Historical Bitter Creek Bridge: Innovation and Preservation

A Fall 2020 Collaborative Project with Arizona State University’s Project Cities & the Town of Clarkdale

Sustainable Cities Network
Arizona State University
Project Cities

PART 1:

Project and community introduction

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Cover images:

**EPICS 104/404 students,
Google Earth, and
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ACKNOWLEDGMENTS

Town of Clarkdale

Robyn Prud'homme-Bauer, Mayor

Doug Von Gausig, Mayor (2004-2020)

Debbie Hunseder, Vice Mayor

Bill Regner, Councilmember

Marney Babbitt-Pierce, Councilmember

Lisa O'Neill, Councilmember

Tracie Hlavinka, Town Manager

Ruth Mayday, Community Development Department Director

Maher Hazine, Public Works Director

Mike Gray, Community Development Project Manager

Guss Espolt, Community Development Technician

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Dave White, Deputy Director, Global Institute of Sustainability and Innovation

On behalf of the Julie Ann Wrigley Global Futures Laboratory, the Global Institute of Sustainability and Innovation, and the School of Sustainability, we extend a heartfelt thank you to the Town of Clarkdale for enthusiastically engaging with students and faculty throughout the semester. These projects provide valuable real-world experience for our students and we hope that their perspectives shine light on opportunities to continuously improve Clarkdale's future livelihood and community well-being.

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To access the original student reports, additional materials, and resources, visit:

links.asu.edu/PCClarkdaleDowntownRevitalization20F

ABOUT PROJECT CITIES

The ASU Project Cities program uses an innovative, new approach to traditional university-community partnerships. Through a curated relationship over the course of an academic year, selected Community Partners work with Project Cities faculty and students to co-create strategies for better environmental, economic, and social balance in the places we call home. Students from multiple disciplines research difficult challenges chosen by the city and propose innovative sustainable solutions in consultation with city staff. This is a win-win partnership, which also allows students to reinforce classroom learning and practice professional skills in a real-world client-based project. Project Cities is a member of Educational Partnerships for Innovation in Communities Network (EPIC-N), a growing coalition of more than 35 educational institutions partnering with local government agencies across the United States and around the world.

ABOUT SUSTAINABLE CITIES NETWORK

Project Cities is a program of ASU's Sustainable Cities Network. This network was founded in 2008 to support communities in sharing knowledge and coordinating efforts to understand and solve sustainability problems. It is designed to foster partnerships, identify best practices, provide training and information, and connect ASU's research to front-line challenges facing local communities. Network members come from Arizona cities, towns, counties, and Native American communities, and cover a broad range of professional disciplines. Together, these members work to create a more sustainable region and state. In 2012, the network was awarded the Pacific Southwest Region's 2012 Green Government Award by the U.S. EPA for its efforts. For more information, visit *sustainablecities.asu.edu.*

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ASU Sustainable Cities Network
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Project Cities

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Sustainability through local action

ABOUT CLARKDALE

The Town of Clarkdale, Arizona is located on the banks of the Verde River in the north central part of Arizona. It is a thriving community and is the gateway to the Sycamore Canyon Wilderness Area in the beautiful Verde Valley. Founded in 1912, Clarkdale is renowned as the first master-planned community in the state of Arizona and was developed with a "Live, work, play" ideology intended to provide its residents with a wholesome living experience. Clarkdale has just over 4,300 residents who thrive in the fresh, clean air of the Verde Valley.

CLARKDALE TEAM

Project Cities Community Liaison

Tracie Hlavinka, Town Manager

Clarkdale Project Leads

Tracie Hlavinka, Town Manager

Ruth Mayday, Community Development Department Director

Maher Hazine, Public Works Director

Mike Gray, Community Development Project Manager

Guss Espolt, Community Development Technician

Celebrating historic charm. Creating a prosperous future.

clarkdale.az.gov

Town of Clarkdale

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September 20, 2021

Dear Town of Clarkdale Residents:

On behalf of the Town Council and the Town of Clarkdale, we would like to express our appreciation to all who have been involved with the ASU Sustainable Cities Project. Over the past two years, the Town has been fortunate to work with nearly 100 students across disciplines to develop strategies for improving the lives of Clarkdale residents. As you know, the Design Principles Guidelines for the Town of Clarkdale's Downtown District and 89A Commercial Corridor was recognized by the Arizona Planning Association Conference in 2020; we have incorporated portions of that document into our General Plan.

This recognition speaks to the quality of work produced by the students that participate in the program, and why our continued partnership is so important to the Town of Clarkdale. Because we are a small town with a small staff, our capacity to research and produce in-depth documents is limited; the ability to work with the students and faculty at ASU provides us with the expertise we need to accomplish our goals for our community, while providing the students with hands-on, documentable experience in the public sector.

The Town of Clarkdale looks forward to our continued collaboration with Sustainable Cities Network and another successful year with the students at ASU.

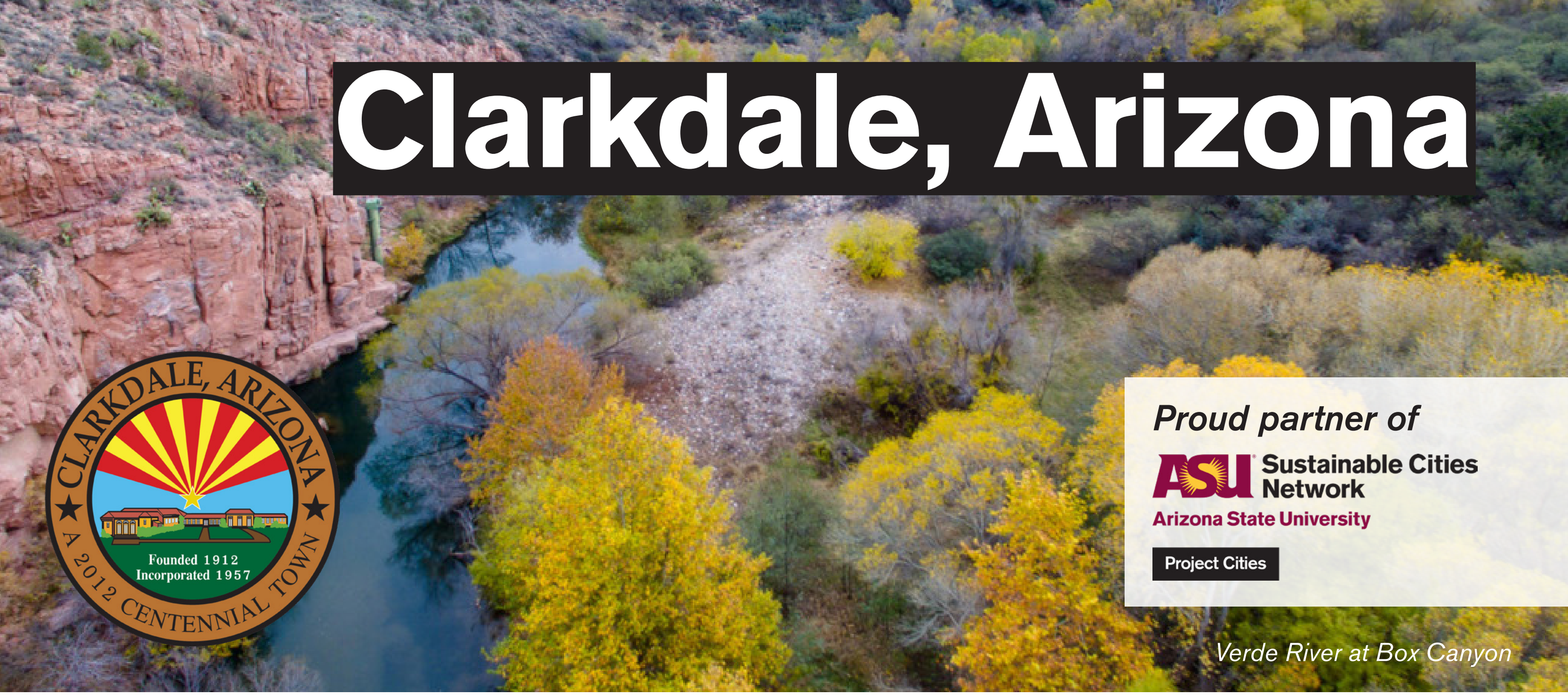
Sincerely,

Robyn C. Prud'homme-Bauer

Robyn Prudhomme-Bauer, Mayor

Rob Sweeney, Interim Town Manager

Clarkdale, Arizona



Verde River at Box Canyon

Demographics

total population: **4,424**

36% of residents are over the age of 65

median age: **56.27**

78% of residents are homeowners

67.1% of the population has some college education, 31.75% are college graduates

median yearly income: **$45,304**

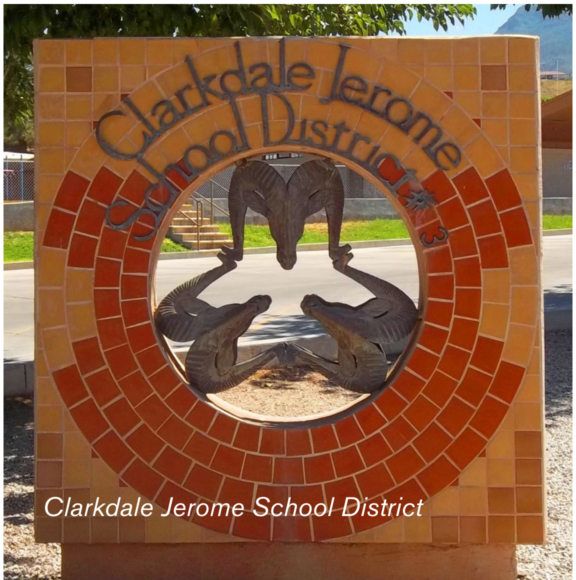
Schools

Clarkdale is home to the Yavapai College Verde Campus and the Small Business Development Center. Yavapai College has one of the leading viticulture and enology schools in the Southwest. High school students in Clarkdale attend Mingus Union High School, and the Clarkdale-Jerome Elementary School boasts an excellent reputation for educating students from Kindergarten through 8th grade.

Sustainability

In Clarkdale's 2013 General Plan, the City identified four main sustainability objectives: **water use, ecological design, sustainable construction** and **mixed use development**. In 2019, Clarkdale announced its partnership with ASU's Project Cities to enliven the Central Business District with a sustainability orientation.

Clarkdale Park



Clarkdale Jerome School District

Tuzigoot National Monument

History

The Town of Clarkdale is located on the banks of the Verde River in the north central part of Arizona. It is a thriving community and is the gateway to the Sycamore Canyon Wilderness Area in the beautiful Verde Valley. Founded in 1912, Clarkdale is renowned as the first master planned community in the State of Arizona. The town was founded to house the employees of the smelter in Clarkdale, as well as the mine workers from Jerome. Ahead of its time, Clarkdale boasted underground utilities, sewers, paved streets, stylish homes and a thriving commercial center.

The main town site was located on a ridge overlooking the industrial smelter complex and was developed with residential homes, including upper and lower-income housing, a commercial area, an administrative center, schools, recreational and cultural facilities, and parks. They intended to include all the parts typically found in a small town within a comprehensive planned design. Today, the original town site of Clarkdale is recognized as a Historic District on the National Register of Historic Places.

The original rail line that served the smelter is now host to a scenic excursion train, the Verde Canyon Railroad, which allows travelers a four-hour round trip to view the protected ecosystem of the Sycamore Canyon Wilderness Area and Verde River firsthand. In addition to the excursion branch, the Arizona Central Railroad (the parent company of the Verde Canyon Railroad) ships materials by rail to Salt River Materials Group, a local cement manufacturer.

Verde Canyon Railroad

Attractions

Hop aboard the Verde Canyon Railroad for the longest-running nature show along the Verde River. Spot bald eagles and enjoy an array of special events onboard throughout the year. Experience the Arizona Copper Art Museum housed in the restored Clarkdale High School with its dazzling array of thousands of gorgeous copper artifacts (some of which you can touch). Float the Verde River with experienced local river outfitters and enjoy unspoiled riparian areas adjacent to the Audubon Important Birding Area in Tavasci Marsh. Dance the night away every weekend to live music. Explore the Tuzigoot National Monument featuring the ruins of an ancient Sinagua Indian pueblo. Savor local terroir at Clarkdale's wineries, the Chateau Tumbleweed tasting room and winery or the Southwest Wine Center in the heart of Yavapai College's Verde Campus in Clarkdale.

Downtown Business District


Downtown Business District

The historic Downtown Business District boasts many treasured historic assets and is the center of Clarkdale's government, cultural and historic core. The Town and downtown-area business owners have invested heavily to keep the town core thriving. As of 2019, there are four vacant properties in the Business District that pose opportunities for redevelopment, including a former grocery store, apartments and the old Grand Theatre. $1.5 million in streetscape improvements in the Downtown Business District were completed in March 2005.

Clarkdale revitalization plan

1. Develop a strategy to **encourage public and private investment**
2. Produce a **report of building conditions** including a revitalization plan for each building, cost estimates on the repairs and possible funding sources
3. Develop a **parking, pedestrian and bicycle connection plan**
4. Identify creative use of existing spaces to **promote foot traffic** in the area

Business Highlights

- Clarkdale has 83 businesses
- Workforce is composed of 45% blue collar; 54% white collar
- 90% of businesses have less than 20 employees
- Annual events, such as Clarktoberfest, the Car Show, wine festivals, and multiple block parties, are anchored in the historic business district


Historic Downtown Mainstreet

Leading industries as of 2019

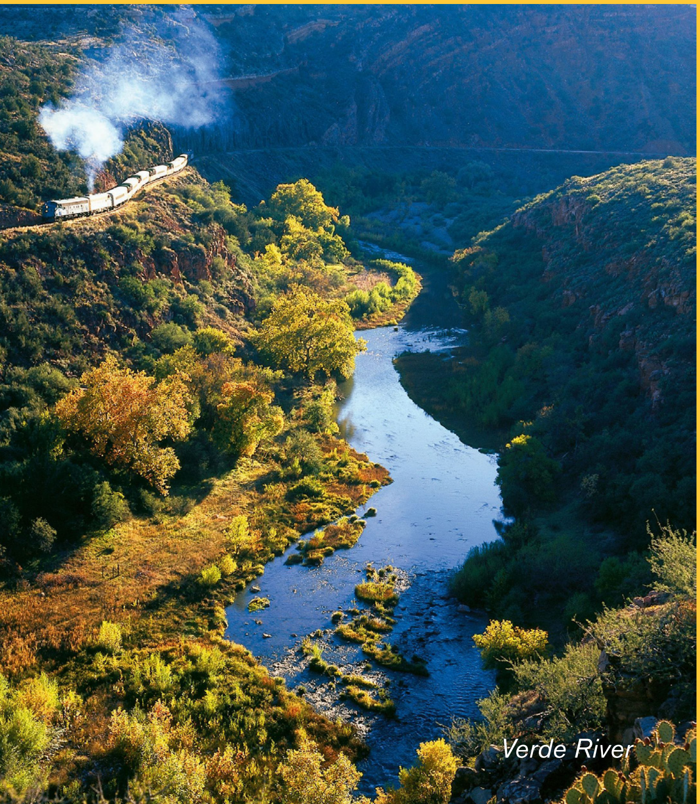
Public Administration	Education	Information	Transportation & Warehousing
167 Jobs	110 Jobs	108 Jobs	87 Jobs

Kayaking on the Verde River

Local ecology

The Verde River bisects the north portion of Clarkdale at a low elevation of around 3,300 feet. The west side of the town boundary is located along the foothills of Mingus Mountain in the Black Hills Range at a high elevation of approximately 4,600 feet above sea level. On the northeast border of Clarkdale, the National Park service operates the 42-acre Tuzigoot National Monument, an 800-year-old Sinagua pueblo, which is surrounded by hiking trails and hosts a complete museum. Tavasci Marsh borders Tuzigoot National Monument and has been designated as an Important Birding Area by the North American Audubon Society. Arizona State Parks also manages the Tuzigoot River Access Point along the Verde River in Clarkdale. The town is surrounded by the Prescott National Forest to the west and the Coconino National Forest to the east. In addition, trust lands of the Yavapai-Apache Nation are located within the town boundary.

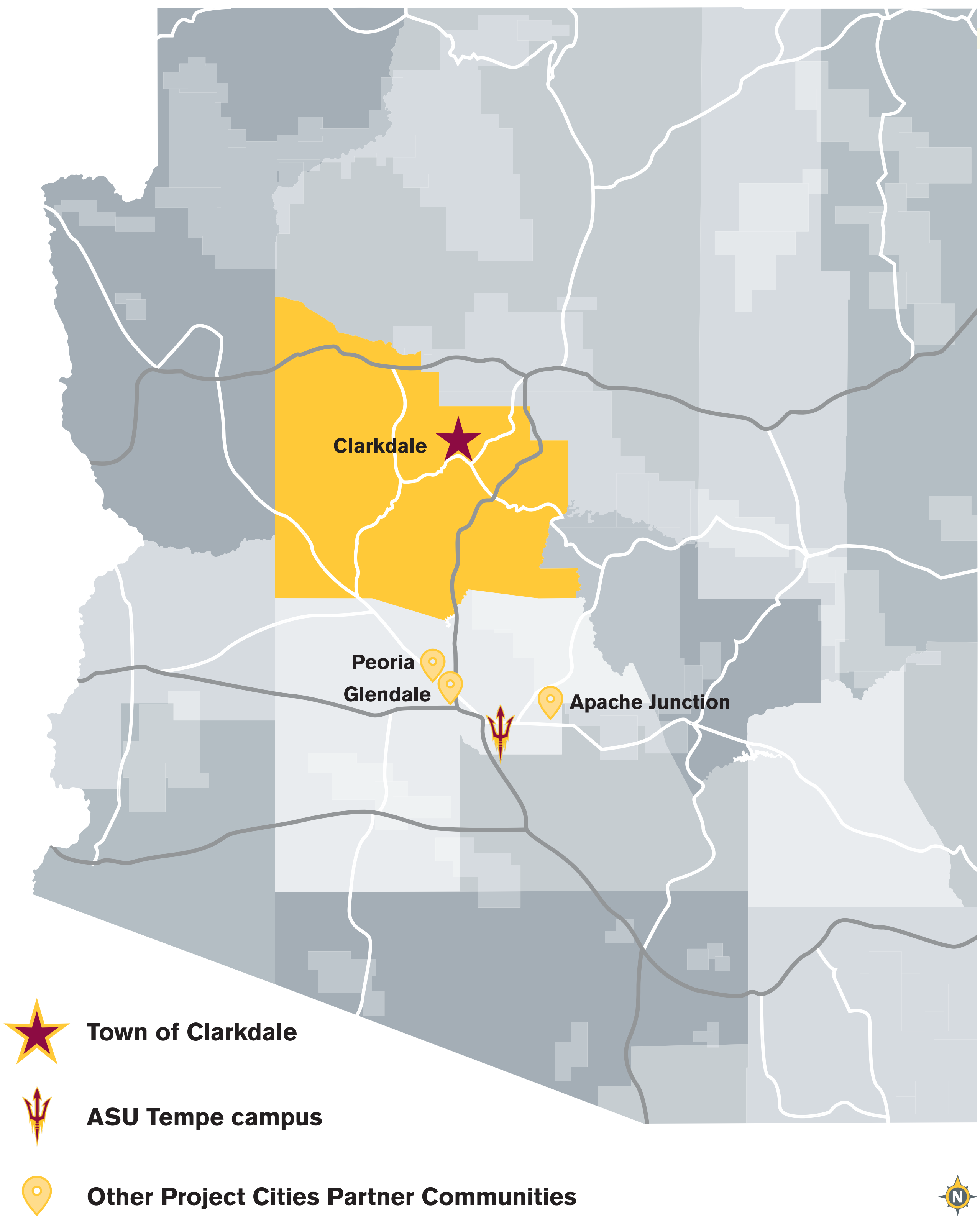
Local wildlife



Verde River

Sycamore Canyon

MAP OF PROJECT CITIES PARTNER COMMUNITIES IN ARIZONA



The following report summarizes and draws highlights from work and research conducted by students in FSE 104/404 EPICS Gold, for the Fall 2020 partnership between ASU's Project Cities and the Town of Clarkdale.

To access the original student reports, additional materials, and resources, visit:

links.asu.edu/PCClarkdaleDowntownRevitalization20F

Sustainable Cities Network
Arizona State University
Project Cities

Sustainability through local action

EXECUTIVE SUMMARY

The Town of Clarkdale is a historic community, with a past long intertwined with the United Verde Copper Company and other mining entities. Clarkdale was founded in 1912 to support the United Verde Copper Company's mine and smelter near the Town of Jerome. As Clarkdale boomed alongside local industry, Bitter Creek Bridge was constructed in 1917, with the intention of running one of the local roads, Broadway Street, to the smelter. With the closure of the mines, Clarkdale has still retained the landmark bridge, and to this day it connects local traffic to the tourist destination, the Verde Canyon Railroad, as well as the historic downtown district.

Figure 1 *Verde Canyon Railroad (left) and a vintage photograph of Clarkdale's historic downtown district (right), by Town of Clarkdale*

Clarkdale is proud of its heritage and has maintained its historic infrastructure, particularly in the downtown district. In addition to the historic district, the Town boasts the Bitter Creek Bridge, a single-lane bridge that connects downtown Clarkdale with additional residences on the north side of town. The bridge's original structure has been maintained, but as the Town expands and modernizes, the bridge's structural integrity needs to be evaluated to ensure user safety.

To assist with this challenge, Clarkdale partnered with the ASU Project Cities program in a continuation of the Downtown Revitalization project portfolio, which began in the Fall of 2019. The Fall 2020 continuation of the project involves a small group of students in the **FSE 104/404: EPICS Gold** class, who consulted with the Town to investigate the bridge infrastructure, and develop potential design features that can be used to enhance the bridge, while maintaining its historic character.

The EPICS design process is iterative, and as the students identified potential improvements, they also considered the impact of the feature on the community, as well as identified strengths and weakness for each solution. Students ultimately developed two primary solutions, strengthen and expand the existing bridge, or build an entirely new bridge while retaining the old bridge as a tourist destination. With each proposed improvement, students produced design mockups, a summary table of findings, and proposed design feature strengths and weaknesses. Students chose not to settle on one proposed solution for Clarkdale, and instead provided various well-suited options for the Town to consider.

The following class summary report dives into the design process, including the stakeholder identification, factor analyses, and a breakdown of each proposed solution. Students provide thoughtful insight into the current state of bridge renovation as well as recommendations for Clarkdale's consideration as they move forward with the project.

KEY STUDENT RECOMMENDATIONS

Recommendations for renovating Bitter Creek Bridge	Read more
Investigate the feasibility of strengthening the Bitter Creek Bridge using various methods, such as carbon fiber reinforcement process, to ensure the safety of pedestrian and local traffic.	pp.34-35
Consider expanding the current bridge structure to allow for multiple lanes and pedestrian access utilizing methods such as expansion joints and open joints.	pp.34-36
Explore opportunities for building an entirely new bridge structure to accommodate Clarkdale's traffic while maintaining the original bridge structure for tourism.	pp.28, 37
Consider a twin bridge structure, allowing for one way traffic on each bridge.	p.37
Research potential grants and other funding opportunities to support the construction of a new bridge.	pp.31-32, 38

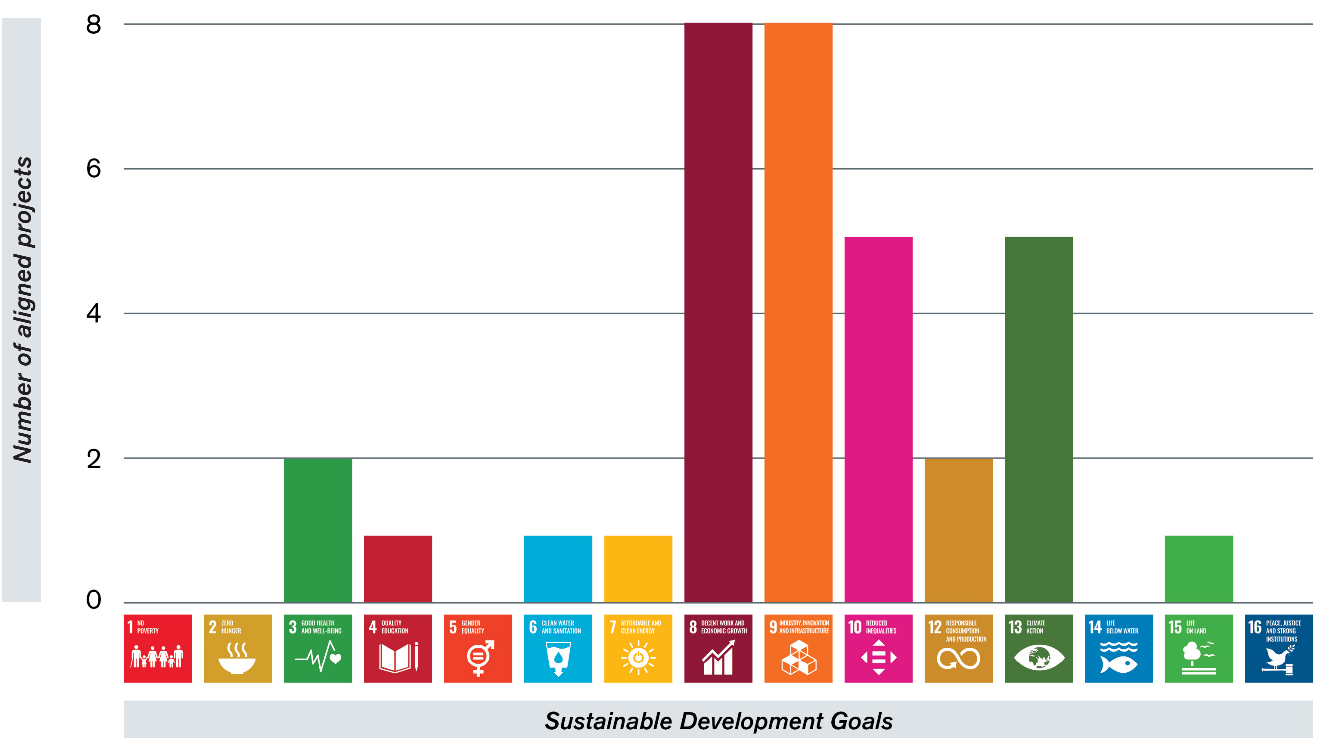
Recommendations for preserving the history of Bitter Creek Bridge	Read more
Prioritize expanding the current bridge to accommodate tourist traffic and highlight the bridge's historic significance to the community.	pp.34-36
Determine alternative sites for a larger bridge structure appropriate to Clarkdale's needs while preserving the original Bitter Creek Bridge's function of connecting the Town to the Verde Railroad and historic downtown.	p.37

TOWN OF CLARKDALE PROJECTS: ALIGNMENT WITH THE UNITED NATIONS' SUSTAINABLE DEVELOPMENT GOALS

As the leading international framework for sustainable decision-making, the 17 Sustainable Development Goals (SDGs) lay out a path for partnerships toward global peace and prosperity. The SDGs provide a set of goals and metrics for project impact to be measured, offering an illustration of the benefits experienced by the cities, towns, and students who participate in a Project Cities partnership. For details on the SDGs, visit **sdgs.un.org/goals**.

Every project in the PC program aligns with SDGs 11 and 17.

The figure below illustrates SDG project alignment throughout the Town of Clarkdale's partnership with Project Cities, through the Fall 2020 semester.



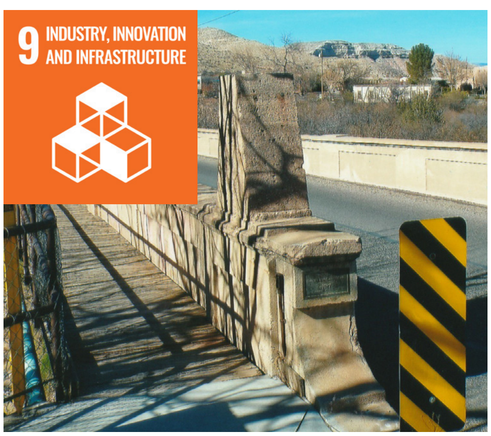
TOP THREE GOALS ADDRESSED IN THE FOLLOWING REPORT

As a continuation of the Clarkdale Downtown Revitalization portfolio, this project focuses on innovative infrastructure solutions while preserving the historic character of the town. The suggestions for Bitter Creek Bridge outlined in this report take into account feasibility and community impact to provide well-rounded recommendations for Clarkdale to consider.

Goal 8: Decent Work and Economic Growth

"Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all."

The design and construction of a Bitter Creek Bridge enhancement could help create a multitude of employment opportunities.



Goal 9: Industry, Innovation, and Infrastructure

"Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation."

Preserving the town's historic infrastructure while considering different solutions to update or enhance it is beneficial for current and future residents and visitors.

Goal 11: Sustainable Cities and Communities

"Make cities and human settlements inclusive, safe, resilient and sustainable."

Infrastructure maintenance and resilience is critical to maintaining healthy communities by guaranteeing safe transport and accessibility.

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PART 2:

Historic Preservation & Renovation of Bitter Creek Bridge

DESIGN IDEAS TO INCREASE BRIDGE CAPACITY WHILE MAINTAINING HISTORIC INTEGRITY

FSE 104/404:
EPICS GOLD

IRA A. FULTON SCHOOLS OF ENGINEERING

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Maher Hazine

Ruth Mayday

PROJECT GOALS

The goal of the project is to explore bridge expansion opportunities for the Bitter Creek Bridge that preserve its historic character and function. Students also worked with the Town of Clarkdale to conduct a traffic study to assess the bridge's traffic and inform the structure's ability to continue serving its current function, safely and more efficiently. Students proposed several design features for Bitter Creek Bridge which have been organized in a summary table on page 38 of this report.

INTRODUCTION

The Town of Clarkdale, Arizona, has a deep and rich history. Many of the structures within the town are on the Historic Register, including the Bitter Creek Bridge. This bridge is the sole entry point to the Verde Canyon Railroad, a tourist attraction that brings hundreds of thousands of tourists in every year. The bridge is just over one lane wide, impeding the traffic flow as cars must stop on either side to let oncoming traffic pass. The Town is interested in exploring various options, such widening the existing bridge while maintaining its historical character or installing an additional bridge.

Figure 2 *Current state of Bitter Creek Bridge, via Wikimedia Commons at* **https://commons.wikimedia.org/wiki/File:Clarkdale-Broadway_Bridge-1917-2.jpg**

The Town partnered with a team of EPICS students to generate these possible solutions to begin planning and construction as soon as possible. The team worked closely with Maher Hazine, Director of Public Works and Utilities for Clarkdale. The Town is located approximately 100 miles north of Tempe. Several programs in the Town are currently operating to update old infrastructure to meet current demands while still maintaining the history of the community.

This semester's EPICS team generated a list of possible solutions for the Town and recommendations for the best solution within their semester-long time constraint. The team began by gathering data from the Town to better understand project constraints. Students then researched and refined their suggestions so they may be evaluated against the community partner’s needs. Finally, the team will assessed their designs and suggestions and presented them to the Town of Clarkdale at the Fall 2020 End-of-Semester Showcase event.

Project area context

The Town of Clarkdale was established by copper miner William A. Clark. Clark purchased the United Verde Mines and, in 1901, and began constructing a smelter to process ore near Jerome. As construction of the smelter finished, Clark established Clarkdale as a company town and designated Broadway as the main road to the smelter. To connect Broadway to the smelter, Bitter Creek Bridge was constructed in 1917 to carry Broadway over Bitter Creek (Fraser Design, 2004). Following the closure of the mines, Clarkdale retained Bitter Creek Bridge for its local traffic. Nationally recognized as a historic bridge, the Bitter Creek Bridge has been recognized for its still intact concrete detailing and call back to a fundamental bridge design in Arizona. The bridge is also recognized for its ties to the Verde Copper Company, one of Arizona’s early industries.

Figure 3 *Bitter Creek Bridge context location map from Google Earth*

RESEARCH METHODS

EPICS students conducted site analysis of the Bitter Creek Bridge. In collaboration with Clarkdale, students researched various methods for conducting a traffic count to gauge the average traffic on the bridge. Additional information on the traffic count methods can be found in Appendix B of the original student work, at **links.asu.edu/PCClarkdaleDowntownRevitalization20F**. The Town of Clarkdale proceeded with the pneumatic road method, using road tube sensors to send a burst of air pressure when a vehicle's tires pass over the tubes; however, the collected data was corrupted and thus unusable. As part of the design process, students conducted a PESTLE analysis to contextualize the project's impacts in various spheres of impact, including social, political, environmental, and more.

Students also utilized a functional decomposition to break down the various features of each proposed solution, identify the strengths and weaknesses of the design, and provide rough design specifications to estimate construction cost. Functional decomposition tables are available in Appendix A of the original student content at **links.asu.edu/PCClarkdaleDowntownRevitalization20F**. Students primarily worked with the Town's Public Works Director and Town Engineer, Maher Hazine. Students also worked directly with Ellen Yates, the Town's Operations Administrator.

EPICS@ASU overview

The Engineering Projects in Community Service (EPICS) program is a design-based learning program for students. Coming from an array of disciplines, EPICS students work various real-world challenges that directly benefit the community. The EPICS program adopts a design process, an iterative multi-step process that encourages students to return to previous phases as the project develops.

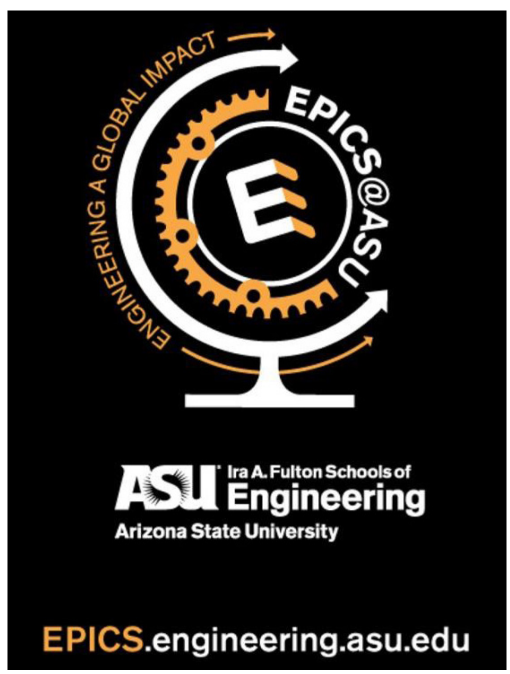

Figure 4 *EPICS@ASU graphic element*

Often these projects are multi-semester and include high stakeholder involvement from the partner communities to inform the ideation and development of the projects. Projects span four broad theme areas, including sustainability, community development, health, and education. With a human-centered focus, EPICS projects focus on building empathy with stakeholders and encourage the contextualization of engineering projects in the social, political, economic, and environmental dimensions. Over the course of a semester, students will work closely with their community partners and faculty mentors to conduct site visits, develop prototypes, and comprise key deliverables to the community partner.

Historic preservation webinar

On October 29, 2020, students joined the Town of Clarkdale for a webinar about Clarkdale's historic preservation efforts. Attendees from the Town of Clarkdale included Bill Regner, a Clarkdale Councilman; Michael Lindner from the Clarkdale Historical Society; Ruth Mayday, Community Development Director; and Mike Gray, a Planning Manager. The students were also joined by Dr. Lauren Allsopp, a Sustainability Scientist with ASU and Faculty Associate with the School of Geographical Sciences and Urban Planning. Dr. Allsopp has been recognized for her research into historic masonry and mortars and construction technology and interest in historic structures. In preparation for the students' work with the historic bridge, representatives from the Town of Clarkdale and Dr. Allsopp convened to discuss the importance of historic preservation, particularly in Clarkdale, as well as provided preliminary recommendations for the Town of Clarkdale to preserve the Bitter Creek Bridge while enhancing its utility.

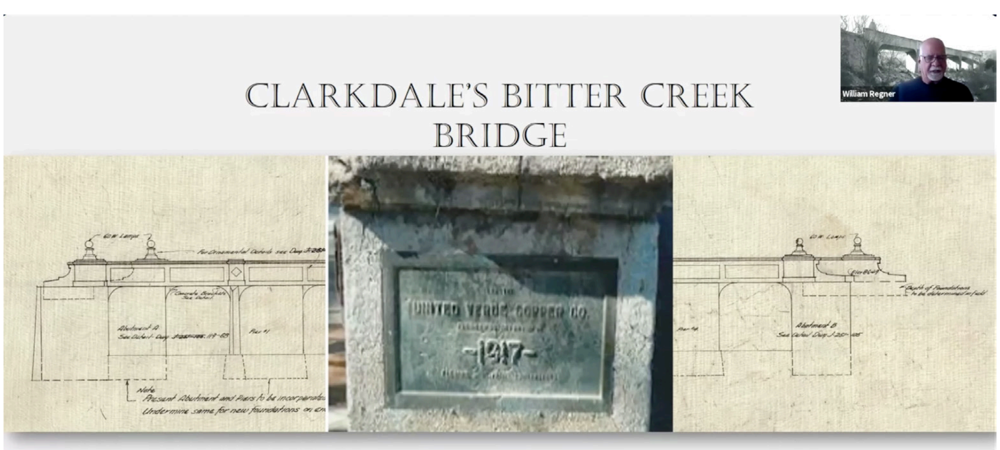

Figure 5 *Excerpt from Bill Regner's portion of the historic preservation webinar*

The webinar kicked off with a video from the Clarkdale Historical Society, which detailed Clarkdale's origins as a company town for the Verde Copper Company. Due to the overcrowding of Jerome, Arizona, which at the time primarily served the surrounding mining communities, William Andrew Clark set out to establish a new town, one that would become the first master planned community in Arizona. Clark purchased land along the Verde River, and created a company town, which would include a centralized business district, and homes built from bricks, a stark difference from the wooden buildings in Jerome. Clark's plans followed the newly sprung "City Beautiful Movement," a movement that emphasized open spaces and aesthetically pleasing streets and buildings. As the smelter thrived, Clarkdale served as an economic generator up until the closure of the smelter in 1953. Following the loss of the town's economic generator, businesses and residents slowly began to move out of the town, and in recent years Clarkdale has focused its efforts on preserving the community's historic integrity and looks to it to strengthen its sense of identity, while revitalizing the town as an economic hub for tourism and new businesses.

"While we have loved and appreciated our history, we haven't really embraced it in a way that might give it its due as the most under utilized asset we have in Clarkdale, our story. We have a story to tell. We're the first master planned community in Arizona, we're the quintessential company town. This is a story we have that we are in danger of losing." -Bill Regner

Michael Lindher detailed Clarkdale's current historic preservation efforts. The National Register of Historic Places is vital to maintaining a community's history, being on the registry opens a community up to potential grants that can fund preservation efforts, as well as promote education about the community. The Clarkdale Historic District was officially added to the Register in 1998, and includes the Upper and Lower residential areas, as well as the downtown business district, and Town center. As the Clarkdale Historical Society reviewed their strategic plan, one of the goals is to support the preservation of its structures by retaining its place on the National Register of Historic Places. To see this through, Clarkdale's Town Council established the Historic Preservation Commission.

Following a discussion about Clarkdale's current preservation efforts, Bill Regner presented on the Bitter Creek Bridge. Built in 1917, the bridge was built to accommodate two lanes of traffic, and to connect Clarkdale to the Verde Railroad. As the Town matured, and technology advanced, what was once two lanes can now only support one lane. While the students were tasked with enhancing the bridge's structure for multi-lane traffic, there are several critical features to preserve including its concrete detailing, parapet walls, lighting fixtures, and length.

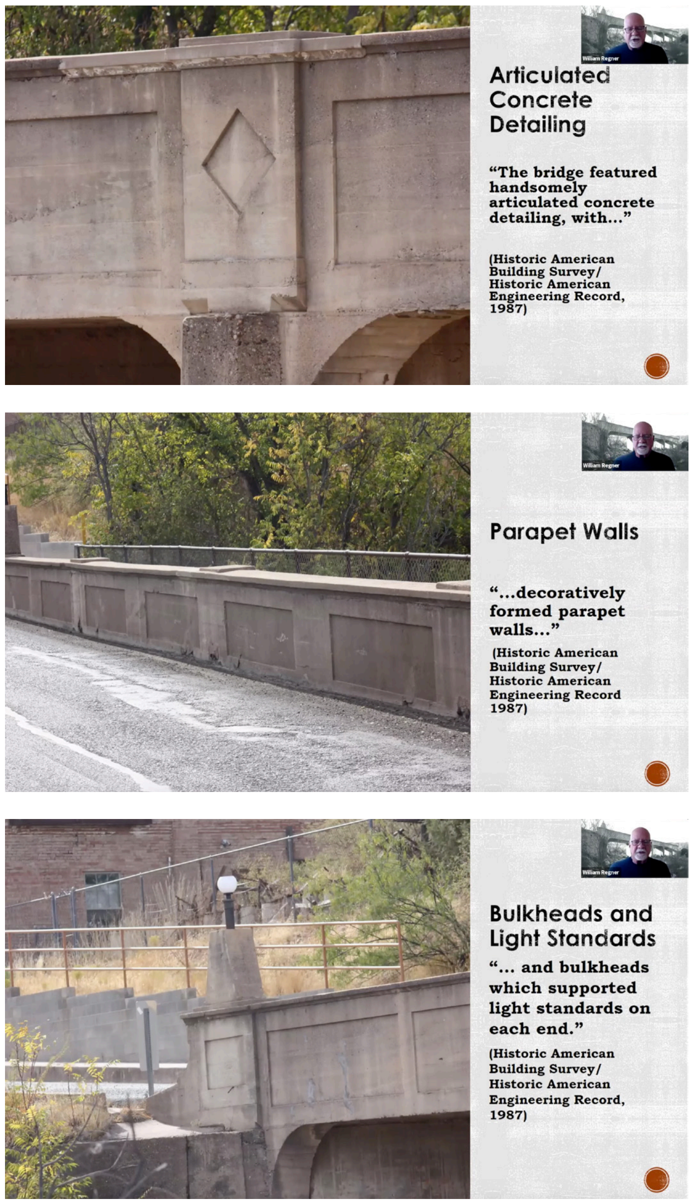

Figure 6 *Notable quotes about Bitter Creek Bridge from the Historic American Building Survey/Historic American Engineering Record, 1987*

Dr. Lauren Allsopp provided key recommendations for the bridge's preservation for the Town of Clarkdale and the students' consideration. Dr. Allsopp recommended a structural analysis for the bridge in order to gauge its ability to withstand multi-lane traffic, as well as major structural renovations. Dr. Allsopp also pointed out that if the bridge structure is altered in any significant way, including the addition of a car lane or bike lanes, the structure can be removed from the National Register. Remaining on the National Register has several benefits including tax reductions for the Town as well as providing grants for renovation efforts. Dr. Allsopp shared reservations about adding to the bridge structure and inquired about the possibility of building an entirely new structure nearby, which Ruth Mayday and Bill Regner agreed as a potential alternative for the students to investigate. Additionally, Dr. Allsopp recommended using the original Bitter Creek Bridge for local pedestrian traffic, while a new structure can be used for visitors and heavier traffic flows. She also brought up several points about the bridge's ability to accommodate additional weight, since the bridge was originally built during a time when cars weighed far less than they do now.

In addition to building a new structure, Dr. Allsopp recommended reinforcing the existing concrete with a 100% plant-based epoxy from Eco Safety Products. She remarked that the plant-based epoxy is widely used by ADOT and the City of Phoenix and can be helpful for maintaining the bridge's original concrete structure. As the webinar wrapped up, Dr. Allsopp issued two final recommendations for both the Town of Clarkdale and the students. First, she recommended that the students evaluate where the potential second bridge can go, with careful consideration for Clarkdale's terrain. Secondly, she recommended that students evaluate the potential cost for building a structure, as well as the cost for renovating the existing structure.

FINDINGS AND ANALYSIS

The current state of the bridge is not wide enough for two lanes of traffic to flow in opposite directions. The bridge is also not strong enough for larger RV's to travel across. Clarkdale is looking for designs that widen the current bridge, making it accessible to two-lane traffic, and adding sidewalks and bike lanes. Strengthening the bridge is also a high priority. To start, students recommend conducting a traffic study to reclassify the road. Reclassifying the road will allow it to apply for funding, such as grants, which can help jumpstart design and construction efforts.

Figure 7 *Bitter Creek Bridge south-facing view, showing concrete details and added pedestrian access, from Google Earth*

Social context of community partner and PESTLE analysis

To start the design process, students conducted a PESTLE analysis of Clarkdale's Bitter Creek Bridge (Figure 8). Identifying key factors with the bridge design project informed the student's design concepts with a holistic understanding of the many factors involved in implementing a project at the town level.

Bitter Creek Bridge design PESTLE analysis	
Factor	***Details***
Political	Since the Town of Clarkdale is responsible for the project, there is a certain level of bureaucracy and “red tape” surrounding the project, which can lead to potential delays. Part of the project involves the traffic study to reclassify the bridge from a major to a minor collector. If any part of the ADOT requirements for the study or application is not met, the project would be set back by needing to repeat this process.
Economic	Widening a bridge is an expensive process. The current cost estimate is \$950,000. If the Town of Clarkdale cannot secure the Off System Bridge grant, they will need to find another funding source. If the Town receives the grant, they are required to contribute 5.7% of the funding for the project. This means that they must have \$54,000 to contribute under the current cost estimate. The bridge is the only point of access to the train depot. Any time construction might block the usage of the bridge, this would cause the train depot to have a significant drop in the number of visitors or cause it to shut down during the time that the bridge is closed.
Social	Citizens of Clarkdale have expressed deep pride in the historic nature of their town. If the bridge is to be socially sustainable, it must preserve that history.
Technological	As a historic site, the bridge cannot change very much in looks. The materials used for this project must match the original bridge materials. The materials may not be strong enough to widen and strengthen the bridge to Clarkdale’s specifications. Since the bridge cannot be closed for very long during construction, the plan must involve some technologies that allow for the bridge to stay open.
Legal	Since the bridge is a historic site, there is complex legislation regarding any changes due to the National Historic Preservation Act. Before plans can be finalized, they must be carefully checked against these laws.
Environmental	The bridge runs over Bitter Creek, which is still a small creek running through the town. The renovation cannot interfere with the ecosystem in the creek.

Figure 8 *Student PESTLE analysis of suggested Bitter Creek Bridge design interventions, to evaluate various social and environmental factors for the project*

Basic project constraints

One constraint is the fact that the bridge has been classified as a historical landmark, so when it comes to the building and redesign, the materials and design concepts should be the same. Right now, the focus is on ways to widen and strengthen the bridge without needing to make any design changes. There is a trend in new advancements in travel technology that is constantly changing the roads, and as these trends continue there may be another reason to modify this bridge in the future. The Town of Clarkdale has identified an overall budget of $1 million pending the traffic study results. In addition, students contended with significant time constraints, with 13 weeks to complete a preliminary design review.

Bitter Creek Bridge student project timeline	
Time frame	***Description of task***
Weeks 1-3	Meet with community partners to identify the main problems with the Clarkdale bridge
Weeks 4-5	Begin research on traffic studies
Weeks 6-7	Finish and present design review
Weeks 7-8	Begin research on how to strengthen and widen a bridge
Weeks 8-10	Complete the design tools
Weeks 10-11	Brainstorm potential designs
Weeks 11-12	Decide which designs are better than others
Weeks 12-13	Final presentation

Figure 9 *Student semester timeline outlining the design process and final deliverable*

Design details

To start the design process, students crafted preliminary design parameters for the bridge. A bridge with a 2-lane road, sidewalks on either side, and walls for pedestrian safety. The line dividing the lanes in the center of the road is the “centerline.” From the centerline out to one edge of the bridge, the following is needed: 9’ lane, 2’ shoulder, 4’ sidewalk and curb, 1’ parapet wall for a total of 16’ per side.

Renovating the bridge

Students identified two mechanisms for renovating the current bridge: strengthening and expanding the current bridge. This can be done by widening the bridge on one side or both sides. Due to the historical nature of the bridge, strengthening the existing structure will be paramount to ensuring its safety and durability.

Strengthening the bridge

Students researched several methods for strengthening the existing structure. There are a variety of existing methods for strengthening a bridge depending on its materials and structural components. The methods referenced in Figure 10 have been compiled from Horse, a construction company based out of China (Horse Construction, n.d.).

Strengthening Bitter Creek Bridge

Method	*Description*
Carbon Fiber Reinforcement Process (CFRP)	"CFRP can improve the bearing capacity of beam reinforcement. By sticking carbon fiber cloth to the tensile area of the steel bar, the flexural bearing capacity will be reinforced and strengthened. CFRP is used to reinforce old bridges. At present, the general calculation method is to convert carbon fiber cloth to a certain amount of steel according to a certain standard."
Bonded steel plate reinforcement method	"Steel-plate reinforcement bonding method uses epoxy resin structural adhesive to bond the steel plate or steel on concrete flexural members which forms together to improve the bending resistance reduce cracks."
Pressing FRP reinforcement method	"Pressing FRP reinforcement method improves the bearing capacity of bridge structures by significantly reduce deformation of the structure and improving the bearing capacity of the structure, as well as decreasing crack widths. Typically, this method saves on engineering costs and materials."
Enlarging member section and reinforcing method	"When the strength, stiffness, stability, and crack resistance of the beam are not enough, the reinforcement method can usually be used to increase the reinforcement. The enlargement of concrete cross section can be adopted by thickening the bridge panel and increasing the height and width of the main beam."
Reinforcement method of rebar planting	"Rebar planting utilizes epoxy mortar for rebar connections and heavy anchoring. This method can be used to anchor structural steel connections such as steel columns and beams."

Figure 10 *Potential methods for strengthening Bitter Creek Bridge by Horse Construction*

Expanding the bridge

In addition to strengthening the Bitter Creek Bridge, students investigated methods for expanding the existing structure. The Bridge can be expanded on either one or both sides, depending on Clarkdale's needs. Expanding the existing bridge can help maintain its original structure and preserve its historical significance to the community. The methods listed in Figure 11 describe various joints that can be used to expand the bridge.

Expanding Bitter Creek Bridge	
Method	***Description***
Expansion joints	"Bridge expansion joints are designed to adjust its length to accommodate movement by external loads, shrinkage, or temperature variations, and allow for continuous traffic between bridge structures and interconnecting structures, such as another bridge" (Lin, W. & Yoda, T., 2017).
Open joints	"Open joints allow water and debris runoff from a bridge to move freely through the joint but are often subject to debris buildup, which can render them ineffective. These types of joints include butt joints, sliding plane joints, etc." (Peterson, 2018).
Closed joints	"Closed joints prevents debris and water from penetrating the bridge but must be designed specifically for the size and movement properties of the intended joint. These include the following types of joints: poured joints, asphalt joints, etc." (Peterson, 2018).
Longitudinal joints	"Longitudinal joints between a widening and an existing bridge have been the greatest single source of bridge maintenance problems. Therefore, widenings are to be attached to the existing structure without longitudinal expansion joints" (Caltrans, 2010).

Figure 11 *Potential methods for expanding Bitter Creek Bridge*

Widening on one side

It is suggested to widen the bridge on the east side since the west side already has a sidewalk. This can be done by removing the wall on the east side to widen the road. Currently, there is 18 feet of roadway width. Since the barrier and walkway already exist on the west side, all that must be accounted for is two lanes, two shoulders, one sidewalk and curb, and one parapet wall. Given the existing width of the roadway, and what features need to be added to the east side, students determined 9 feet of widening is needed for the expansion as outlined by Figure 12.

$$[2 * (9' \text{ lane} + 2' \text{ } shoulder) + 4' \text{ } sidewalk\ and\ curb + 1' \text{ } parapet\ wall] - 18' existing\ roadway = 9' of\ widening$$

Figure 12 *Student calculation to reach the nine foot widening recommendation*

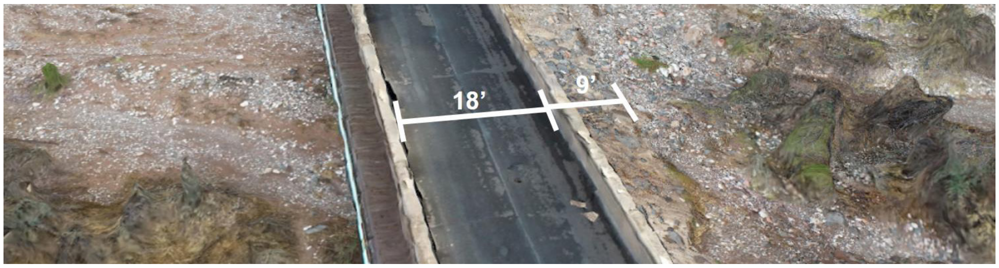

Figure 13 *Bitter Creek Bridge computer model illustrating the suggested 9 foot expansion*

Widening on both sides

To widen on both sides of the bridge, the current walkway will need to be removed, as well as the walls on both sides. The current centerline of the road would remain the same.

$$(2 * 16' \text{ } total\ width\ per\ side) - 18' \text{ } existing\ roadway = 14' \text{ } of\ widening$$

Figure 14 *Student calculation to reach the 14 foot widening recommendation*

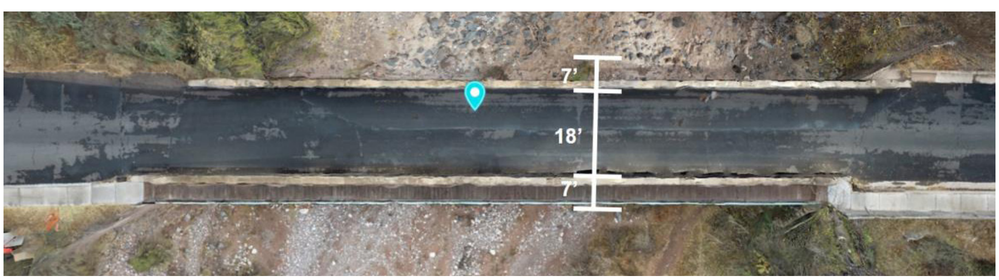

Figure 15 *Bitter Creek Bridge computer model illustrating the suggested 14 foot expansion*

Building a new bridge

Since extending a bridge can take a long time, be costly, and requires a lot of hard work, Clarkdale can also consider designing and building a new bridge. The newly designed bridge can have one bridge for going one way and have the other going in the opposite direction.

New bridge

The blue line in Figure 16, labeled as "Alternate Route 3," designates the proposed location for the replacement of the current Bitter Creek Bridge.

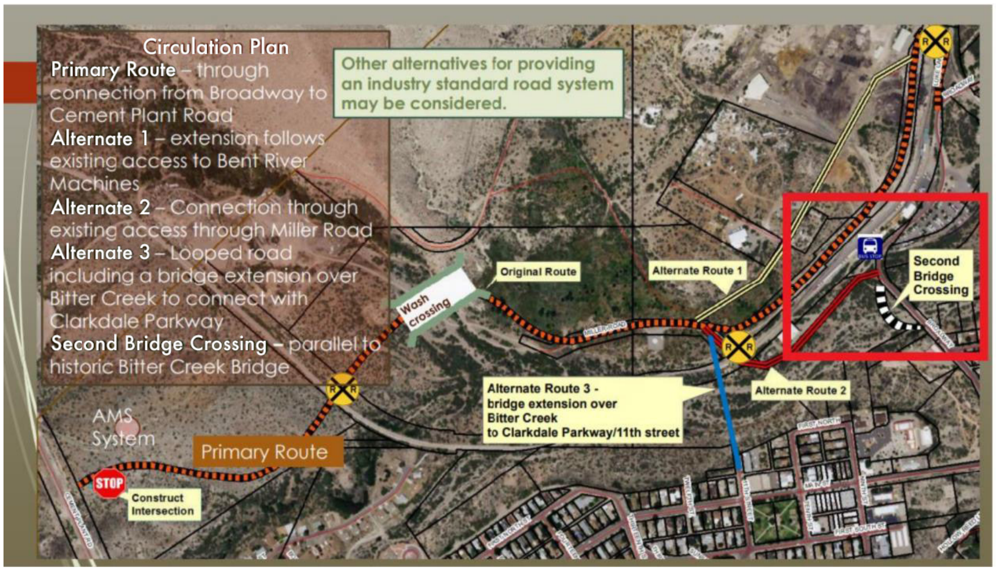

__Figure 16__ Annotated Bitter Creek Bridge area map, highlighting suggested alternate routes and added structure placements

Twin Bridge

A twin bridge is a second bridge that runs parallel to the first, with each bridge carrying one direction of traffic and the two directions rejoining on either side of the structure. In Clarkdale's case, the current bridge could be used as one of these bridges since it can accommodate one direction of travel, and an additional bridge could be constructed nearby. This would likely be more expensive than simply expanding the current bridge, and Clarkdale may not own the land they want the bridge to be located. However, the construction of a twin bridge would not jeopardize the historical nature of the existing bridge.

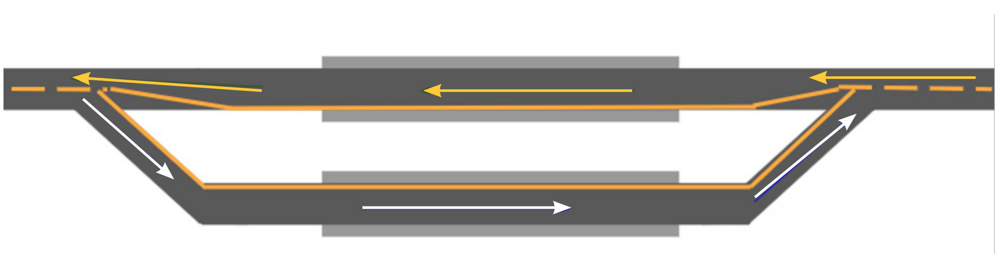

__Figure 17__ Conceptual illustration of the proposed twin bridge

Summary of potential designs

Proposed Bitter Creek Bridge design interventions			
Solution	*Description*	*Pros*	*Cons*
Widening bridge on east side	Remove east wall to make room for two small traffic lanes	Funding secure from an ADOT grant, pending traffic study result Historical aspect of the bridge would be similar if not unchanged	Removing the east wall can limit spacing in both lanes, with walkways and bike lanes
Widening bridge on both sides	Remove walls and walkways Increase space on both sides Add barriers to increase safety	Funding secure from an ADOT grant, pending traffic study result Historical aspect of the bridge would be similar, if not unchanged Much larger walk/bike lane and improved bridge size Additional roadway width, barriers, and walls would be present on both sides	Removing west wall and walkways can limit spacing in both lanes, as well as walkways and bike lanes Would generally cost more to expand on both sides rather than one side
Twin bridge	Exact replica of old bridge, matching width and style	Historical aspect of the original bridge would be unaltered, new bridge would be very similar One direction of traffic would run on each bridge, reducing confusion, and possibly reducing car accidents	Constructing a new bridge would generally cost more than restructuring an existing bridge Several structures present on the south end of the bridge can make it difficult to split lanes Existing grants for expanding the bridge would not apply to building a new one, so more investigation would need to be done around appropriate grants
New bridge	Provides an alternative route for traffic and leaves old bridge for historical aspect	Historical aspect would be untouched Old bridge could become a tourist attraction	Funding options for a new structure would need to be evaluated The Town may not own the property the suggested bridge design is intended for

Figure 18 *Summary of student-identified bridge interventions*

CONCLUSION

Clarkdale demonstrates a passionate commitment to preserving the Town's historical character, both through its work on the Downtown historic corridor and now the Bitter Creek Bridge. As the Town evolved into a contemporary setting, the bridge still serves its function to connect Clarkdale residents to the downtown area. In collaboration with the Town of Clarkdale, students with the EPIC program at ASU investigated and researched potential design features to understand the bridge's current state and provide key recommendations to improve the bridge.

After thorough research, students identified two key approaches to improving the Bitter Creek Bridge. To start, the Town of Clarkdale can strengthen the existing structure through a variety of structural improvements. In conjunction with strengthening the existing structure, students recommend expanding the bridge on one side or both to allow for two-way traffic and pedestrian crossing. By expanding the current bridge, the Town can retain key historical attributes of the original features while making the bridge accessible and functional for the town's needs. Students also investigated the feasibility of building an entirely new bridge. By constructing a new bridge entirely, Clarkdale can design a new structure that meets Clarkdale's needs while preserving the original structure as a destination spot for tourists and residents.

While devising these features, students took into careful consideration the impact the project would have on Clarkdale's visitors and residents, as well as preserving the historical integrity of the structure. Through careful evaluation of each solution, students keep their research open-ended with the potential for future research, such as a successful traffic study and potential funding opportunities for the bridge's improvement. As a continuation of Clarkdale's commitment to preserving its historic integrity, the students have provided possible designs to support Clarkdale's efforts in preserving and enhancing one of its most significant historic structures.

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To access the original student reports, additional materials, and resources, visit: **links.asu.edu/PCClarkdaleDowntownRevitalization20F**

APPENDIX A

Functional decomposition for student design process

Possible designs for expanding the current bridge or adding another bridge	
Feature	***Function***
Multiple possible designs	Showcase the options available to the Town
Illustrations	Provide a visual representation for added comprehension
Rough design specifications (bridge width, materials, etc.)	Create a basis for construction cost and time estimates
Construction cost and time estimates	Show costs of each design to the town

Figure 1 *Summary of student process for each protential design feature*

List of pros and cons for each design	
Feature	***Function***
List of pros	Show the direct and indirect positive influences of the design
List of cons	Show the direct and indirect negative influences of the design

Figure 2 *Summary of student process for each protential design feature*

Recommendation of which designs best fit the Town of Clarkdale's needs	
Feature	***Function***
Decision matrix	Share the methods used to generate the recommendations
First choice design	Determine the best solution for the town based on the criteria listed
Second choice design	Give an alternative in case any factors prohibit the first choice

Figure 3 *Summary of student process for design recommendations*

APPENDIX B

Brainstormed methods for conducting a traffic study		
Method	*Description*	*Challenge*
Pneumatic road tube counting	Pneumatic road tube sensors send a burst of pressure along a rubber tube when a vehicle's tires pass over the tube. The pressure pulse closes an air switch, producing an electrical signal that is transmitted to a counter or analysis software. Cars drive across rubber tubes laid across the road while sensors detect pressure changes.	Cars traveling very close together may be picked up as one large vehicle (Mutliaxle). In addition, temperature sensitivity of the air switch, and cut tubes from vandalism and truck tire wear.
Manual counting	One person can count to 2,500 vehicles an hour. Two people will be needed if estimates show there will be more cars than the previous figure or if there are free right turn lanes.	This can be long and tedious. The counter needs to stay alert to ensure accurate counts.
Magnets	Magnetic sensors are passive devices that indicate the presence of a metallic object by detecting the perturbation (known as a magnetic anomaly) in the Earth's magnetic field. Consequently, a magnetometer can detect two vehicles separated by a foot. This potentially makes the magnetometer as accurate as or better than the inductive loop detector at counting vehicles.	Installation of magnetic sensors requires pavement cut, coring, or boring under the roadway and thus requires lane closure during installation. Magnetic detectors cannot generally detect stopped vehicles. Also, some models have small detection zones.
Infrared/ radar	A traffic flow sensor is a device that indicates the presence or passage of vehicles and provides data or information (using radar sensors) as signal control, freeway mainline and ramp control, incident detection, and gathering of vehicle volume and classification data.	The installation and maintenance of in-roadway sensors such as inductive-loop and magnetic field sensors can disrupt traffic and pose a safety risk to the installers, cost and safety issues associated with mounting over-roadway sensors where existing structures are not available also exist.
Acoustic (audio recordings)	The measurements have shown that this measurement location requires a specific sound source connected to vehicles passing in maximum of two lanes. Four synchronous video recordings were made for the evaluation of the type and number of cars passing by.	The data collected can be inaccurate depending on a few things like weather, the acoustic sensor, and range of the sensor. The method is costly and doesn't produce the most accurate results.

Figure 4 *Potential methods for conducting a traffic study to inform bridge design*