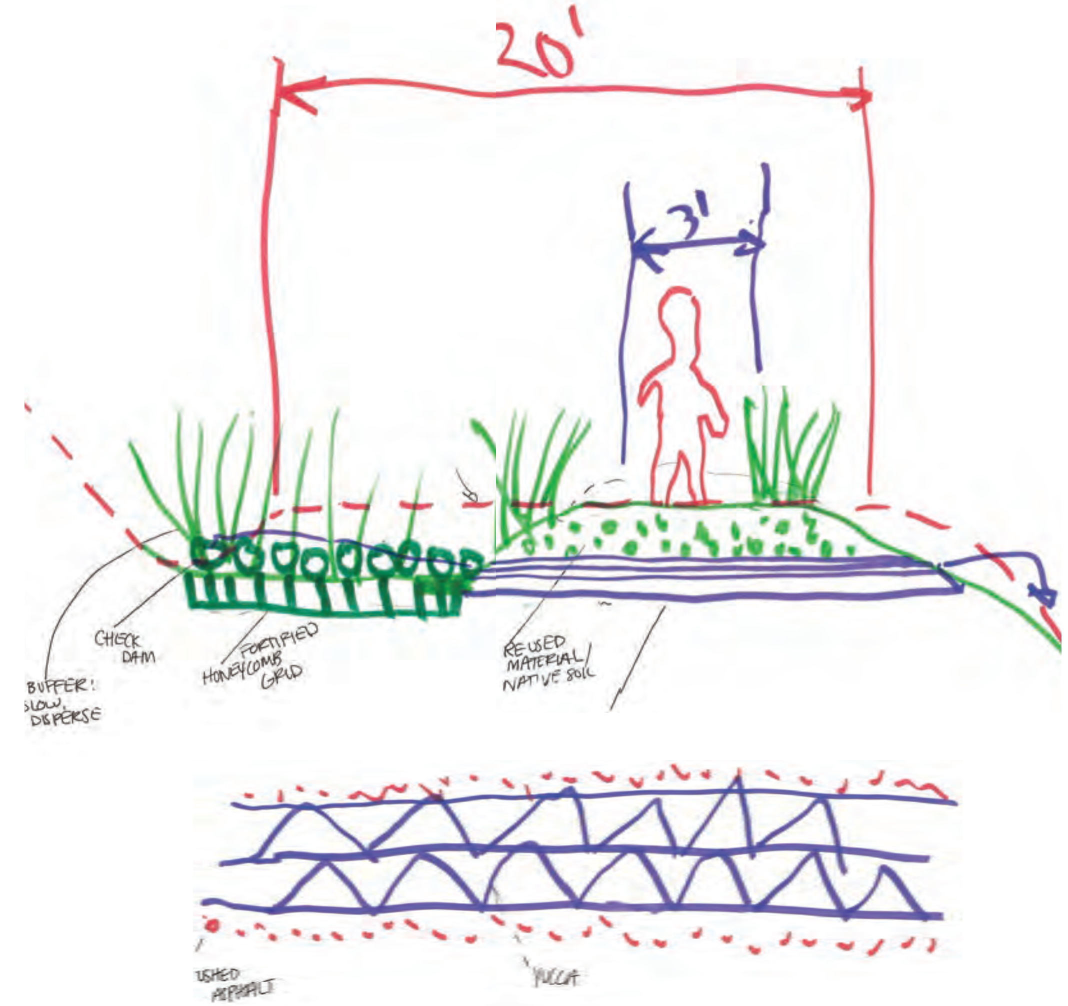
TEAM 7

Team Participants
Megan Bowes, OSMP Plant Ecologist
Scott Belonger, Trails Designer
Ailsa Wonnacott, Executive Director of Association for Community Living
Victoria La Rocca, Architect

Team Task
Design concepts for a trail designed for equestrian and pedestrian use.

Inspiration
A trail in this area is not compatible with nature, so we want to incorporate as many lost functions as possible. Create a trail that does not look like a trail.

Design Ideas
Create a buffer zone and meander using the 5 foot trail area which will help carry water. Fortify it with a honeycomb grid to hold the trail in place during a rain event. Fill grid with native deep rooted plants. Disperse water using different methods. This is the most important function. It will also address concern over water flowing to the cottages. Put smaller terraces leading up to the cottage area. Keep as much water in the system as possible. Need to address concern that the sub layer should be permeable, yet may silt up over time.



DESIGN CONCEPTS FOR A PEDESTRIAN/ EQUESTRIAN TRAIL

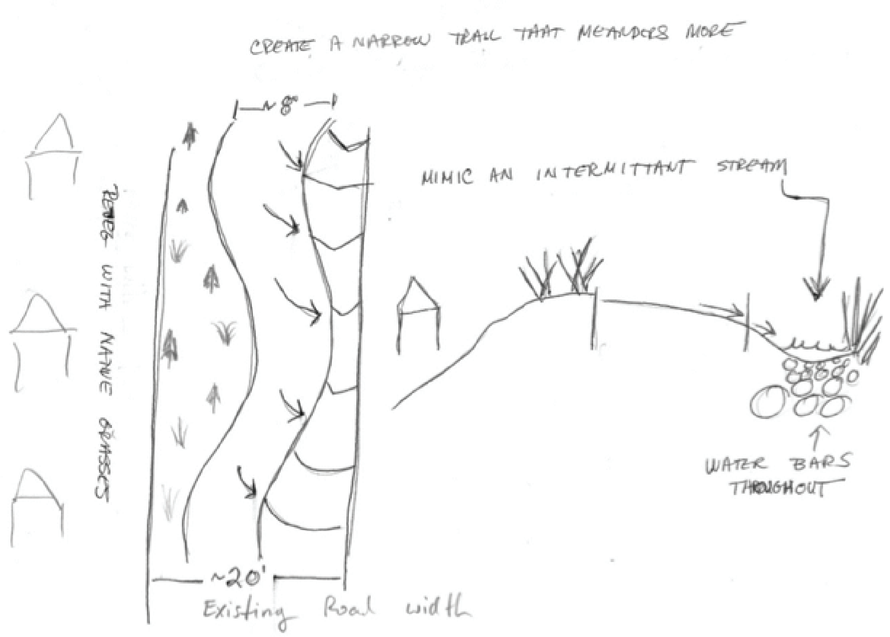
TEAM 8

Team Participants
Christian Nunes, OSMP Wildlife Ecologist
Paul Rovnac, OSMP Construction Project Coordinator
Lisa Dierauf, OSMP Education
Julie Friedler, Sustainability Analyst

Team Task
Design concepts for a trail designed for equestrian and pedestrian use (Mary: kept phrase treatment consistent w/ similar teams)

Design Ideas
Drainage actually worked in the V-ditch on the uphill side of this trail during the flood of 2013. There is a need to control the water. Provide enough room in the trail for passing. A natural surface will compact over time and not allow infiltration. There is not a concern with under trail infiltration, important to let the water go where it wants to go. Water wants to flow downhill and under the surface, so we want to avoid water flowing across the surface of the trail. Allow water to flow as if there were no trail. Create an ephemeral stream landscape with plunge pools for slowing down the water on the uphill side of the trail. Use only 3 feet for the trail with buffer zones and check dams on the rest of the area and meander 12 – 15 feet on either side of the existing trail. Restore with native plants, trees and shrubs on the downhill side, which will also serve to reduce fire danger.

On the uphill side, at available locations, channel off and pool the water in certain locations to slow down and allow infiltration. There will be a flow only during large rain events. What hits the ditch is water coming off the trail. Increase the size of the retention basin (existing at the end of Bluebell Road) and add 2 other basins located at the bottom of loop around the rest area for an integrated approach. The natural characteristics of crusher fines is that it has the ability to absorb water and when it freezes, it will return to its original shape. Remove the existing road surface down to a compression base with a stream on the uphill side. When the existing surface is removed there will be a lot of reusable materials. Use any kind of surface materials as a replacement. Crushed asphalt would encourage water to flow under the surface.



DESIGN CONCEPTS FOR A PEDESTRIAN/ EQUESTRIAN, ACCESSIBLE TRAIL

Boulder Open Space and Mountain Parks Biomimicry Design Charrette

TEAM 9

Team Participants
Kirk Mills, Engineer
Zack Stansfield, OSMP Trails
Martin Ogle, Founder, Entrepreneurial Earth
Andi Rutherford, Ecological Landscape Designer

Team Task
Design concepts for a trail designed for equestrian and pedestrian use that is wheelchair accessible as much as possible, due to grade constraints. (Mary, added period)

Inspiration
Life maintains form through living processes. Try to maintain form as much as we can though different processes that come along during and after construction to keep the trail healthy.

Yucca funnels water towards the dense tap root, where life is located. Use bio-swales to create areas of dense vegetation to take care of that water. See humans as part of life and maybe incorporate a sign on the trail: This is a "living trail" not built like a concrete room, built and then left to sit, and get community involvement.

Design Ideas
Exercise on-going processes that could be sustained through people participating in keeping the trail system going.

We felt that it was not possible to make this trail wheelchair accessible, consider using some type of assistance for people with mobility challenges (horses, etc).

Design for the 90% with a few emergency features and require human engagement when there is an extreme weather event. People can come and help maintain the structure if there is a flood, for example.

Employ bio-cementation (using living microbe to assist with structure). Use swale vegetation that is native to the area – study other swale-type areas for ideas. Identify key areas – places where degradation could have a negative effect on the whole system, and give these areas extra attention. Overall we should look at all of the ideas presented in the charrette and try to find out how they can be put together in a way that makes sense.

TEAM 10

Team Participants
Halice Ruppi, OSMP Jr Ranger Program Coordinator
Whitney Orosel, OSMP Education
Cheryl Spector, Architect
Mathew Pfeiffer, Engineer

Team Task
Design concepts for a trail designed for equestrian and pedestrian use that is wheelchair accessible as much as possible, due to grade constraints.

Design Ideas
Single trail for all uses
Smooth surface for wheels
Waxy surface inspired by the beetle to use as a surface application
Flexible materials to address freeze/thaw

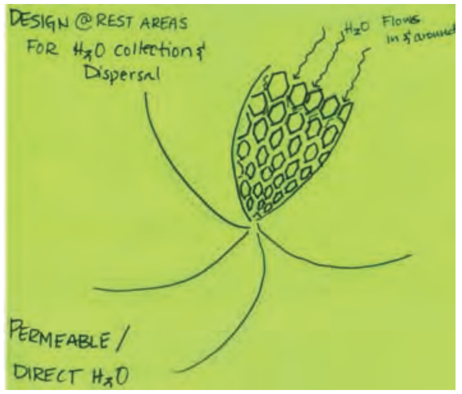
Direct vs. displaced water flows due to grade. May need to go outside the 20 foot pathway to address the grade issues for accessibility.

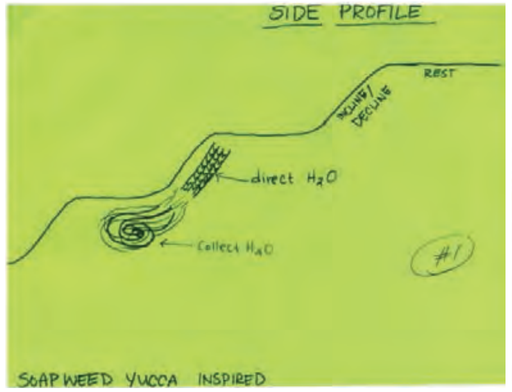
Use non-toxic materials according to Biomimicry principles. Would be great to use graphine as a surface coating (not yet on the market) it is made with a hexagonal structure of carbon that is layered. It would be very strong and flexible, hard and clear, so it can look like you are on dirt.

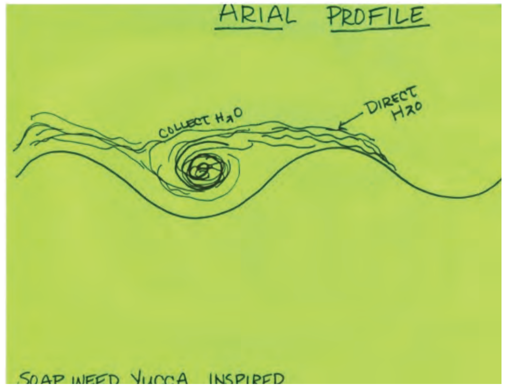
Consider the perspective of the trail for someone in a wheel chair, it's important what the trail looks like, since this is very different from when someone is standing. Think about things that would entice user to keep going and enjoy the experience especially since the grade will be steeper than the standard specs recommend.

Address this issue by signage along the way at pull outs with interesting scenery. These can be areas to rest and engage with nature. This would be multi-functional, combining rest area with viewing areas, and they could be structured to collect water in accord with the yucca design principles. The pullout surface would be a rosette. During a large rain event, a design could divert water to a cistern and use solar pumps to direct it where you'd want it for use later.

Where possible, alter the grade/path to make it more accessible.







TEAM 11

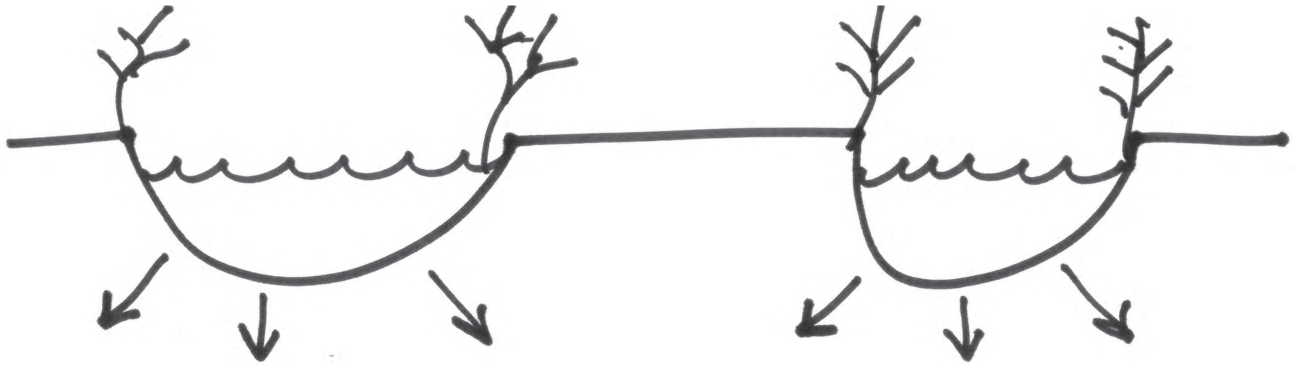
Team Participants
Brad Skowronski, OSMP Trail Contract Supervisor
Jim Reeder, OSMP Manager
Sam Steel, CU Student
Jake Kelsey, Graduate Student
Dave Barry, OSMP Trailheads

Team Task
Design concepts for a trail designed for equestrian and pedestrian use that is wheelchair accessible as much as possible, due to grade constraints.

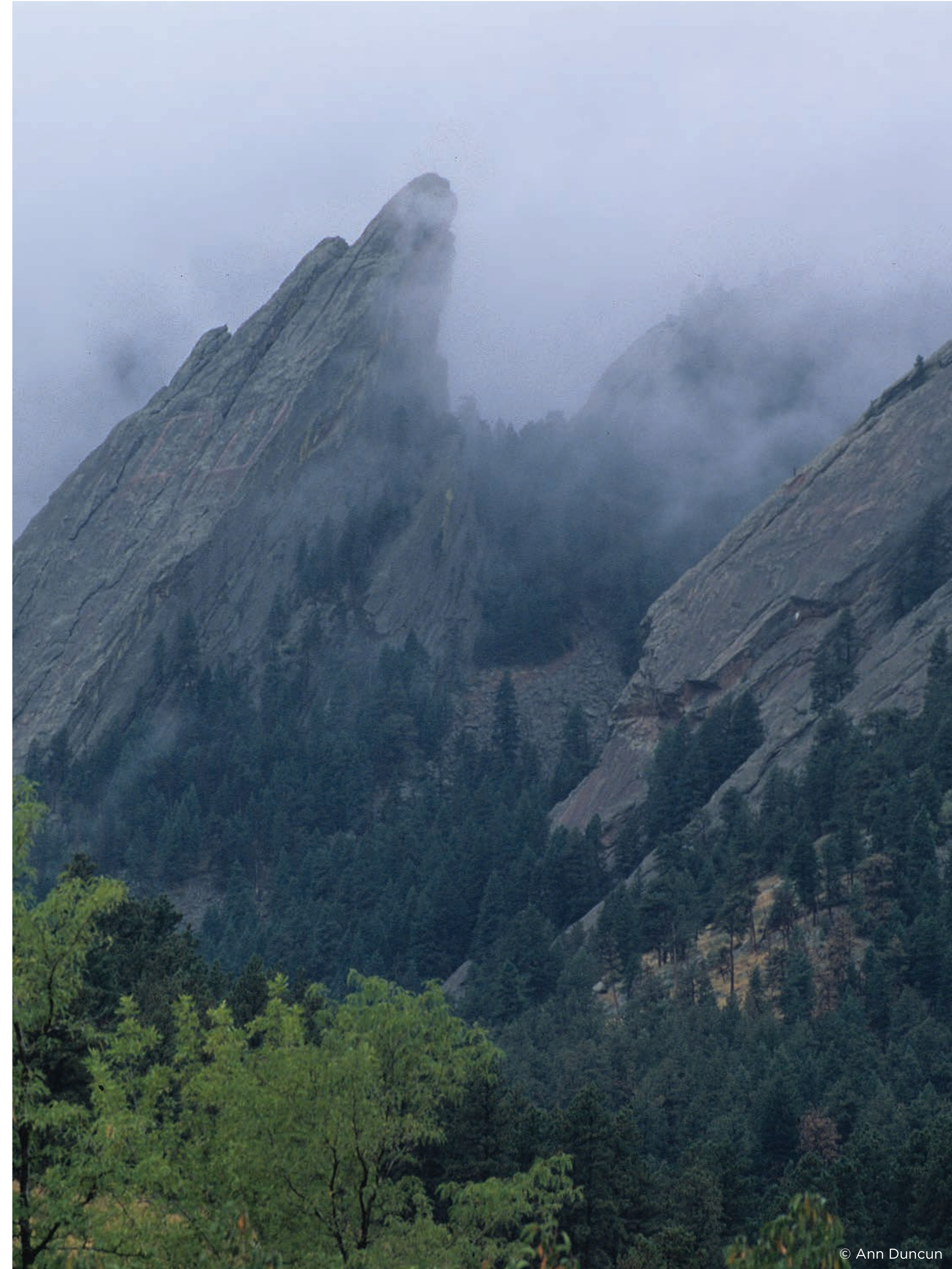
Design Ideas
Use the structural integrity of the honeycomb and shrilk polymer as the material. This material has the properties of chitin, strong, flexible, and resilient and is used in hexagon infrastructure.

Use crusher fines which are local and abundant silica-based binding agents. Much like bone, this material produces piezo electric energy which theoretically could be captured and used to power a sign telling visitors about the trail system. Manage water via bio-swale.

Compost toilet to reduce the need for vehicles. Get people in the local community to help remove the old trail. Use recovered asphalt in surface design.



Top to Bottom, Left to Right
Rough-legged Hawk *(Buteo lagopus)*, Orb Weaver *(Argiope trifasciata)*, Mountain Mahogany *(Cercocarpus montanus)*, Pasque Flower *(Anemone pulsatilla)*, Boxelder Bug on Green Gentian *(Eustoma grandiflorum gentianaceae)*, Wyoming Ground Squirrel *(Spermophilus elegans)*



Stormy Day in the Flatirons